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National Uranium Resource Evaluation

A SUMMARY GEOLOGIC REPORT ON THE MISSOULA/BITTERROOT DRILLING PROJECT, MISSOULA/BITTERROOT BASINS, MONTANA

**Field Engineering
Corporation**

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Grand Junction, CO 81502

March 1981

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
Grand Junction Office, Colorado

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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.

A SUMMARY GEOLOGIC REPORT ON THE
MISSOULA/BITTERROOT DRILLING PROJECT,
MISSOULA/BITTERROOT BASINS, MONTANA

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ABSTRACT

The objective of the drilling project was to obtain information to assess the favorability of the Tertiary sedimentary units in the Missoula and Bitterroot Valleys for uranium potential. The group of Montana Tertiary basins, including the Missoula and Bitterroot Basins, has been assigned a speculative uranium potential of 46,557 tons of U_3O_8 at \$100/lb by the 1980 National Uranium Resource Evaluation report. The seven drill holes, two in the Missoula Valley and five in the Bitterroot Valley, verified observations made during surface studies and provided additional information about the subsurface that was previously unknown. No uranium was found, although of the two localities the Bitterroot Valley is the more favorable. Three stratigraphic units were tentatively identified on the basis of lithology: pre-Renova clastic units, Renova Formation equivalents, and Sixmile Creek Formation equivalents. Of the three, the Renova Formation equivalents in the Bitterroot Valley appear to be the most favorable for possible uranium occurrences and the pre-Renova clastic units the least favorable.

INTRODUCTION

The Missoula/Bitterroot drilling project was composed of seven drill holes having an aggregate total depth of 14,436 feet (4,400 m). These holes obtained data relevant to the stratigraphy and uranium favorability of Tertiary intermontane basin sediments in Missoula and Ravalli Counties, Montana. The project area lies within the eastern part of the Hamilton and the southeastern part of the Wallace, Idaho and Montana, National Topographic Map Series (NTMS) 2° quadrangles. The drill sites were located in the Missoula and Bitterroot Valleys. The Bitterroot Valley is approximately 45 by 10 miles (72 by 16 km) in size and extends from Darby, Montana, on the south to Lolo, Montana, on the north. It is bounded by the Bitterroot Mountains on the west and the Sapphire Mountains on the east. The Missoula Valley extends approximately northwest of Missoula, Montana, for about 50 miles (80 km). The group of Tertiary basins, including the Missoula and Bitterroot Basins, was assigned a speculative uranium potential of 46,557 tons of U_3O_8 at \$100/lb by the 1980 National Uranium Resource Evaluation (NURE) report.

Access to the Bitterroot Valley is provided by U.S. Highway 93, which connects with U.S. Interstate Highway 90 at Missoula, Montana. Interstate 90 passes through the Missoula Valley northwest of the City of Missoula (Figure 1).

The Missoula/Bitterroot project was authorized by the NURE Project Office (NPO) in February 1976. Initial project planning was undertaken by the Bendix Field Engineering Corporation (BFEC) Geology Division, Spokane Regional Office. Subsequently, in March 1977, the responsibility for further project planning and implementation was assigned to BFEC's Data Acquisition and Development Department (DADD).

The objective of the Missoula/Bitterroot project was to obtain subsurface data that would enable more accurate assessments to be made of the favorability for uranium in Tertiary sediments in the Missoula and Bitterroot Valleys. The purpose of this report is to make and transmit preliminary evaluations of the data obtained by the drilling.

FIGURE 1. Location map, Missoula and Bitterroot Valleys, Montana.

A comprehensive interpretative study of drill cuttings and cores was made by Dr. Robert W. Fields of the University of Montana Geology Department under BFEC subcontract 77-073-E. A large portion of the discussions in the sections on regional geology and summary and preliminary assessments of subsurface data are taken directly from R. W. Field's report (written commun., 1979).

PROJECT OBJECTIVES

Subsurface data relevant to Tertiary sediments in the Missoula and Bitterroot Valleys were almost entirely lacking prior to the inception of this project. The principal objective was to obtain subsurface data that would permit more accurate assessments of the favorability for uranium mineralization in the strata underlying these two valleys.

The objective was accomplished by drilling, coring, and logging seven holes into or through the Tertiary sedimentary sequences of the Missoula and Bitterroot Valleys.

PROJECT SCHEDULE

A preliminary study of the project area by W. Levitch, U.S. Department of Energy (DOE) Regional Geologist (written commun., 1976), concluded with the recommendation that the area be further investigated by a drilling project and BFEC Geology Division was authorized to proceed with project planning. A drilling proposal that incorporated 12 drill holes was then prepared (see Figure 2). Five holes were located in the Missoula Valley and the remainder in the Bitterroot Valley. In March 1977, responsibility for further planning and implementation of the Missoula/Bitterroot project was assigned to DADD.

The Montana Bureau of Mines and Geology (MBMG), under subcontract to BFEC, undertook all necessary land status studies, obtained permits for drilling and supplied geologic consulting services during the project. Land studies were to be completed before the start of the drilling. A report that summarized and interpreted the geologic data obtained was to be compiled after the completion of drilling.

Land status studies, permitting, and environmental analyses were virtually complete by November 1977. Two of the 12 originally proposed drill holes were deleted from the program due to land status and budgetary considerations. Of the sites that were drilled, one was located on U.S. Forest Service (USFS) land and the remainder on fee land.

In December 1977, NPO authorization to proceed was received by BFEC. At that time it became evident that not all of the 10 proposed holes could be immediately justified. In February 1978, a joint DOE-BFEC decision was made to drill four holes as a basic program. An optional program of an additional six holes was to be drilled if the information obtained by the basic program was favorable. A contract to drill the basic, and possibly the optional, program was awarded to XL Drilling of Montrose, Colorado, on May 2, 1978.

Separate contracts were negotiated for drill-site services such as "mudlogging" and geophysical logging. The "mudlogging" contract was awarded to Monaco Engineering on May 19, 1978, and the geophysical contract was signed with Goodwell, Inc., of Upton, Wyoming, on July 11, 1978.

FIGURE 2. *Drill-hole location plan for Missoula/Bitterroot drilling project.*

Lines MB-2 to MB-4 and MB-6 through MB-8 to MB-9 refer to correlation diagrams, see Figures 6 and 12.

The first hole was started on May 9, 1978, and the last hole was completed on April 6, 1979. Drilling was discontinued between January 9, 1979, and March 23, 1979, because of severe weather. Seven rotary holes, with intermittent spot cores, were drilled for a cumulative total depth of 14,436 feet (4,400 m). Three of the six optional holes were deleted from the program by a joint DOE-BFEC decision on September 5, 1978. The deleted hole locations were shown to be unfavorable by data obtained during the basic drilling program.

The MBMG and the U.S. Geological Survey (USGS) utilized six drill holes for hydrologic and heat-flow transfer studies. Four-inch (10 cm) diameter casing was installed in four of the holes for hydrogeologic studies and 2-inch (5 cm) casing was placed in two of the remaining holes for heat-flow transfer studies. The final site restoration was conducted by the MBMG after hydrologic testing was completed.

PROJECT PROGRAM

The seven holes drilled ranged in depth from 1,030 to 2,907 feet (313.9 to 886.1 m). Aggregate total depth was 14,436 feet (4,400 m), of which 319 feet (97.2 m) were spot cored. Except for two holes in which casing was installed by water-well rigs, all project drilling was completed by one Gardner-Denver 2000 rig capable of reaching depths of as much as 3,500 feet (1,066.8 m). Conventional rotary drilling methods with mud circulation were used (see Table 1). Drilling was extremely difficult because of the abrasive nature of the conglomeratic formations encountered. The drill sites were selected because:

1. They were located in geologically favorable areas.
2. They were on fee land.
3. There was good vehicle access to the drill sites requiring a minimum of road construction.

Cutting samples were collected at 10-foot (3.1-m) intervals by either Monaco, XL Drilling, or BFEC personnel. These samples were washed and divided into four parts: One for the MBMG, one for the University of Montana, one for BFEC, and the fourth for immediate microscopic examination. The mineralogy and lithology of all cutting samples and cores were described and compiled on lithologic logs at the drill site (see Appendices A and B). The data recorded included the following:

1. Sample lithology, color, and degree of induration.
2. Sandstone or conglomerate fragment or grain size, mineralogy, sorting, and roundness.
3. Sandstone matrix mineralogy and abundance.
4. Presence and abundance of organic carbonaceous material and/or sulfide minerals.
5. Petrology of basement rocks.

Table 1. Locations and drill-hole data.

Hole no.	Rotary drilling		Cored		Total		Elevation		Location				Topographic Map
	feet	meters	feet	meters	feet	meters	feet	meters	Qtr.	Sec.	T.N.	R.W.	
MB-2	2,436.5	742.65	78.5	23.93	2,515	766.57	3,429	1,045.16	SWSWSW	17	15	21	Alberton, Montana.
MB-4	2,827	861.67	80	24.38	2,907	886.05	3,538	1,078.38	NWSENE	24	14	20	NW Missoula, Montana.
MB-6	1,687	514.20	71	21.64	1,736	529.13	3,612	1,100.94	SWNESE	32	10	20	St. Mary Peak, Montana.
MB-8	2,689.5	819.76	32.5	9.91	2,722	829.67	3,488	1,063.14	NENENW	6	9	19	Stevensville, Montana.
MB-9	1,020	310.90	10	3.05	1,030	313.94	4,016	1,224.08	NWNWNW	26	10	19	Cleveland Mt., Montana.
MB-11	2,416	736.40	0	0	2,416	736.40	3,505	1,068.32	SWNWNW	18	6	20	Hamilton North, Montana.
MB-12	1,063	324.00	47	14.33	1,110	338.33	3,792	1,155.80	NWNWNW	14	6	20	Corvallis, Montana.

The project program stipulated that spot cores were to be cut in either zones of uranium mineralization or at favorable stratigraphic horizons. No zones of uranium mineralization were encountered, however, and it proved to be impossible to accurately predict the lithology that would be penetrated; consequently, cores were taken at intervals which best served to identify the lithologic units present. All cores were split; one portion was delivered to the University of Montana and the other was sent to the MBMG for future study. The University of Montana submitted a cut of their core segments for paly-nology studies. The results are shown in Appendix C.

Each cutting sample and core was scanned with a scintillometer. No radio-metric anomalies were detected. Except for examination by low-power binocular microscope, no analytical work was performed on cutting samples. Some of the cores were subjected to close scrutiny; thin-section petrologic studies and clay mineral separations and identifications were made of selected samples (see Appendix D). Portions of the cores were also submitted to the BFEC analytic laboratory in Grand Junction, Colorado, for emission spectroscopy, organic carbon, and trace-element analyses. All cutting samples and cores have been studied and described independently by the University of Montana staff members under the supervision of Dr. R. W. Fields.

Most of the drill holes were geophysically logged from total depth to surface by Goodwell, Inc., logging units. The logs obtained included the following: Gamma-ray, spontaneous potential (SP), resistivity, neutron, caliper, and density. In-house BFEC units also logged several holes, obtaining potassium/uranium/thorium (KUT) logs from MB-2, MB-6, MB-8 and MB-12. Microfiche of all logs are included in Appendix E. For additional information see GJBX-127(79).

REGIONAL GEOLOGY

This section of the report was taken in its entirety from the report by Dr. Robert W. Fields, University of Montana Department of Geology, submitted as part of a contractual requirement between the MBMG and BFEC (R. W. Fields, written commun., 1979).

The mountain ranges of western Montana are separated by broad, usually linear valleys, often referred to as intermontane basins. As presently understood, these basins share a common geologic history. That history has been well documented by Robinson (1961, 1963, 1967) in the Toston, Townsend, Clarkston, and Three Forks areas; Kuenzi (1966), Kuenzi and Fields (1968b, 1971), and Kuenzi and Richard (1969) in the Jefferson River Basin; Dorr and Wheeler (1964) and J. A. Monroe (written commun., 1974) in the upper Ruby Basin; R. M. Petkewich (written commun., 1972), Petkewich and Fields (1971), and Petkewich and Hoffman (1969) in the lower Beaverhead Valley; Dorr (1956) in the Madison Valley; Konizeski (1957) in the Deer Lodge Basin; Konizeski (1961) in the Douglass Creek Basin; and Gwinn (1961a, 1961b), D. L. Rasmussen (written commun., 1969), and Konizeski and Donohoe (1958) in the Drummond and Flint Creek Basins. Fields, in Tedford, and others (written commun., 1978), reviews the total information on western Montana continental Tertiary deposits.

The oldest Tertiary alluvial sediments in any of the basins mentioned above are upper Eocene (see Figure 3). They have been dated on vertebrate paleontologic evidence. They occur as scattered outcrops in a number of basins: Lima, lower Beaverhead, lower Ruby, upper Ruby, and the Three Forks Basins.

FIGURE 3. Generalized stratigraphic column of the Tertiary basins in Montana.

The origins of the basins are somewhat obscure. Tectonic, erosional, and regional climatic factors were certainly important in their original delineation and development. The Tertiary sediments rest unconformably on sedimentary rocks of Precambrian, Paleozoic, Mesozoic, or very early Cenozoic ages or on granites related to either the Idaho or Boulder batholiths. In other areas, the contact is with volcanics such as the Cretaceous Elkhorn Mountain Formation or the very early Tertiary Lowland Creek and Challis Volcanics.

The regional tectonic framework produces a two-fold orientation in the majority of the basins. One of the orientations is north-northwest to south-southeast (upper Beaverhead and Missoula Basins), while the other intersects that trend and is generally east-northeast to south-southwest (upper Ruby Basin). In addition one basin, the Three Forks, trends essentially east-west. In such cases the shapes and orientations of the basins are explained by the local influence of major faults associated with them. Some few valleys, such as the Flathead and Bitterroot, are essentially north-south features and are controlled by major north-south tectonic structures.

DEPOSITIONAL HISTORY OF THE TERTIARY

East of the Continental Divide

In the basins east of the present Continental Divide, the sequence of deposition and basin history is basically the same. It can be outlined as follows:

1. Tectonic development which began during Laramide (Late Cretaceous/Paleocene) crustal shifts.
2. This was accompanied by a period of erosion in the warm, moist climate of Paleocene through middle Eocene time. During that interval through-flowing major drainage systems evacuated most, if not all, debris being shed by the surrounding uplands.
3. In late Eocene time a new pattern of erosion and deposition resulting from a major climatic change was initiated. The basins were no longer flushed by large through-flowing streams; instead, internal drainage and a drier climatic cycle characterized the area, similar to what is now present in central Nevada and other parts of the southwestern United States. Both depositional and paleontologic evidence verify this change.
4. These arid conditions caused the intermittent deposition of sediments that have been named the Renova Formation (Kuenzi and Fields, 1971) in basins east of the Continental Divide. Renova sediments consisting of fine-grained, microcrystalline carbonate mud, oolitic smectite mud, devitrified volcanic ash, arkosic sand, and minor quantities of gravel representing flood plain, stream channel, shallow pond (playa), alluvial fan, and sheetwash deposition spread over the pre-basin rocks to a depth that essentially filled the structural basins.

5. In early Miocene time Renova deposition was halted abruptly by a period of greatly increased precipitation brought on by another major climatic shift. During this period through-flowing stream drainage was re-established and extensive quantities of Renova Formation sediments were evacuated from the basins.
6. Individual basins were differentially stripped of their fill and a new topography of considerable relief developed. For a time, possibly 1 to 5 million years, through-flowing drainages continued to cut down through the Renova Formation and into pre-basin rocks.
7. Later in the Miocene the climate returned to an arid cycle, ending the episode of downcutting (see Figure 3). Stream drainages rapidly abraided and the basins once again began to choke with sediments derived from internal sources. The countryside again took on the general appearance of the very arid basins present in the southwestern United States or northern Mexico, but it was probably not as hot.
8. These conditions resulted in the rapid accumulation, on an intermittent basis, of sediments assigned to the Sixmile Creek Formation (Kuenzi and Fields, 1971) in basins east of the Continental Divide.
9. Sixmile Creek sediments are characterized by subangular sand and gravel with small quantities of tuffaceous silt and rounded cobble and pebble conglomerate. They accumulated on the flanks of the basins, as well as on the flood plains.
10. In the late Miocene aridity became more severe. This is indicated by increasing grain size of the sands and gravels, which are sometimes intimately mixed with vitric tuff, and sandy and silty channel deposits. Erosion and deposition continued on an extremely arid, sparsely vegetated landscape where choked stream channels, alluvial fans, mudflows, and sheetwash phenomena, as well as aeolian deposits, formed the bulk of the sediments.
11. Once again basin sediments covered the pre-basin rocks and the remnants of the Renova Formation, this time essentially "drowning" mountain ranges and bedrock ridges in their own debris.
12. In Pliocene time basin filling was again interrupted by another dramatic change in climate and stream regime. This change was marked by through-flowing streams and strong downcutting that has been interrupted only a few times during the Pleistocene and sub-Recent.
13. Continued excavation of the basins has removed an enormous quantity of material and left Renova and Sixmile Creek strata deeply and differentially eroded. This has exposed even the lower parts of both formations, as well as large areas of pre-basin rocks, in almost all of the present basins.

West of the Continental Divide

West of the Continental Divide a similar set of data exists in the Drummond, Flint Creek, Douglass Creek, and Deer Lodge Basins. This has been verified by several workers, primarily Gwinn (1961a, 1961b) and Rasmussen (written commun., 1969). It can be summarized as follows:

1. Basin formation in Laramide time (Late Cretaceous-Paleocene).
2. Probably earliest Tertiary sedimentation in late Eocene to early Oligocene.
3. Renova Formation equivalents deposited from late Eocene to early Miocene.
4. Unconformity and time hiatus in late-early Miocene time.
5. Sixmile Creek equivalents laid down from early Miocene through early Pliocene.
6. Deposition ceased during the Pliocene and down-cutting began.
7. Erosion and partial stripping of the basins continues until at least sub-Recent time.

FAULTING IN THE BASINS

Throughout the Tertiary, the region of western Montana was very active tectonically. There is abundant evidence of faulting throughout the period, but there appear to be three episodes of intensified activity. Each of these episodes coincides with drastic climatic changes which occurred in Paleocene-Eocene, late-early Miocene, and Pliocene to Recent. Most of the recognized faults are normal ones and some are quite extensive. For example, in Railroad Canyon near Leadore, Idaho, and in the Gravelly Range-upper Ruby Basin areas, vertical fault displacement exceeds 4,000 feet (1,219.2 m). Most of this extensive faulting is Pleistocene in age.

The faults in most areas have displacements ranging from a few tens of feet to 100 feet (to 30.5 m). A few specific areas (east of the Pioneer Mountains and the north end of the Ruby Range) appear to be chopped up into chaotic slivers by faults which tilt the Tertiary beds to near vertical attitudes. Most of the faults disrupt Renova Formation sediments and are probably Miocene in age. Sixmile Creek beds are either undisturbed or are disturbed to a lesser extent.

GEOLOGY OF THE MISSOULA AND BITTERROOT VALLEYS

The Tertiary geologic history of the Missoula and Bitterroot Valleys appears essentially similar to that of the other valleys and basins discussed in the section on regional geology. Both are intermontane basins initiated by Laramide tectonism. Both have been filled with sediments twice and partially excavated twice. Thin, but widespread covers of Quaternary and Recent alluvium and Quaternary glacio-lacustrine deposits are present. Present topography is generally the result of erosion and deposition by streams ancestral to the modern river systems.

Bitterroot Basin

The western perimeter and most of the floor of the Bitterroot Valley are occupied by crystalline rocks related to the Idaho batholith. The Sapphire Mountains of the eastern side of the valley are mainly a block of Precambrian Belt Supergroup quartzite-argillites. According to recent structural studies, they may have slid off the rising Idaho batholith along a gravity glide-plane. The resulting mylonitic detachment zone forms a marginal portion of the western Bitterroot Valley floor.

The basin is occupied by three principal lithologic units; i.e., Sixmile Creek Formation equivalents, Renova Formation equivalents, and a group of basin-flanking alluvial fan deposits of varying ages called the pre-Renova fanglomerates (MB-12), and upper Tertiary/Pleistocene clastic units (MB-6). The Sixmile Creek Formation equivalents are composed mainly of pebble conglomerates and sandstones with minor interbedded claystone and siltstone. The conglomerate is composed of granite, gneiss, and quartzite clasts, while the sandstone is micaceous and arkosic. These strata appear to be stream channel point-bar sequences in which sand and gravel are the dominant grain sizes. They unconformably overlie Renova Formation equivalent beds.

Renova Formation equivalents are sequences of interbedded tuffaceous claystone, siltstone, and arkosic sandstones. Subordinate intercalations of pebble conglomerate composed of granite, gneiss, and quartzite clasts are present. Coal beds are not uncommon, stringers and partings of lignitic carbonaceous material are abundant and disseminated pyrite frequently occurs in trace amounts. These strata were deposited in flood plain, overbank, swamp, and stream channel depositional environments. They unconformably overlie weathered granite and "granite wash", or pre-Renova fanglomerate.

Several coarse conglomerate units were penetrated by drill holes located near the lateral boundaries of both the Bitterroot and Missoula Valleys. These units are composed mainly of cobbles and boulders of granitic rocks, gneiss, and quartzite. Matrices are sandy and silty to clayey or calcareous (MB-12). In several drill holes (MB-9 and MB-12) the conglomeratic strata underlie Renova Formation equivalents while in MB-6 they constitute the entire Tertiary section. Portions of these conglomeratic units may grade basinward into and intertongue with Renova Formation equivalents. They are believed to have been deposited as repeating sequences of mudflow and fanglomerate deposits derived from the adjacent uplands of the Sapphire Mountains and Bitterroot Mountains. They are probably confined to a narrow belt along both flanks of the Bitterroot Valley.

Missoula Basin

The Missoula Basin is underlain by Precambrian Belt Supergroup sediments as are the surrounding mountains (Bonner Quartzite, McNamara Formation, and Miller Creek Formation). The basin's northeast and southwest boundaries are largely coincident with the Clark Fork and Nine Mile Creek-Albert Creek faults, respectively. The basin is mainly occupied by the conglomeratic Sixmile Creek Formation and the fine-grained Renova Formation equivalents. Thick alluvial fanglomerate deposits along the paleo-scarp of the Clark Fork fault underlie and may interfinger with Renova Formation

equivalent strata. Strata of Sixmile Creek Formation equivalents were not penetrated by project drilling. That is attributable to the hole locations being located near the northeast boundary of the basin. By analogy with Bitterroot Valley stratigraphy, Sixmile Creek Formation equivalents were either not deposited or have been stripped from the basin flank by erosion.

PREVIOUS INVESTIGATIONS

In addition to the numerous stratigraphic studies listed above (see regional geology) the following BFEC investigations and reports are relevant to the uranium favorability of the project area.

A report by Wopat, and others (1977), identifies several favorable characteristics of Tertiary strata within the Bitterroot Basin. They include: The presence of thick Cenozoic sedimentary sequences with a high percentage of sandstone and conglomerate and containing thin interbeds of tuffaceous material; host rocks which are arkosic or feldspathic, poorly sorted, and permeable; and minor amounts of carbonaceous material. The report's final conclusion was that, "although a favorable sedimentary rock sequence is present, the strata lack known uranium occurrences and radioactive anomalies and potential host rocks contain no known reductants or permeability barriers".

A BFEC report on the Montana portion of the Hamilton, Idaho and Montana, NTMS quadrangle (Aamodt, 1978) points out that since most of the stream sediment and water samples relate either to the valley-bounding pre-Tertiary rocks or to the uppermost Quaternary-Tertiary strata, their assay results are of limited value in assessing the uranium potential of the Tertiary sediments but they do show that the level of dissolved uranium in Bitterroot Valley streams is higher than in those of the Missoula Valley.

An aero-radiometric survey of the Hamilton, Idaho and Montana, NTMS quadrangle was completed in the summer of 1976. The data obtained by this survey are presented in a report by Geodata International, Inc. (1979). An evaluation summary was prepared by the geophysics department of DADD. This supplemental evaluation states, "Even though the radiometrics did not find any excessively high readings in this quadrangle, there are a few areas that should be ground checked. One mile west of the town of Victor, on map line 10, is a thorium anomaly indicated 27 ppm eTh with a corresponding 5 ppm eU. This anomaly could be due to cultural effects, however, it could be checked easily." A U.S. Bureau of Mines publication by Eilertsen and Lamb (1956), reports radioactive monazite placer deposits in the general vicinity.

CRITERIA FOR URANIUM MINERALIZATION FAVORABILITY ASSESSMENTS

The criteria used to assess the favorability for uranium mineralization in the Tertiary sediments encountered by drilling are those defined in recent BFEC reports on recognition criteria for uranium occurrences (Mathews and others, 1979, and Mickle and Mathews, 1978). These deposits belong in the "Wyoming" roll-type category; class 240; subclass 241.

A more specific eight-point outline incorporating all the above criteria was defined in a BFEC report by Wopat and others (1977). The sedimentary units drilled are considered favorable if:

1. Thick (1,000-foot; 300-m or more) sequences of Tertiary sedimentary rocks derived from granitic-silicic volcanic provenances are present.
2. These sequences include from 30 to 80 percent sandstone (or conglomerate), some beds of which are 20 to 200 feet (6.1 to 61 m) thick, reduced, feldspathic to arkosic, poorly sorted, medium to coarse grained, and/or permeable.
3. Carbonaceous material and/or pyrite occurs within or adjacent to potential host rocks and a reducing fluid or gas is present.
4. Uranium minerals or anomalous radioactivity is detected within the strata penetrated.
5. Pervasive, post-depositional alteration (i.e., iron staining) of potential host rocks is present.
6. Unconformities bound or occur in the rock sequences penetrated.
7. Siliceous, tuffaceous rocks overlie or are intercalated with the potential host rocks.
8. The strata dip at low angles (1° to 5°) and faults are present.

SUMMARY AND PRELIMINARY ASSESSMENT OF SUBSURFACE DATA

The lithologic descriptions and interpretations that follow are excerpted from Dr. Fields' report (written commun., 1979)

MISSOULA VALLEY

Hole MB-2 (Figure 4) was drilled to a depth of 2,515 feet (766.6 m) where it was abandoned in Tertiary conglomerate due to drilling difficulties. Eight intervals (78.5 feet; 23.9 m) were cored. Average core recovery was 65 percent. The hole was logged to total depth (T.D.) with the standard log suite and to 2,100 feet (640.1 m) with the BFEC/KUT system.

Lithologic Descriptions and Interpretations of Hole No. MB-2.

0 to 30 feet (0 to 9.1 m)	<u>Quaternary alluvium:</u> Unconsolidated light-gray to brown and yellow silt and sand containing occasional pebbles. Larger clasts appear to be locally derived from Precambrian source areas to the north of the drill site.
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This interval is typical of most Quaternary outcrops on the north side of the Missoula Valley. They appear to represent old river channel deposits probably laid down by the ancestral Clark Fork River at a time when the valley floor was at this higher level. The sediments correspond to the sediments laid down in point bars by the Clark Fork River of today.

FIGURE 4. Generalized lithologic log of Missoula/Bitterroot project hole no. MB-2.

30 to 810 feet
(9.1 to 246.9 m)

Renova Formation equivalents: Probably an Oligocene sequence of interbedded, light-gray to medium-tan, arkosic sandstone, tuffaceous siltstone, and claystone with occasional coal seams. Between 30 and 40 feet (9.1 to 12.2 m) the bit penetrated a coal seam approximately 4 feet (1.2 m) thick. The entire section contains stringers and partings of carbonaceous material. Thin beds of pebble conglomerate appear to be present throughout the section. From 550 to 810 feet (167.6 to 246.9 m) the sandstone contains traces of pyrite. Few individual beds are cemented with calcium carbonate. No glass shards were observed but occasional "ghosts" are present.

These beds with their coal seams, sand lenses, tuffaceous siltstones, and mudstones correlate well with surface outcrops of the Oligocene units dated by R. W. Brown (1954) at O'Keefe Creek in the area of the old coal mines north of the City of Missoula's sanitary landfill (3 mi; 4.8 km north of the city) and elsewhere in the basin. These sediments represent deposition on flood plain, overbank, swamp, and channel environments and are part of the lower Oligocene to lower Miocene cycle of deposition.

810 to 2,515 feet
(246.9 to 766.6 m)

Pre-Renova Formation clastic unit, possibly Eocene or Paleocene: This unit is a repeating sequence of conglomerates. Clasts are dark reddish brown to dark gray, purple, green, and pink, composed of argillite and quartzite. The matrix is generally brick red, but at certain intervals it grades to gray and green. Each interval fines upward from very angular to subrounded rock fragments (8 inches; 20 cm) to pea-sized, angular to subrounded gravel, and coarse sand. In almost all cases the conglomerate clasts are matrix supported, show poor sorting and are chaotically oriented. It is rare to find well oriented or imbricate bedding of the larger clasts. Both the conglomeratic fragments and the supporting matrix appear to be derived from nearby sources in the Precambrian Belt Supergroup.

The conglomerate lithofacies are unlike anything observed in outcrop in any other Montana basin, west or east of the Continental Divide. They represent a series of rapidly deposited sediments, the predominant lithologic characteristics of which are matrix-supported larger clasts, angular to subrounded grains, poorly sorted size ranges, lack of orientation, evidence of scouring, and the formation of soil zones. All these features point to a sequence of alternating mudflows and braided stream deposits.

The trace of the Clark Fork fault lies approximately 0.75 mile (1.2 km) north of the drill site. To the north of the fault, and extending for many miles, units of the Precambrian Belt Supergroup crop out. South of the trace only Tertiary or Quaternary rocks are exposed.

The Clark Fork fault is a low-angle normal fault, upthrown on the north. It is a prominent geologic feature of the region and has been active since late Cretaceous time. Its vertical throw is shown by the thickness of the Tertiary section in well MB-2 to be at least 2,500 feet (762 m).

Dr. Fields (written commun., 1979) relates the great thickness of the conglomerate sequence (more than 1,700 feet; 518.2 m) to the presence of the Clark Fork fault and its resultant scarp to the north of the Missoula Valley. Streams poured Belt Supergroup clastic sediments, both fine-grained and larger angular clasts, over that scarp forming a line of massive alluvial fans composed of mudflows and braided stream deposits along the north side of the Missoula Valley. This massive build-up probably occurred either during Eocene or Paleocene time, or throughout most of both epochs.

Sediments of the Renova Formation equivalent lithologic facies were apparently deposited as an onlapping, unconformable sequence over the fans, thus preserving them in the deeper, heretofore unrevealed, parts of the basin.

Hole MB-4 (Figure 5) was completed in Precambrian Belt Supergroup basement rocks at a depth of 2,907 feet (886.1 m). Five spot cores (70 feet; 21.3 m) of Tertiary sediments and one basement core (10 feet; 3.1 m) were obtained (average core recovery was 58 percent). The hole was geophysically logged to T.D. with the standard log suite.

Lithologic Descriptions and Interpretations Hole No. MB-4

0 to 90 feet
(0 to 27.4 m)

Quaternary alluvium: Interbedded stream-channel gravel and sand. Clasts are reddish brown, pink, purple, green, and grayish brown quartzite and argillite, locally derived from Precambrian sources upstream (north) in the Butler Creek drainage. Outcrops of similar lithology occur along the banks of Butler Creek both upstream and downstream from the MB-4 well site.

90 to 2,800 feet
(27.4 to 853.4 m)

Renova Formation equivalents, probably Oligocene: Hole MB-4 penetrates a thick section of Tertiary sediments which ranges from poorly to completely consolidated, gray, carbonaceous siltstone and mudstone containing many thin stringers and seams of bituminous and lignitic coal to gray, grayish-green, tan, and brown, fine- to coarse-grained, angular to sub-rounded, arkosic sandstone to gray, reddish-brown and purple, poorly sorted pea-sized gravel and cobble conglomerate. The section can be subdivided into a series of units based on the predominant lithology in that part of the section.

90 to 640 feet
(27.4 to 195.1 m)

The interval is interbedded light gray to tan arkosic sandstone, siltstone, and claystone with numerous coal seams and stringers. This interval is marked by much disseminated lignitic plant debris. Tuffaceous material is also scattered throughout the interval, but is generally devitrified. Individual beds, the sandstone units in particular, may be calcareous.

FIGURE 5. Generalized lithologic log of Missoula/Bitterroot project hole no. MB-4.

640 to 1,360 feet
(195.1 to 414.5 m)

Unconsolidated to highly indurated, gray, tan, light-pink and reddish-brown to purple, angular to rounded, poorly sorted conglomerate. Some units show prominent graded bedding and some evidence of matrix support. Clasts range from 0.5 to 15 cm. Light-gray to green and medium-brown mudstone and siltstone probably occur as thin (10- to 20-foot; 3- to 6.1-m) beds and lenses within the conglomerate unit. These beds, like the interval above, contain numerous coal seams. All of the finer grained sediments within this section contain abundant lignitic plant remains. The conglomerates comprise 80 percent of the total thickness of this sequence, mudstone and siltstone perhaps 12 percent, and sandstone and coal 4 percent each.

1,360 to 2,400 feet
(414.5 to 731.5 m)

Another thick section is silty, calcareous, mica-ceous, carbonaceous, light gray, buff, light brown or green claystone, much like the conglomerate interval above, but with less siltstone and more sandstone and conglomerate. Distributed throughout this sequence are gray to tan, coarse to fine, angular to rounded grains of arkosic sandstone and pea-sized gravel.

Graded bedding is common. This unit contains more coal than in the interval above; about 10 percent of the total thickness of the unit. Claystone and siltstone (approximately 55 percent), sandstone (30 percent), and conglomerate (5 percent) are the other principal lithologies present.

Highly indurated, light gray, medium brown, and occasionally purple, poorly sorted conglomerate as in the sequence from 640 to 1,360 feet (195.1 to 414.5 m).

2,400 to 2,800 feet
(731.5 to 853.4 m)

Organic claystones are intercalated with the conglomerate as beds and possible soil horizons. Chips are mottled with gray, grayish black, brown, and purple. Traces of coal appear in many samples and carbonaceous debris is common throughout the section. Beds within the interval are high oxidized.

2,800 to 2,907 feet
(853.4 to 886.1 m)

Tectonic breccia/Precambrian Belt Supergroup argillite-siltite basement rock: This is an interval of angular breccia derived from Precambrian Belt Supergroup rocks. Core number 6, from 2,895 to 2,905 feet (882.4 to 885.4 m), illustrates this lithologic description. The breccia is composed of very angular to angular, poorly sorted (0.5 to 20 cm), pink to reddish brown and purple clasts of argillite and siltite. The matrix is composed of ground-up rock of the same lithology as the clasts. This appears to be a breccia of tectonic, rather than sedimentary origin. The clasts are stretched, distorted, and

frequently broken with off-set as great as 3 to 5 cm. The apparent orientation of clasts is near perpendicular.

It is my interpretation (Fields, written commun., 1979) that the tectonic breccia is the gouge zone of the Clark Fork fault (or a splinter fault parallel to the main one) and is composed of brecciated Belt Supergroup sediments. If this interpretation is correct, the Clark Fork fault is probably a relatively low-angle fault that dips to the west and possibly flattens with depth.

The sequence from 90 to 2,800 feet (27.4 to 853.4 m) appears to correlate grossly with the unit from 30 to 810 feet (9.1 to 246.9 m) in hole MB-2 and is identified as Renova Formation equivalent. In addition, this interval contains numerous coal seams and much disseminated lignitic debris, a feature observable in outcrops in the Missoula Basin at O'Keefe Creek and at the old coal mines north of the city's sanitary landfill (see discussion of MB-2, p. 16). Hole MB-4, in O'Brian Creek, is approximately halfway between and on strike with the two outcrops noted above.

As at the outcrop areas and in MB-2, the sediments represent deposition in flood plain, overbank, coal swamp, and channel environments and are part of the lower Oligocene to lower Miocene period of deposition. The conglomerates within the Renova sequence at MB-4 may be related to its proximity to the Clark Fork fault. As at MB-2, the fault lies approximately 0.75 mile (1.2 km) north of MB-4. The conglomerate clasts are derived from Precambrian Belt Supergroup rocks and were probably shed from the region north of the fault. The basal conglomerates (2,400 to 2,800 feet; 731.5 to 853.4 m) are probably not related to those identified in MB-2 as the pre-Renova Formation clastic unit. They appear to predate the deposition of the coal-bearing units assigned to Renova Formation equivalents in both MB-2 and MB-4.

Favorability assessment of Missoula Valley Tertiary Sediments

The two holes, MB-2 and MB-4, drilled in the Missoula Basin were both located near its northeast boundary in close proximity (0.75 mile; 1.2 km) to the Clark Fork fault. As a result, the sedimentary sections encountered are probably not typical of the entire basin (Figure 6). By analogy to the Bitterroot and other basins, it is expected that a Sixmile Creek Formation equivalent is both extensive and well developed and that the conglomerate of the pre-Renova Formation clastic unit is restricted to narrow belts adjacent to the flanks of the basin. The favorability of each of the three stratigraphic units, i.e., the pre-Renova Formation clastic unit, the Renova Formation equivalent, and the Sixmile Creek Formation equivalent is discussed separately below.

The pre-Renova Formation clastic unit is a repeated sequence of fining upward, matrix-supported, conglomerate units. The clasts are composed of Belt Supergroup argillite and quartzite and the matrix is generally brick-red clay that grades into minor gray to green zones. Formation permeability is usually low. Pyrite is rare and confined to the gray or green mudstone intervals. Neither carbonaceous nor tuffaceous material was identified. Most of the unit has been strongly oxidized, presumably during or shortly after deposition. No zones of anomalous radioactivity were detected. The pre-Renova clastic unit

FIGURE 6. Generalized geologic section of the Missoula Valley from hole no. MB-2 to MB-4.

exhibited only three of the eight favorable characteristics conducive to uranium mineralization and is, therefore, considered unfavorable.

The Renova Formation equivalent is composed mainly of interbedded, light gray to tan, arkosic sandstone, tuffaceous siltstone, and claystone. Coal beds and carbonaceous stringers and partings are common. Traces of pyrite are present. No zones of pervasive alteration were identified and no anomalous radioactive intervals were found.

The Renova Formation equivalent exhibits five of the eight recognition criteria indicated:

1. Thick sedimentary sequences derived in part from volcanic origins.
2. The sequences include at least 30 to 80 percent sandstone.
3. Coal beds, carbonaceous stringers, and partings are common. Traces of pyrite are present.
4. No uranium minerals or anomalous radioactivity was detected.
5. No zones of pervasive alteration were identified.
6. Unconformities bound this formation.
7. Tuffaceous rocks are intercalated with the potential host rocks.
8. Strata dip at variable angles and much faulting is present.

No subsurface data relevant to a Sixmile Creek Formation equivalent was found in the Missoula Valley during this project.

BITTERROOT VALLEY

Hole MB-6 was completed at 1,736 feet (529.1 m) in a granitic mylonite (Figure 7). Seven intervals (71.0 feet; 21.6 m) were cored. The average core recovery was 39 percent. The hole was logged to T.D. with the standard log suite and the BFEC/KUT system. The site of this drill hole, not more than 0.5 mile (0.8 km) east of an outcrop of "border zone" gneiss from the eastern front of the Bitterroot Mountains, places it in the detrital fan deposits of material shed from the high relief area. As the sediments of both the Tertiary and Quaternary parts of the section were derived from the same source area, their lithologies should be essentially the same. The only criterion for identifying Quaternary from Tertiary strata might be a different degree of weathering. This could not be determined from the cutting samples.

Lithologic Descriptions and Interpretations Hole No. MB-6

0 to ? feet

Quaternary alluvium: The depth of Quaternary alluvium could not be determined in this hole. From the surface to 630 feet (192 m), the sediments are unconsolidated and essentially of the same lithology.

DEPTH	STRATIGRAPHIC COLUMN	DESCRIPTION
300'		Unconsolidated cobbles and boulders of granite gneiss and schist in sand matrix (Quaternary alluvium and upper Tertiary-Pleistocene Conglomerates)
600'		(Unconformity)
900'		Poorly consolidated to unconsolidated sandy siltstone and claystone with cobbles and boulders (Middle Tertiary clastic unit)
1200'		
1500'		(Unconformity)
1736'		Mylonite (granitic composition)

FIGURE 7. Generalized lithologic log of Missoula/Bitterroot project hole no. MB-6.

? to 630 feet
(? to 192 m)

Upper Tertiary/Pleistocene fanglomerate: Largely unconsolidated cobbles and boulders (as large as 50 cm) of granite, gneiss, and schist in a coarse-grained, dark-tan to dark-gray sandstone matrix. The lower half of the section appears to have more sandstone and siltstone than the upper half (as much as 40 percent in samples from low in the section). Individual cobbles and boulders are composed of granite, border zone gneiss, some schistose rock, occasional anorthosite, and milky quartz.

Evidence of deep weathering is apparent through the entire unit. Traces of abundant amounts of weathered garnet, chlorite, and sillimanite are found along with weathered feldspar and mica (biotite, muscovite, and sericite) in the sand-sized fraction. In cores, evidence of deep weathering is present as rinds on individual boulders.

The sediments in this interval are interpreted as representing large fanglomerate deposits derived from the eastern border of the Idaho batholith. The massive boulders seen in cores imply torrential runoff with resultant mud, debris, and high-gradient intermittent stream flows.

The fans might well have appeared as dramatic as those seen in Death Valley, California, today. The depth and extent of weathering may imply that the climate was much warmer and wetter during the time of deposition than it is today or that weathered material was carried into the basin from the Bitterroot Mountains; an area of higher elevation and greater precipitation.

630 to 1,570 feet
(192 to 478.5 m)

Middle Tertiary clastic unit(?): A sequence not unlike the upper Tertiary/Pleistocene fanglomerate unit in gross appearance. The suite of boulders, cobbles, and finer material is present but the proportion of fine material is much greater. Weathering effects appear to be severe. The unit appears to grade generally upward from 60 to 70 percent conglomerate at the base to only 10 to 20 percent near the top.

In contrast to the overlying unit in which clay-sized material is absent, this unit is composed of as much as 80 percent silt and clay materials. Its sand-sized fraction ranges from 10 percent to as much as 45 percent of individual samples and is higher than that of the preceding unit.

This unit probably represents a period of deposition under conditions of less severe gradient on fans along the east flank of the Bitterroot Mountains. It

may grade basinward into rocks that are elsewhere dated as Renova Formation equivalents. Hole number 7, which was not drilled but was planned between MB-6 and MB-8, could well have verified that possibility.

1,570 to 1,736 feet
(478.5 to 529.1 m)

Mylonitic detachment zone: Geophysical logs indicate that the mylonitic detachment zone of the Sapphire block (Hyndman, 1977, 1979; Chase, 1977) on the east flank of the Bitterroot dome (east face of the present Bitterroot Mountains) was penetrated at approximately 1,650 feet (502.9 m). This zone is marked by foliation and shear planes that now dip 20° to 25° east. This shear zone is well known both north and south of MB-6.

Cores show a shear-plane-set dipping as much as 30° (direction unknown; cores were not oriented). Circumstantial evidence implies agreement with a mylonite shear zone/Sapphire block concept (see Hyndman, 1977 and 1979 for a full discussion of this major tectonic feature).

Hole MB-8 was completed in granite "basement" at a depth of 2,723 feet (830 m) (Figure 8). Two spot cores (22.5 feet; 6.9 m) were obtained in the Tertiary section and one (10 feet; 3 m) at T.D. Total core recovery was 100 percent. The hole was geophysically logged to T.D. with the standard log suite and to 2,100 feet (640.1 m) with the BFEC/KUT system.

Lithologic Descriptions and Interpretations Hole No. MB-8

0 to 30(?) feet
(0 to 9.1? m)

Quaternary alluvium: Interbedded stream channel gravel, sand, and clay. Clasts are mostly of granite and gneiss with subordinate quartz, quartzite, and fresh feldspar compositions. They appear to be locally derived from both the Bitterroot Mountains and the Sapphire Mountains. Outcrops of similar lithologies occur in the adjacent drainages and north and south along the pediment benches on the east side of the Bitterroot Valley. The unit grades downward into sediments of Sixmile Creek Formation equivalents(?).

30(?) to 1,200 feet
(9.1? to 365.8 m)

Sixmile Creek Formation equivalents(?), Miocene(?): An interval dominated by pebble conglomerate and sandstone with minor amounts of siltstone and claystone. The interval from 530 to 670 feet (161.5 to 204.2 m) is occupied mainly by claystone and siltstone. The rocks of the entire unit are poorly consolidated. Samples were difficult to analyze because there were problems with the hole caving in from above and the samples may have become contaminated.

FIGURE 8. Generalized lithologic log of Missoula/Bitterroot project hole no. MB-8.

Conglomerate clasts are mostly of granitic and gneissic rocks but chips of white to pink and brown quartzite and argillite are common. The size of the clasts is probably no larger than 6 to 8 cm. The sandstone is medium to fine grained, angular to rounded, white to buff, micaceous and arkosic. The proportion of siltstone and claystone cuttings varies with depth. They are most noticeable in the middle of the unit and are light tan to brown. These data are interpreted as indicative of a stream channel point-bar sequence in which gravel and sand were the dominant grain sizes. The clays and silts probably represent sedimentation in backwater, slough, and occasional overbank depositional sites. This lithologic interval is similar in general character to local members of the Sixmile Creek Formation known east of the Continental Divide and in the Drummond-Flint Creek Valleys west of the Divide.

1,200 to 2,450 feet
(365.8 to 746.8 m)

Renova Formation equivalents, probably Oligocene:
This unit is a 1,250-foot (381-m) section of Tertiary sediments ranging from indurated tuffaceous claystone and siltstone to friable sandstone and some conglomerate.

Claystone and siltstone predominate and range in abundance from 30 to 90 percent of individual samples. They are tuffaceous, light buff, light brown, light to dark gray, and grayish green, in places calcareous, and contain scattered inclusions of lignitic plant material. The sandstone is light gray to tan to dark gray, moderately to poorly sorted, subangular to rounded, feldspathic to arkosic. Occasional pyrite grains and organic material are present. In some parts of the interval subtly graded bedding is apparent. The sandstone comprises 10 to 70 percent of individual samples.

Conglomerate is quite subordinate in this interval, comprising less than 40 percent in all but the upper 300 feet (91.4 m). Its appearance is similar to that of conglomerates in the section above. It is possible that some of the clast chips are cavings from that upper section, as many are too large to be bit cuttings.

This unit appears to correlate with the Renova Formation equivalents in MB-2 and MB-4 in the Missoula Valley. Each drill intercept has a predominant mudstone-siltstone component. Each is tuffaceous with occasional glass shards, contains organic detritus, and pyrite is especially abundant in the sandstone facies.

As in the other drill holes and in outcrops in the Missoula Valley, these sediments represent deposition in flood plain, overbank, swamp, and channel environments. This interval in MB-8 is probably part of the sedimentary facies known to have been deposited along the east side of the Bitterroot Valley during the lower Oligocene to lower Miocene depositional cycle.

2,450 to 2,490 feet
(746.8 to 759 m)

Granite wash, possibly Eocene: This is an interval containing intensely weathered granular grains of quartz, feldspar, and mica representing an ancient granular disintegration surface over a granitic terrain. The boundary between this grus and the Tertiary sediments appears to be gradational. A similar relationship is present along the east side of the Boulder batholith. There it represents an old erosional surface formed under deep weathering conditions. Such conditions are known to have existed during Eocene and Paleocene time in the western United States and are considered as having been present prior to the deposition of the Renova Formation equivalent.

2,490 to 2,723 feet
(759 to 830 m)

Granite, Idaho batholithic material/Sapphire slide block (see Hyndman, 1977 and 1979): A medium-grained, gray granite composed of biotite, orthoclase and plagioclase feldspar, and quartz. The rock is deeply weathered at the top but becomes fresher toward the base of the core at 2,723 feet (830 m). The entire thickness is marked by two prominent directions of fracture and slickensides; one nearly vertical and the other 30° degrees from horizontal. The planes strike approximately 120° from one another. Fractures are closely spaced (4 to 15 cm). Biotite is smeared and stretched along all fracture surfaces. The surfaces are white, green, red, and orange, and appear highly polished.

Hole MB-9 was completed in granite basement at a depth of 1,030 feet (313.9 m) (Figure 9). No cores of Tertiary sediments were obtained. One 10-foot (3-m) core was cut in basement rocks. The hole was logged to T.D. with the standard suite of logs.

Lithologic Descriptions and Interpretations Hole No. MB-9

0 to 20 feet
(0 to 6.1 m)

Quaternary colluvium: Unsorted, angular to subrounded pebbles of gray quartzite in a matrix of coarse, light-gray sand. The boundary between colluvium and the underlying strata is indistinct. It can be seen in outcrop near the well site where a thin colluvial cap rests on an old Pleistocene pediment surface sloping basinward from the Sapphire Mountains.

FIGURE 9. Generalized lithologic log of Missoula/Bitterroot project hole no. MB-9.

20 to 100 feet
(6.1 to 30.5 m)

Sixmile Creek Formation equivalents(?), Miocene(?): An interval of conglomerate composed of white to dark grayish-green micaceous quartzite clasts that are locally derived. Their source can be seen in outcrop 0.5 mile (0.8 km) east of the drill site. Occasional lenses of fine- to medium-grained, arkosic sandstone and some claystone and siltstone are present. This unit appears similar to the strata within the interval from 30 to 1,200 feet (9.1 to 365.8 m) in MB-8 and is thought to represent point- bar and channel deposits laid down by the ancestral Bitterroot River during Pliocene(?) time when the valley flood plain stood at this higher level. It is assumed that a greater thickness of the Sixmile Creek equivalents(?) existed at this site but that Pleistocene and later erosion removed all but about 100 feet (30.5 m) of the material.

100 to 700 feet
(30.5 to 213.4 m)

Renova Formation equivalents, probably Oligocene: Six hundred feet (182.9 m) of Tertiary strata, not significantly different from those of the Renova Formation equivalent sections in MB-2, MB-4, and MB-8. The upper 400 feet (121.9 m) of this section is especially like the Renova equivalent in the lower half of the same unit in MB-8. It is tuffaceous and from 240 to 300 feet (73.2 to 91.4 m) the claystone contains many fragments of lignitic coal. The lower 200 feet (61 m) is predominantly conglomerate (as much as 90 percent), composed of quartzite pebbles in a coarse-grained sandstone matrix.

Samples from a depth of about 600 feet (182.9 m) are composed of gray siltstone and claystone containing sparse glass shards. This interval (100 to 700 feet; 30.5 to 213.4 m) is clearly a part of the Oligocene cycle of deposition.

700 to 750(?) feet
(213.4 to 228.6? m)

Granite wash, possibly Eocene: Below 700 feet (213.4 m) the conglomerate becomes a concentration of angular fragments of quartz, feldspar, and biotite. The top 20 feet (6.1 m) exhibits reddish-orange limonitic stains.

This unit, like that of MB-8, represents an ancient granular disintegration surface over a granitic terrain. The resulting grus appears to have been redeposited by a stream coursing over the older granitic surface. The upper 20 feet (6.1 m) may represent an old soil horizon.

750 to 1,030 feet
(228.6 to 313.9 m)

Granite, Idaho batholithic material/Sapphire slide block (Hyndman, 1977 and 1979): This is the same granite seen at the base of the section in MB-8. The core from MB-9 does not show the degree of fracturing or weathering seen in the one from MB-8.

Hole MB-11 was abandoned in Tertiary conglomerate at 2,416 feet (736.4 m) because of major hole problems; no cores were obtained (Figure 10). Only the uppermost 400 feet (121.9 m) of the hole was logged with the standard suite.

Lithologic Descriptions and Interpretations Hole No. MB-11

A review of the information obtained from this drill hole (the first of the project) indicates that the sample data are unreliable because of severe contamination by cavings from uphole. A close study of the chip samples does point to some lithologic variations, but the stratigraphic position of separable boundaries can only be guessed. The confidence of the following interpretation is extremely low.

0 to 300(?) feet
(0 to 91.4? m)

Quaternary alluvium: The thickness of Quaternary alluvium could not be determined. It is composed of fine- to coarse-grained, gray, arkosic sand and pebble- to boulder-sized gravel. Granitic material is more abundant but clasts of granite gneiss, mica schist, quartz, and some quartzite are present. The detrital materials are identical in percentage and composition to gravels presently being deposited by the Bitterroot River 328 feet (100 m) west of the drill site. The Quaternary material represents stream channel and bar deposits laid down by a very competent stream, probably larger than the present Bitterroot River. Fields' interpretation (written commun., 1979) is that stream deposition was continuous throughout Quaternary time and continues today.

300(?) to 2,416 feet
(91.4? to 736.4 m)

Designation questionable: No significant changes are present in what might be the Tertiary part of the stratigraphic section. Arkosic sands and ground-up granitic chips are dominant in the cuttings.

The granitic look of the samples is due to the milling-up of granite, gneiss, schist, and quartz boulders and cobbles. Throughout most of this interval gravel and sand constitute from 70 to 100 percent of individual samples.

Two exceptions are noted. From 350 to 400 feet (106.7 to 121.9 m) and from 470 to 520 (143.3 to 158.5 m) clay and silt comprise 70 and 50 percent, respectively, of the samples taken. Here and elsewhere in the section where silt and clay are present, a tuffaceous origin is suspected. A few glass shards can be found but never enough to constitute a significant part of any sample. They are probably secondarily derived.

FIGURE 10. Generalized lithologic log of Missoula/Bitterroot project hole no. MB-11.

In all probability this entire interval is representative of deposition in the channels of an ancient braided stream, probably the ancestral Bitterroot River. Whether this includes a significant part of the Tertiary section or contains only Pleistocene glacial outwash material must remain a question. One possible interpretation is that the hole was drilled to T.D. in Pleistocene gravels related to glacial outwash originating primarily in the Bitterroot Mountains to the south and west. A second interpretation is that the Tertiary section is present and that the bit never penetrated the coarse-grained facies of the Sixmile Creek Formation equivalents(?).

A third possible interpretation cannot be overlooked. Downhole sample cuttings are essentially indistinguishable from those obtained from the granite section in MB-8, MB-9 and MB-12. It is indeed possible that the assumed granite floor of the Bitterroot Valley was penetrated somewhere uphole.

Hole MB-12 was completed in granite basement rocks at a depth of 1,110 feet (338.3 m) (Figure 11). Four spot cores (37 feet; 11.3 m) were obtained in Tertiary sediments and one bottom-hole core (10 feet; 3 m) was cut in basement rocks. Total core recovery was 71 percent. The hole was logged to T.D. with both the standard log suite and the BFEC/KUT system.

Lithologic Descriptions and Interpretations, Hole No. MB-12

0 to 50 feet
(0 to 15.2 m)

Quaternary colluvium: An interval of arkosic sand, weathered granite, quartzite, and calc-silicate pebble gravel. The sand is fine grained, light gray to green, mottled white to brown, calcareous, and contains traces of volcanic ash which is probably secondarily deposited. The boundary between the colluvium and the underlying strata is indistinguishable in drill cuttings but can be observed in outcrops close to the drill site where it separates a rather thick cap (0 to 60 feet; 0 to 18.3 m) of the Pleistocene pediment surface upon which MB-9 was spudded. At MB-9 the cap was thin (0 to 20 feet; 0 to 6.1 m).

50 to 120 feet
(15.2 to 36.6 m)

Sixmile Creek Formation equivalents(?), Miocene(?): A 70-foot (21.3-m) thick unit of mostly angular, coarse- to fine-grained, yellow, orange and reddish-brown limonite-stained sand. Minor amounts of pink to tan, calcareous clay are present, mostly as coatings on sand grains. Several small pelecypod shells were observed, indicating deposition in a channel or pond environment. This interval is correlated with the Sixmile Creek Formation on the basis of lithologic similarity and stratigraphic position.

120 to 780 feet
(36.6 to 237.7 m)

Renova Formation equivalents(?), possibly Oligocene(?): The upper 430 feet (131.1 m) portion of this interval is dominated by tuffaceous claystone and thin tuff beds. The clays and ash are dark gray or light pinkish-tan to light buff and brown, partly

DEPTH	STRATIGRAPHIC COLUMN	DESCRIPTION
	Recent colluvium
	(Unconformity)
	Coarse- to fine-grained sand (Sixmile Creek Formation equivalents)
	(Unconformity)
200'
400'		Claystone (tuffaceous) interbedded with some sandstone and conglomerate, trace organic matter (Renova Formation equivalents)

600'

(Unconformity)
800'		Boulder conglomerate (pre-Renova Formation conglomerate)

1000'		(Unconformity)
	Granite
1110'

FIGURE 11. Generalized lithologic log of Missoula/Bitterroot project hole no. MB-12.

calcareous, and contain glass shards. Interbedded with the clays and ash are lenses and stringers of fine- to coarse-grained, micaceous, light gray to brown pebbly sand. Sample descriptions also indicate that repeating sequences of gravels composed of calc-silicates, hornfels, granite, and quartzite pebbles are present. The clasts in the sand are the same as in the gravel.

The interval becomes more sandy and conglomeratic toward its base. In the lower 200 feet (61 m) the ash concentration is lost and replaced by a waxy, red, highly altered claystone with occasional inclusions of black organic debris. The claystone is probably derived from tuffaceous sources.

This interval appears to correlate with the Renova Formation equivalents designated in MB-2, MB-4, MB-8, and MB-9. Claystone, siltstone, and sandstone are dominant. The fine sample fraction is tuffaceous and contains organic waste.

780 to 960 feet
(237.7 to 292.6 m)

Pre-Renova fanglomerate, possibly Oligocene or Eocene(?): A unit of conglomerates composed of rocks and boulders as large as 50 cm in size. The clasts are of granite, diorite, monzonite, and calc-silicate composition. They are well rounded to subangular, deeply weathered, and tightly cemented with calcite. Veins of calcite occur throughout. The boulders and cobbles appear to be matrix-supported by fine gravel and gray to tan, coarse-grained sandstone.

This unit may represent a tectonic conglomerate derived from nearby metamorphic terrain of the Sapphire Mountains. This conglomerate lithofacies is unlike anything observed in surface outcrops or in other project drill holes. It appears to represent a thick sequence of mudflows and fanglomerate deposits that poured off the upland region to the east, now the Sapphire Mountains.

960 to 1,110 feet
(292.6 to 338.3 m)

Granite, Idaho batholithic material/Sapphire slide block (see Hyndman, 1977 and 1979): A medium- to fine-grained, gray to tan granite composed of biotite, orthoclase and plagioclase feldspar, and quartz. The rock is massive with open fractures having yellowish-green to yellowish-brown stained surfaces. The middle 2 feet (0.6 m) of core number 5 is a yellow, weathered granite. The feldspars are highly altered and fractures are filled with light yellowish-green, waxy clay. This is the same granite present at the base of drill holes MB-8 and MB-9. Core number 5 (1,090 to 1,100 feet; 332.2 to 335.3 m) in MB-12 is not as completely weathered or as

fractured as the granite in MB-8 and is finer grained than that penetrated by either MB-8 or MB-9.

Favorability Assessment of Bitterroot Valley Tertiary Sediments

The locations of the five holes drilled fall on two parallel lines that cross the valley perpendicular to its length and are spaced 25 miles (40.2 km) apart. The drill holes penetrated three Tertiary stratigraphic units; i.e., a Sixmile Creek Formation equivalent, a Renova Formation equivalent, and basin-flanking fanglomerates variously designated as pre-Renova fanglomerate, middle Tertiary clastic unit, and upper Tertiary/Pleistocene clastic unit (Figure 12).

The Sixmile Creek Formation equivalent is composed of pebble conglomerates and sandstone with minor amounts of siltstone. The conglomerate is composed of granite, gneiss, and quartzite clasts, while the sandstone is micaceous and arkosic. Only negligible pyrite and organic carbonaceous material were identified within this unit; no hydrocarbons or reducing gases were detected and no anomalous radioactive zones are present. No zones of pervasive post-depositional alteration were penetrated. An unconformity doubtlessly exists between this unit and the underlying Renova Formation equivalents but could not be pinpointed. The Sixmile Creek Formation equivalent exhibits four of the eight favorable recognition criteria:

1. Thick sequences of rocks derived from granitic provenances are present.
2. These sequences include from 30 to 80 percent feldspathic or arkosic sandstone or conglomerate.
3. Only negligible amounts of reductants were present.
4. No uranium anomalies or mineralization was detected.
5. No zones of pervasive post-depositional alteration were penetrated.
6. Unconformities bound the sequence penetrated.
7. Siliceous, but not tuffaceous, rocks are intercalated with the host rocks.
8. The strata appear to dip at low angles.

The Renova Formation equivalent is composed mainly of interbedded tuffaceous claystone, siltstone, and arkosic sandstone with subordinate beds of pebble conglomerate composed of gneiss, granite, and quartzite clasts. Sparse pyrite and more abundant lignitic carbonaceous material are present. Methane gas was detected in the basal portion of this unit (MB-8). No zones of anomalous radioactivity were noted, but some post-depositional alteration exists. The Renova Formation appears to be the most favorable and meets seven of the eight recognition criteria:

1. Thick sequences of sedimentary rocks derived from granitic-silicic and volcanic provenances are present.

FIGURE 12. Generalized geologic section of the Bitterroot Valley from hole no. MB-6 through MB-8 to MB-9.

2. These sequences include from 30 to 80 percent sandstone or conglomerate.
3. Reductants are presented in the form of abundant epigenetic carbonaceous material and some pyrite.
4. No uranium mineralization or anomalous radioactivity was detected.
5. Some post-depositional alteration was present.
6. Unconformities bound the rock sequences penetrated.
7. Siliceous and tuffaceous rocks overlie and are intercalated into the potential host rocks.
8. The strata dip at low angles (1° to 5°) and faults are present.

The various conglomerate units that occur along the flanks of the Bitterroot Basin are composed mainly of intrusive and gneissic cobbles and boulders. Matrices are sandy and silty to clayey. No hydrocarbons, hydrogen sulfide gas, pyrite, organic carbonaceous material, or zones of anomalous radioactivity are present. Although the sedimentary components appear to have been derived from a severely weathered terrain, no zones of pervasive post-depositional alteration were identified. These data indicate minimal favorable criteria.

SUMMARY OF STRATIGRAPHIC INFORMATION

The Missoula/Bitterroot drilling project has provided significant information verifying known outcrop data and has brought to light considerable data that were heretofore unknown.

VERIFICATION OF KNOWN SURFACE DATA

1. Confirmation of a two-fold sequence of Tertiary sedimentary strata that correlates with the Renova Formation and the Sixmile Creek Formation of the intermontane basins east of the Continental Divide.
2. Appearance of lithologies in both sequences of strata that indicate similar ecological conditions to those known east of the Continental Divide.
3. Confirmation of the depth of fill in the Missoula and Bitterroot Valleys. Both appear to be deep (3,000 feet; 914.4 m) structural basins, reasonably similar to those in other parts of west-central and southwestern Montana.
4. The sediments of both the Missoula and Bitterroot Basins are, for the most part, derived from local sources.
5. Evidence that the Renova Formation and Sixmile Creek Formation equivalents, but in particular the Renova equivalents, contain bentonitic mudstones and claystones with glass shards and "ghosts";

indicates they are probably reworked rhyolitic tuffs. Clay analyses indicate the presence of abundant smectite, which is more than likely the alteration product of volcanic ash and glass. Some of the clays may be the result of the diagenesis of volcanic glass, feldspar grains, and mica while large quantities of ground water migrated through the system.

6. Confirmation that grain sizes of Sixmile Creek Formation equivalents are coarser than those of the Renova Formation equivalents.
7. Presence of lignitic stringers, coal seams, and abundant organic trash in the Renova equivalents, especially in the Missoula Valley.
8. Evidence that the Tertiary section rests on granitic basement rocks in the southern half of the study area (holes MB-8, MB-9, and MB-12). This contact is observable in only one or two surface outcrops along the eastern edge of the Bitterroot Valley (near MB-9 and MB-12).

ACCUMULATED DATA UNKNOWN BEFORE THE DRILLING PROJECT

1. Indications of more abundant coarse conglomerate, gravel, and coarse-grained sandstone strata in the Missoula/Bitterroot Valleys than in basins east of the Continental Divide.
2. Occurrence of massive and very thick pre-Renova conglomerates composed of large boulders, cobbles, gravel, and coarse-grained sand probably deposited by mud and debris flows or intermittent streams on large alluvial fans. Well MB-2, at Houle Creek in the Missoula Valley, and MB-12, on Hamilton Heights in the Bitterroot Valley, illustrate such occurrences. These conglomerates differ from each other because each is composed of clasts derived locally from bedrock of different character. Both are unlike anything observed in outcrop in the Missoula and Bitterroot Valleys or in any of the intermontane basins east of the Continental Divide. They are probably the result of early Tertiary tectonic events, the evidence of which is found only in the deeper, yet unexposed, parts of the basins. Units of similar origin and composition may well be present elsewhere.
3. These data provide evidence for a depositional cycle in Oligocene or Eocene time, or in both epochs, that was heretofore unrecognized.

INFORMATION YET TO BE VERIFIED

1. Drill cuttings did not provide data necessary to define the mid-Tertiary unconformity that has been recognized in all of the basins studied east of the Continental Divide. The recognition of both Renova Formation and Sixmile Creek Formation equivalents in several of the Missoula/Bitterroot project holes and in surface outcrops points to the existence of an unconformity and hiatus in both valleys similar to that identified elsewhere.
2. No vertebrate fossils were observed in either cuttings or cores; thus, no additional paleontological information was acquired. Several small bivalve shells were observed in cuttings from the

70- to 80-foot (21.3- to 24.4-m) interval in MB-12. Unfortunately, they were unidentifiable and produced no new data.

3. The pollen and spore analyses proved to be of limited value to the present study. It was hoped that the palynology would provide direct information concerning ages of pollen and spores from specific intervals, as well as paleoenvironmental interpretations, but it did not.

CONCLUSIONS

Of the three lithologic units present, the Renova Formation equivalents can be assigned the best stratigraphic favorability for uranium occurrences. The other two units (Sixmile Creek Formation and pre-Renova clastic units) are considered to be unfavorable. The assessment is based on the criteria used in this report. The criteria crucial for identifying areas prospective for Renova Formation equivalent uranium mineralization may be:

1. The regional extent of pervasive post-depositional alteration.
2. Proximity to equivalents of the Challis Volcanics in the southern Bitterroot area, the best potential source of uranium in ground water within the project area.

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APPENDIX A

LITHOLOGIC DESCRIPTIONS OF CUTTINGS
(See color microfiche in pocket)

APPENDIX B

LITHOLOGIC DESCRIPTIONS OF CORES

Cores from the Missoula/Bitterroot drilling project
are available for study at:

Department of Geology
University of Montana
Missoula, Montana 59812

or

Montana Bureau of Mines and Geology
Montana College of Mineral Science and Technology
Butte, Montana 59701

Well No.	Run	Footage	Description
#2	1	811'-821' Rec 6'	Top ~1" ang-(rnd) Qtzt v fine-med, dk gn, pk, pu, gn + (sdy) argillite, pu, pbls ~1.5"-1.5" diam. Lower ~9" interbedded siltstone, sandstone and conglomerate, most contacts gradational; layering extremely fine scale in siltstone and f. sandstone, wavy; med-crs sands <1" thick; single conglom layer ~1/4" thick; cons; layers perpendicular - ~25° to core length, srtd within layers.
		811'-812' Rec ~10"	Siltstone m-dk gy, sdy, with f. wavy stringers (<.01") of blk org mat. Sandstone - v fine - crs. (rnd)-(ang): Qtzt, pu, red, lt-dk gn, wh; Argillite, pu, red, lt-dk gn, gy, blk. Conglom - pbls to 1/4", (rnd)-(ang) Qtzt + Argillite as above.
		812'-813'	Dom (srtd), silty, Sandstone, v fine-med, m gy-dk gy where concentration of dk organic mat finely dispersed and fine stringers. 2 thin horizons of blk org mat and lt gy med-crs mud chips (?) at top and bottom; massive-swirly texture. lower 1.5" (srt) fine-crs, silty sandstone, dom Argillite, gn, gy, red, pu, wh, (ang)-rnd., massive(?).
		813'-814'	Top ~2 1/2": Sandstone (srtd), silty, v fine-crs, m. gy, massive Black coal chips, layer originally prob = 1" thick. Conglom ~1", (srtd), rnd-(ang) pbls to ~1/4", Argillite, blk, lt-dk gn, pk, pu, red, gy + mnr f. Qtzt, pk, pu, gy; pbls grain supported in matrix of v fine-med, slty, (srtd) sandstone. Sandstone, ~3" as above Top 2 1/2" Lower ~5": Sandstone, v fine-fine, slty, m (pk) gy containing mottled blobs of lt gy sltst up to 1.5" diam, concentrated in lower 1.5" esp, gradational and sharp boundaries between two lithologies, massive.
		814'-815'	Top ~5": interbedded: lt gy Sltst with blk org stringers (<.01"), + blk (cly), (sdy), ~1" layers } coal dk gy Sltst which may grade into and/or } lenses include coal stringers (<.05") } <.1" Middle ~3" Blk coal, fissile, hard. Lower ~4" massive unit containing rnd-(ang) pbls Qtzt & Argillite to .75" in matrix support; matrix (srtd) slty fine-crs sandstone with blk org mat stringers.

Well No.	Run	Footage	Description
#2		815'-816'	~8" dom <u>Siltstone</u> lt-m gy, (sdy) with v fine blk org stringers, sandy at top with a few crs pbls scattered throughout, massive to mottled and sinuously bedded ~perpendicular to core length on <1 cm-mm scale. lt (yell) gy cly concentrated in mm scale sinuous layers in lower 3".
		816'-821'	<u>fragments of conglom</u> <u>Upper</u> pbls & cobbles <.5"-2", dom <u>Siltite</u> and <u>Argillite</u> , lt-dk gn, pu, dk (gy) pu <u>Lower</u> Broken fragments of <u>Sltst</u> , <u>srted</u> , (sdy), m gy, as above + mn <u>Sandstone</u> (srted) fine-med as above, cons.
#2	2	965'-975' Rec 4"	Ang-(rnd) Boulders <u>Qtzt</u> fine-med, pk, (pk) pu, gn, (gn) gy, tan, (<u>mic</u>), <u>Siltite</u> & <u>Argillite</u> , (br) gy, gn, pu, (gn) gy.
#2	3	980'-990' Rec 3'	(Rnd)-Ang Boulder, cobbles, & pebbles <.25"-5" <u>Qtzt</u> as above & <u>Siltite</u> & <u>Argillite</u> as above & blk. Some of these large grains occur in a matrix of (srted) gn clay & sand, fine-crs: grain support dominates; many grains are weathering to clay in place. In general, this core is very poorly consolidated.
#2	4	1072'-1084' Rec 5'	Ang frags of <u>Sltst</u> , (gy) gn, cons, srted, (sdy); Ang-(rnd) <.5"-4" chunks: <u>Qtzt</u> , pk, (pk) pu and finely banded lt-dk gn <u>Siltite</u> (sdy) + <u>Argillite</u> .
		1072'-1073'	
		1073'-1074'	Top 8" <u>Sltst</u> (srted), <u>cons</u> , lt gy, m(blue) gy, lt (gy) gn, (red) brn; textural change to <u>slty</u> fine sand occas assoc with lt gy mottles; (red) brn band ~1.5" wide perpendicular to core length - mottled (1/8 - 1/2" thick) usu. elongated in same direction, but not distinctly layered. Lower 4" <u>Conglom</u> , matrix-supported, massive, cons; <u>Grains</u> ~35%, Pbls to .5", (ang)-rnd, often lathe-shaped, dom <u>siltite</u> + <u>Argillite</u> , lt-dk gn, lt-dk gy, pk, pu + med-crs sand of same composition, some pbls altering with dk (red) brn lim halo which may be separated from residual grain by (wh) cly rim. Matrix ~65%, m(red) brn <u>Siltst</u> , (srted), <u>sdy</u> , cly.

Well No.	Run	Footage	Description
#2		1074'-1075'	~9½" as above massive <u>Conglom</u> , but lacking lim halos on weathering grains.
		1075'-1076'	~1' as above massive <u>Conglom</u> lower 3" grades to larger max. grain size ~.75".
		1076'-1084'	~1' <u>Conglom</u> , cons, massive, some grain support, similar to above, but more & larger grains; <u>Grains</u> ~70% (ang)-rnd, com 1/8"-1/4", but up to 2", many lathe-shaped: dom Siltite & Argillite, pu, (gn) gy, red, finely banded lt-dk gn, some wthrd (yell) gn, (brn) yell, yell, lt gy; mnr Qtzt, pk; <u>Matrix</u> ~30% m(red) brn Sltst-Sandstone, (srtd), v <u>fine-crs</u> (cly).
#2	5	1232'-1243' Rec 11.6'	<u>Conglom</u> , cons, massive, dom grain support, similar to above, but larger grains; <u>Grains</u> ~70%, ang-(rnd), com .25"-1", up to 5": dom Siltite (sdy) + Argillite, lt-dk gy, pk, (pk) pu, finely banded lt-dk gn; mnr Qtzt, fine
		1232'-1235.5'	grained, pk-wh; some grains <u>wthrd</u> , with permeating yell-(orng) brn lim stn; <u>Matrix</u> ~30% m(red) brn, (srtd) Sltst-Sandstone, v fine-crs, (cly)
		1235'-1243'	<u>Conglom.</u> (cons)-cons, massive, dom grain support; <u>Grains</u> ~75%, dom(rnd)-rnd, com. .25"-2", up to 4", dom gn and pu Siltite (sdy) + Argillite, other colors mnr; com Qtzt, fine-med, (pk) pu, gn, (mic); some grains wthrd wh-(yell)wh; <u>Matrix</u> very poorly srtd. sltst-crs sand of same composition as grains. 1236.5 ~2" sandstone, (srtd), fine-med, slty, permeated by med(red)brn stn.
			<u>Note:</u> Contact between the two conglomerate units of Run #5 occurs abruptly at the base of a chunk of the upper unit at ~1235.5'. Lower unit is somewhat less cons; grains are of similar composition to upper, but considerably more rounded; matrix is coarser and generally lacks the (red)brn coloration characteristic of the upper unit.
#2	6	1748'-1758' Rec 10'	<u>Note:</u> Core divisible into 5 or 6 units consisting of a conglomeratic and silty section. In general, contacts are either gradational or obscured by breaks in the core so it is unclear whether these are fining or coarsening upwards. Thickness of a single unit varies from ~2.5' to 9". Coarse sections of units are finer in

Well No.	Run	Footage	Description
			upper 2' & over the entire 10 ft of the core there is a general fining upwards. Composition and color of grains and matrix similar to 1232' 1243' above.
#2		1748'-1754'	<u>Conglom</u> cons, massive, dom grain support; <u>Grains</u> ~75%, (ang)-rnd, com .25"-1", up to 2.5", Siltite + Argillite, lt-dk gn (some finely banded), pu, lt-dk gy, some wthrd yell-(orng) brn, wh; Qtzt, pu, pk, clr gy, mnr gn, med-crs, feldspathic; <u>Matrix</u> ~25%, Sltst, cons, sdy, (srted), m(red)brn. Sltst cons, sdy, m(red)brn, scattered grains m-crs sand & small pbls locally esp. near conglom, mottled coloration locally, (red) brn cly stringers, local patches fine-med sand.
		1754'-1758'	<u>Conglom</u> (cons)-cons, massive, grain support; <u>Grains</u> ~85%, (ang)-rnd, com boulders 1-6", com pbls 1/8-1"; Qtzt, pk, lt(pk) pu, pu, clr lt-m (gy) buff, (gy)wh, (mic), fine-med, feldspathic; siltite + Argillite, lt-dk gn, lt-dk gy, pu, frequently banded, some small pbls wthrd yell or wh cly. <u>Matrix</u> ~15% v. poorly sorted, fine-crs sandstone, slty, (cly), same gen. Qtzt-Argillite-Siltite composition as grains; (red) brn stn permeates matrix locally.
			<u>Note:</u> because size sorting is virtually absent, division between matrix and grains is indistinct. Fractures in boulders and pebbles com., healed with matrix.
			<u>Note:</u> "Contact" between 2 units of run 6 occurs at a break in the core.
#2	7	1937'-1945.5' Rec 5'9"	<u>Conglom</u> (cons)-cons, dom grain support with local areas of matrix support, probable bedding planes up to 45° to core length defined by linear concentrations of med(red)brn clay & silt and by changes in grain size of conglom. <u>Grains</u> ~60%: ang-rnd, com <.25-1.25", up to 4.5" Qtzt & Siltite & Argillite (as above) pk, red, pu, lt-dk gn, gy, buff, some fractured <u>Matrix</u> ~40% Sltst, cly, dk(red)brn, slty. Clay and Siltstone layers and accumulations 1-3" thick.

Well No.	Run	Footage	Description
#2	8	2237'-2247.5' Rec 8.5'	<p><u>Conglom</u> (cons)-cons massive, grain support: <u>Grains</u> ~85%, (ang)-rnd com. lg boulders 1-5", com pbls 1/8-1" Siltite & Argillite, lt-dk gn (most banded, showing fine sed structures like mud clasts), lt-dk gy, pu, some yell wthrd;</p> <p>Qtzt, pk, lt(pk)pu, pu, gy-buff, (mic), fine-med, feldspathic; some fractured; <u>Matrix</u> ~15%, v. poorly srtd, fine-crs sandstone, slty, (cly) all grain sizes represented, compo- sition similar to larger clasts; mnr (red) brn stn. permeates some matrix (lower ~2 ft uncons. frags)</p> <p>Note: This core is very similar to 1754'-1758' above.</p>

Well No.	Run	Footage	Description
#4	1	695'-710'	No recovery.
#4	2	710'-715' Rec 3'.3"	<u>Conglom</u> , uncons-cons, no apparent orientation or bedding, dom. grain support: <u>Grains</u> ~70%, (ang)-rnd, com. .25-1.5", to 4": <u>Qtzt</u> , fine-med, (pu)pk, (gy)pk, lt-dk gy; Siltite + Argillite, lt-dk gy (some finely banded), (gy)gn, pk, pu; Gneiss, med-crs, dk gy Qtz-Fld-Biot with wh Fld augen + tr fine-med granitic mylonite(?) <u>Matrix</u> ~30% (wh)gy sandstone, med grained, (ang)-(rnd) Qtz, clr, gy, wh; Fld, clr, wh, <u>many</u> grains alt to wh cly; com Musc flks; mnr sand-sized grains of Qtzt, Argillite, Siltite; tr (gn) yell lim stn.
#4	3	826'-841' Rec 1'	Uncons frags of <u>Conglom</u> , ang-(rnd) a little matrix similar to above sticks to some frags, <u>Qtzt</u> , pk (pk) gy, fine-med, feldspathic; Argillite, mnr, (gy) gn.
#4	4	Box 1: 1489'-1496'8" Rec 6'10" 1489'-1491.3' 1491.3-1492.6 1492.6'-1494' #4 (Cont'd) 1494'-1495'5"	<u>Sandstone</u> cons, <u>srted</u> , massive, v fine grained at top grading to fine in lower section, lt med gy ("salt-pepper" on small scale", ang-(rnd); Qtz ~40%, clr, gy, wh; Fld ~40% clr, wh (intense alt of Fld gns to wh cly); blk-(gn)blk grains chlor(?) ~20%; some (red) orng lim stn esp on Qtz. Finely streaked & mottled with med gy silt & clay. <u>Sandstones</u> of two grain sizes interfingering across core 1) fine grained sandstone as above 1489'-1491.3' 2) med-crs grained sandstone, cons, srted, ang-(rnd) "salt & pepper": Qtz, clr, gy, wh, tr (red) orng; Fld, clr, wh, much alt to wh cly; blk-(gn)blk chlor? biot?; tr mica flks; tr buff ash Med <u>Sandstone</u> as above, becoming <u>coarser</u> and more poorly sorted by 1493' with a few scattered (~1%) <u>pbls</u> , ang-rnd, .1-.5": Qtzt, red, gy, gn + Argillite, blk, gy; tr buff - m gy ash. <u>Sandstone-Conglom</u> v poorly srted, f-crs sand ~.25% + pbls to ~.25", ~25%, massive, composition as above.

Well
No.

Run

Footage

Description

1495'5"-1495'10" Sandstone, med-crs grained, composition as above 1491.3-1492.6.

1495'10"-1496'8" Conglom cons, v. poorly sorted, massive, grain and matrix support: Grains ang-rnd: Qtzt, med-fine, gy, (gy)wh, (gy)gn, (gy)brn, mn r pk, com. feldspathic; Argillite, blk, gy, gn; mn r Musc flks; Qtz, clr, wh, gy, (red) orgn; Fld, wh, gy, alt to wh cly; Ash, gy-buff, ang wthrd frags, <1% Matrix fine-crs, ang- (rnd) qtz, Fld, Mica flks, wh cly.
Note: This top part of core #4 has very similar composition throughout and may be a single graded bed, since grain size fines generally upwards. White clay is very ubiquitous and at least part of it can be observed to be an alt. product of Fld. grains.

Box 2:

1496'8"-1504' Conglom (occurs in fairly distinct units at 1496'10" - 1497'1.5", 1501'8"-1502.5", 1502'6"-1503'3" and elsewhere (less distinctly) cons, massive, srtd, dom grain support Grains: ang-rnd, com. .1-<.5", up to 1.5"; Qtzt, com fine grained, lt-dk gy, buff, (gy)wh, mn r (gy)gn, mn r (pu) pk, feldspathic (wthrd); Argillite, blk, gn, gy; Qtz, wh, gy, clr; Fld, clr, wh, often wthrd to wh cly; Ash, cons. buff-lt gy Matrix (srtd) sandstone similar to 1495'10"-1496'8" Sandstone Crs-fine, (srtd), graded, composition similar to matrix
Also: coal stringers <1" long at ~1501', 1497.5', 1498.25' (gn) yell organic residue concentrated near coal stringers with tr. occurrences elsewhere.

Note: This section of core #4 is compositionally very similar to the first box, but shows fairly distinct units of graded bedding on a smaller scale. Six graded units ranging in length from ~6" to ~2' occur between 1496'8" and ~1502'. Second box is also generally coarser.

#4

5

2395'-2405'
Rec 10'

-1.5" ang chunk Sltst, lt gy, sdy, cons, massive (on this scale), a blk coal frag .5"x3"x <.1" on broken surface.

Well No.	Run	Footage	Description
		Box 1: 2395'-2401'	<p>-4" Sandstone, cons. <u>slty</u>, lt med gy, fine-med grained, <u>srted</u>: Qtz, <u>ang-(rnd)</u>, clr gy, wh, ~50%; Ash, <u>ang-rnd</u>, (gy) wh-gy, slt, ~35%; slt & cly matrix, gy, ~15%; <u>Blk org stringers</u>: V fine, ~horizontal, sinuous + a few coal stringers ~.05" thick. This unit in sharp lower contact with <u>Sltst</u> dk gy, cons. dk color caused by finely disseminated blk org mat. ~.5" broken at base.</p> <p>-6" Apparent <u>Graded unit</u>, fining upwards: Upper <u>Sltst</u>, dk gy with disseminated blk org mat; in mottled & sinuously bedded contact with concentrations of <u>Sltst</u> med-dk gy, sdy, fine sand-sized grains mostly (gy) wh-gy Ash & some clr, gy Qtz. Lower: size & percentage of Ash & Qtz grains inc from fine to med & crs & from <10% to >85%; fine bands & stringers of blk org mat, sinuous, ~horiz.</p> <p>-~2 ft Sandstone, lt gy ash & qtz, slty, as above + <u>Sltst</u> lt-dk gy as above. 2 units mottled & sinuously horizontally layered on <.1"->1" scale; blk org stringers & disseminated org. concentrations gen. roughly horizontal, occasionally at various angles.</p> <p style="padding-left: 40px;">~5" dk gy <u>Sltst</u> with stringers & disseminated organic mat. trace Coal blobs & stringers up to 3/16" thick, lt gy <u>Sltst</u> mottles & blebs; orientation of stringers & blebs ~45°</p> <p>-lower ~3 ft similar to above: lt-dk gy <u>Sltst</u>; lt med gy Sandstone; blk org mat & coal; contact between diff colored & grain sized units varies from sinuously horizontal to swirly & mottled, with occas grain size grading; gy-(gy wh) ash frags up to 1/4" locally, a coal seam ~1/4" thick crosses core @ ~35°</p> <p>Note: 1) Color in this core is primarily determined by amount of blk org mat disseminated in gen lt-med gy Ash, Qtz & Silt; 2) Roughly horizontal layering appears to be disrupted by soft sed. deformation, some probably graded bedding occurs with scoured lower surfaces.</p>

Well No.	Run	Footage	Description
#4	Box 2:	2401'-2405'	Upper ~2.5 ft similar to above sandstone & sltst & organics At ~2101.5 a <u>Conglom</u> layer ~ $\frac{1}{2}$ " thick dom grain support, cons massive: gen 1/16-1/4" grains Ash, rnd-(ang), (gy)wh- gy, sft ~50%; Qtzt, fine-grained, red, pk, pu, lt-med gy, feld- spathic + dk gy sericitic Siltite, rnd-(ang) ~35%; Matrix Sltst, lt med gy, <u>sd</u> y, ~15%.
			Lower ~1.5 ft <u>Conglom</u> , uncons-(cons), <u>unsrtd</u> , massive Grains from fine sand & silt size to 4" boulders. Larger grains are dom Qtzt, pk, gy, gn + <u>Argillite</u> gn, gy; grains < $\frac{1}{4}$ " also include <u>Ash</u> gy, (gy) wh + <u>Qtz</u> , clr, gy, colorless; med- fine sand also includes mica flks, coal frags & glass shards(?); finer matrix is gy slt. Most of the large grains are shattered; sample does not allow determination of matrix or grain support.
#4	6	2895'-2907' Rec 8'7"	Entire core a <u>Breccia</u> , uncons-(cons), massive to lineated, ang-crushed frags of: Qtzt, fine- med grained, pk, lt-dk pu, some feldspathic; <u>Argillite</u> & <u>Siltite</u> - lt dk pu, pk, gy(pu) Note: 3 rock types above are frequently laminated (esp Argillite & Siltite) on cm-<mm scale within fragments. One chunk has laminations distorted by (healed) small scale faults & folds. Frag- ments com <1", up to 25". Space between frags contains 1) <u>Cly</u> (pk) pu, wxy, flky, sericitic, or 2) <u>Cly</u> , (gy) wh-(pk) wh, <u>sd</u> y or 3) <u>Cly</u> , wh

Well No.	Run	Footage	Description
#6	1	470'-480' Rec 3"	Milled rock chunks 1-5" diameter: 1) <u>Granite</u> , fn-med gr; Qtz, anhedral; gy, wh; Flds, anhedral, wh; Biot; (orng) brn lim stn; 2) <u>Granite Pegmatite</u> , med-crs gr; Fld, wthrd, wh, lt gn; Qtz, gy, wh; Biot; (yell)gn-(yell)orng lim stn
		Top ~1'	
		Middle ~1'	~4" <u>Sandstone</u> fn-crs gr, (srted), (cons) mic, dk(gn) gy, extremely immature slty, Flds, Qtz, Biot; localized blotches of lim stn; contains matrix supported rnd-(ang) pbls <u>wthrd</u> granite Solid chunk <u>Granodiorite</u> fine-med gr with a few <u>crs</u> Fld xls, massive texture with slight foliation of biot & hnb1; 3" + solid chunk <u>Granite</u> fine-med gr Qtz, gy, wh; Fld, wh; Biot; massive, ~4"
		Bottom ~1'	Completely wthrd <u>Granite</u> Qtz, Biot & Musc flks, alt. with Flds, lt (yell) gn gy cly, orng lim stn, (cons) ~4" ~6" <u>Granite</u> chunk fine-med gr, massive, 2 diffuse bands (~1") lim stn; Qtz, gr, wh; Fld, wh; Biot. weathered Granite, lim stn comm, Most Fld alt, ~2"
#6	2	619'-629' Rec 2.5'	<u>Granite</u> fine-med gr with a few <u>crs</u> Fld xls, massive; Qtz, gy, wh; Fld, wh; Biot; 4" <u>Pegmatite</u> v crs, massive anhedral grs: Qtz gy, wh; Fld, wh; Musc; mnr Biot, mnr graphic texture; 6" <u>Slty Sandstone</u> , cons, <u>mic</u> , srted, dk-m gy, f gr, Qtz; Fld; Biot; ~5"
		Top ~1.25'	
		Bottom ~1.25'	<u>Sandstone</u> as above; ~3" <u>Sandstone</u> ~3" f-med gr, cons, <u>mic</u> , srted, lt gy, <u>slty</u> , Qtz, Fld, Biot; with <1" rnd pbls weathered granite in matrix support <u>Conglomerate</u> matrix: (srted), <u>slty</u> , <u>mic</u> , fine-crs gr sandstone, med-dk gy. grains: <u>Granite</u> & <u>Granite Gneiss</u> pbls <1"-3" diam., rnd-(ang), grain support, no obvious alignment. <u>Pegmatite</u> (cons), extremely wthrd, med-crs grs Qtz; Flds, alt. to wh & gn cly; Biot & Musc; 1"-3" chunks; lim stn } Cons ~6"

Well No.	Run	Footage	Description
#6	3	867'-877' Rec 2.5'	Broken and sometimes milled chunks: 1) relatively unwthrd <u>Granite</u> , fine-crs gr, anhedral-subhedral: Qtz, gy, wh; Flds, gy, wh; Musc, Biot, Hnbl(?); some orng lim stn 2) K-spar, Biot, Qtz <u>Gneiss</u> , med-crs gr, foliated, friable, wthrd, 3) <u>Granite</u> , extremely wthrd Flds, wh, most alt. to clay; Qtz; Musc & Biot flks; (gn) brn lim stn
#6	4	1092'-1104' Rec 6'5" ~1.5'	loose <u>cobbles</u> rnd-ang. <1"-5" diameter; fine-med gr <u>Granite</u> ; <u>Granite</u> pegmatite & aplite; biotite, qtz, felds <u>Gneiss</u> ; Qtzite, banded lt-dk gy, feldspathic, (one lg cobble) <u>Conglomerate</u> poorly sorted grs as above, (cons); matrix fine-crs Qtz-Flds-Biot-Musc mineral grs & Gr-Gn-Qtzite rock grs, dom ang sand; massive texture, poor sorting obscures distinction between matrix & clasts as does deep weathering of clasts, some lim stn
		Upper Middle ~2'	<u>Conglomerate</u> , as above; (yell)orng lim stn com, esp around weathering Biot. Intensely wthrd dom Granitic clasts. Part of matrix is prob. totally wthrd clasts now unrecognizable.
		Lower Middle ~1.5'	<u>Sand</u> (srted), fine-crs gr, mic, (cons), friable, (orng) brn lim stn permeates & accents possible in-scale horizontal laminations; Feld, gy, wh, wthrd; Qtz, gy, wh, ang-rnd; Biot & Musc flks, wthrd; contains occas. wthrd Gr pebbles.
		Lower ~1.5'	<u>Conglomerate</u> as above, with a 1" layer of (orng) brn lim stn sand, as above
			Note: weathering in this core has altered most feldspar to clay - looks like ancient soil. Compositional difference between cobbles, pebbles & sand matrix very minor.
#6	5	1357'-1367' Rec 9"	<u>Pegmatite</u> 2" fine-crs: Musc ~10%, Biot ~5%, Felds, wh, 70% some wthrd, Qtz, clr gy, sug, 15%; tr (yell) orng lim stn <u>Granite</u> 7" fine-crs gr, massive, anhedral-subhedral: K-spar & Plag, wh & gy, 55-60%, Qtz, gy, 35%; Mafic, dom Biot, 5-10%, relatively unwthrd.

Well No.	Run	Footage	Description
#6	6	1558'-1568' Rec 3'8" Upper ~2.5'	<p>Chunks (1"-6"), rocks of granitic-granodioritic composition & cataclastic-mylonitic texture</p> <ol style="list-style-type: none"> 1) <u>Gneiss-dom</u> fine-med gr, Musc-Biot-Qtz-Flds(wh); alternation of Biot. rich & Qtz-feld rich layers .1-.3" scale 2) Cataclastic <u>Granite</u>, Musc-Feld-Qtz, fine-v. crs gr; rounded corner in contact with coarse, gn-altering, granitic rock 3) Musc-Biot-Qtz-Feld <u>Gneiss</u>, fine-crs gn; augen .5"-1.0" of Qtz-Fld; mafics <10%. 4) Biot-Qtz-Feld <u>Gneiss</u>, well developed mylonitic texture, Qtz-Fld augen & layers alternate with Biot (hnb1?) rich layers ~.5" scale, mafics ~30% 5) V fine-fine, cons, wthrd, Biot-Qtz-Feld Granite(?); poss. ground & sheared to this grain size; smeared .3" layer Qtz-Fld
		Lower ~1 ft.	Very altered & sheared Biot-Qtz-Feld, med-crs gr., Granite or Granite Gneiss; (cons), friable; intense dk gn-(yell) gn alteration of Biot (+ Feld?)
#6	7	1727'-1736' Rec 9'	<p><u>Mylonite</u> "granitic" composition: Fld, lt (pk) wh - wh, xls rounded and smeared out parallel to foliation; Qtz, mky gy-wh, sheared xls and stringers; small flecks & concentrations of dk gn chlor(?) <1%; mm scale strings of lt gn-dk gn and tan minerals(?) parallel & cross-cut foliation; occas clr-gy Qtz veins <.1"-.5" also cross-cut foliation; (br) gold-(br) red stn occurs in veins & stringers esp at 1736'-1734.5' and 1733'-1732'; lt gn-wh clay occurs throughout with local concentrations. Foliation perpendicular to core length, defined by stringers of Qtz & tan & gn minerals and by deformation of Fld xls, probably originally med-crs grn.</p>

Well No.	Run	Footage	Description
#8	1	1815'-1830'	<u>Silty Claystone</u> , cons, massive lt gn (dry color), many silt-sized glass shards, scattered stringy glass shards to ~.5" long, <.1" wide, <u>srted</u> ; mottled
		1815'-1817'8"	
		1817'8" - 1819'10"	<u>Sandy Siltstone</u> , (cons)-cons, massive, (srted); sand ~30%, <u>fine-crs</u> , ang-(rnd): Qtz, gy, clr, wh; Fld, clr, wh, much alt. to wh cly; tr-com. musc & biot, tr wood frags, tr glass shards; matrix ~10% gn <u>slty</u> claystone, includes silt-sized Qtz+Fld+tr (yell)gn wxy cly.
		1819'10" - 1820'2"	Nodules of <u>slty</u> claystone as above 1815-1817'8" in <u>sd</u> y siltstone as above 1817'8"-1819'10" (2 lg. nodules up to 3") contain thin swirls (<.1") of wxy cly
		1820'2" - 1830'	<u>Claystone</u> , <u>srted</u> , lt (yell) gn (dry color), (cons)-cons, v friable angular chunks and flakes <1", <u>wxy</u>
	Box 1	2310' - 2321'	<u>sd</u> y <u>Cly</u> + cly (conglom) sand;(cons), <u>friable</u> , m (yell) gn wxy cly + <5-80% ang-(rnd) <u>fine-crs</u> sand & pbls to .25": Qtz, clr, gy, wh; Fld, clr, wh, pk, perthitic; Musc + Biot flks; Granite (Qtz-Fld-Biot-Musc) <u>fine-crs</u> (pegmatite?)
#8	2	2310'-2315'	Contains a 6" unit <u>sd</u> y <u>Conglom</u> , (cons), 80% grains as above, but gen coarser (com .1-.25"), matrix sand~5% & dk gn wxy cly ~15%
		2315'-2317'	Upper: ~1'6" <u>conglom Sandstone</u> , cons, massive; matrix 5-15% dk gn cly, wxy; Grains ang-(rnd), com 1/8" to 1/4", Qtz + Fld Xls + Granite + Mica flks as above
			Lower ~6" Graded unit, fining upwards: <div style="display: inline-block; vertical-align: middle; margin-left: 10px;">↑ grades finer</div> <u>Clst</u> - <u>sd</u> y, pbly, cly, lt gn, cons <u>Conglom</u> -lt gn cly <u>Sltst</u> matrix; matrix support dom; grains Qtz, Fld, Granite dom (as above) many large mineral grains wthrd (orng) brn (~30-70% grains), cons <u>Conglom</u> - dk gn wxy <u>Clst</u> matrix; dom grain support; grains as above, but gen coarser (~85% grains) (cons)-uncons

Well No.	Run	Footage	Description
#8		2317'-2319'	<p>Upper $\sim \frac{1}{2}$: 2 units in swirled contact, cons:</p> <p>1) <u>Sltst</u>, cly, srted, with some (yell) gn wxy cly stringers, com fine biot flks</p> <p>2) <u>Sandstone</u> (?), v. poorly sorted, fine-crs sand + som pbls to .25" Qtz gy, wh, clr; Fld; perthitic, clr, wh, wthrd; Granite, Qtz-Fld-Biot; fine-crs Biot flks + books; matrix lt gn cly Sltst</p> <p>Lower $\sim \frac{1}{2}$: Dom <u>Conglom</u> grain support: <u>matrix</u> dk gn wxy cly <25%; <u>Grains</u> ang-(rnd); com 1/8-$\frac{1}{4}$", com wthrd: Qtz, gy, wh, clr; Fld, wh, clr, perthitic; Biot + Musc; Granite</p> <p>+2 cly & Sltst units ~ 1" thick at top & bottom of conglomerate (no contact observed): lt gn sdy, cly Sltst; (yell) gn wxy cly</p>
		Box 2 2310' - 2325'	
		Rec ~ 4 ft.	
		Top ~ 1 '	<p><u>Clay</u> - v. friable, lt-med (yell) gn, slty, v. sdy locally with fine-crs Qtz, Fld, Biot & Granite grains similar to above</p>
#8	2		
		Middle ~ 2 '	<p><u>Conglom</u> dom matrix support, massive, v. poorly srted, cons: <u>Matrix</u> $\sim 50\%$ Sltst lt gn, slt + fine sand sized Qtz-ang, clr gy, wh; Fld, wh; Biot; glass shards(?), mn'r gn wxy cly; <u>Grains</u> $\sim 50\%$ of all sizes com to $< \frac{1}{4}$", ang-(rnd) Qtz; Fld, wthrd com on rims; Biot</p>
		Lower ~ 1 '	<p>Upper 6" - Conglom very similar to lower $\frac{1}{2}$ of interval 2317-2319 ,</p> <p>Lower 6" - Sandstone, fine-crs, grain supported Qtz, fld, Biot + Matrix of lt (yell) gn Cly - wxy, slty, sdy, poorly srted</p>
		Box 1 2709' - 2719'	
			Note: entire core consists of somewhat sheared & fractured <u>Granite</u>
#8	3		<p>Where unaltered: fine-crs massive textured: Qtz $\sim 40\%$, anhedral, dom clr gy⁺, wh; Fld $\sim 50\%$, wh, (gy) wh, subhedral-anhedral; Biot $\sim 10\%$ euhedral-subhedral</p>

Well No.	Run	Footage	Description
#8			<u>Alteration:</u> Fractures & shears occur @ <1" - >5" scale intervals at various angles; slickensides well developed with wh, gn, red, & orng striped polished surfaces; Alt. Biot is smeared & stretched; Qtz is stretched & sheared to fine stringers; Flds are occas fractured; foliated cataclastic texture along shears is occas swirled & folded
3	Box 2 2719' - 2723'		Same as above, but somewhat less altered.

Note: A granite like this could have been the source of grains in sand and conglomerates of cores 1 & 2.

Well No.	Run	Footage	Description
#9	1	970-980 2 boxes ~10 ft rec	<p>Top ~.75 ft. <u>Weathered Granite</u> (prob originally as described below) partly-totally disaggregated; most fld alt. to wh cly or gn mineral; much Biot alt to Chlor; red, yell, brn lim stn esp in fractures and along occas shear surfaces</p> <p>~.75 ft - zone of mild shearing and fracturing ~perpendicular to core in wthrd Granite</p> <p>~1 ft <u>Granite</u> (see description below) somewhat wthrd with much fld alt to wh cly</p> <p>entire Box 2: ~7 ft. <u>Granite</u> massive textured, slightly wthrd, occas fractured <u>Qtz</u> ~25% clr gy, fine-crs, anhedral <u>Plag</u> ~35% wh, some wthrd, fine-crs, anhedral-euhedral <u>K-Spar</u> ~30% wh, (pk) wh, (gy)wh, fine-crs, anhedral-euhedral + 5-10% <u>Crs</u> euhedral megacrysts <u>Biotite</u>-fine-med, occas crs.euhedral-subhedral ~10%</p>

Well No.	Run	Footage	Description
#12	1	400'-410' Rec 3"	Single <u>Rock frag</u> lt gy, <u>cons</u> , v fine-fine grained, contains <u>felds xls</u> & prob qtz, hardness ~6, surface speckled with ~1% fine cavities, brn rhind ~1/8" from surface on undrilled sides
	2	410'-415' Rec 5'+	<p>-8" <u>Ash</u>, (cons), sft, <u>srted</u> lt med gy, massive, abnt. fine glass shards</p> <p>-1" <u>Ash</u>, (cons), sft, <u>srted</u>, (gy) wh, massive, com glass shards, tr. scattered orng lim stn silt sized grains, tr qtz, tr musc</p> <p>-1.5' <u>Ash</u> (cons), sft, srted, massive, med (red) brn, com glass shards, tr qtz, abnt silt-fine sand sized grains (red) brn - dk brn (clay) grains, cons. Contains a few elongate "nodules" as described below: granular micro texture</p> <p>-3' <u>Ash</u> (cons), sft, srted, massive, lt (red) brn, com glass shards, tr qtz, com silt-fine sand sized grains (red) brn-dk brn (cly) grains, cons. "nodules" elongated horizontally in sinuous and discontinuous "beds" 1/4-1/2" apart. Granular micro-texture ~1/10" wide, gen <1" long, dk brn & slightly more resistant than surroundings, contain concentration of brn, wxy cly</p>
	3	768'-778' ~6' Rec	<p>Top ~3 ft. <u>Clay</u>, <u>silt</u> & <u>sand</u>, (cons), <u>unsrted</u>, massive:</p> <p><u>Clay</u> med (red) brn - lt salmon, lt (pk) tan, lt (gy) brn, wxy, often slty, one small section has ~15% wh cly flecks in med (red) brn; occurs disseminated as matrix for sand & concentrated in veins gen <.1" thick ~20%. "<u>sand</u>" ranges from silt to pbls ~1/4", dom ang; Qtz, clr, gy, wh; Flds-wh, clr, often shattered (Qtz + Fld ~75% of the grains); Musc, tr-com, slt-med sand sized flks; tr-com scattered & stringer blk org mat; tr med (yell) gn opaque grains; med-dk (orng) brn lim stn localized in small blotches (gen .1-.5") and grains; tr Ash, lt (gy) wh-wh lower 6" of this section contains a long section of rock (Boulder), v fine grained, lt gy with large blotches of lt-dk (yell) brn stn esp near contact with cly-sand</p>

Well No.	Run	Footage	Description
#12			<p>~1 ft <u>Conglom</u> massive, matrix support, (cons): <u>Grains</u>: ~15%, rnd, pbls com .5", up to 2"; wthr granite; v fine grained, hard, wh, gy, gn rock; pk or (yell)-(gn) brn stn com esp at contact with matrix. <u>Matrix</u> sand & silt & cly, (yell), (pk) or (gn)gy - composition similar to top 3 ft.</p> <p>~1.5 ft <u>rock(?)</u> hard, v. fine grained, sugary, (calc), (yell) gn, gy, wh, (red) brn-(yell)brn mottled coloration (mottles gen .1-.5", uneven)- probably a calc silicate contact metamorphic rock</p> <p>~.5 ft Hornblende Monzonite (or Qtz Monzonite) fine-crs K-spar, wh, pk; fine-crs euhedral- subhedral Hornblende ~5%, tr qtz; somewhat wthr, esp rims around feld & Hornblende</p>
4	880'-892' Rec ~9.5 ft (2 boxes)		<p>Entire core <u>Conglomerate</u>, dom grain support, <u>unsrtd</u>, massive, cons-uncons, clasts range from <.1" to 10" with all intermediate sizes relatively common, rnd-ang.</p> <p><u>Grains</u>: 1) probable calc-silicate metamorphics; gen <u>fine</u> grained, hard, gn, wh, gy, unevenly mottled, speckled, & banded, some have alteration rims (lt colored, sft), one lg boulder has rim of crs euhedral, wthr Plag(?) Xls, some have (orng) brn stn or coloration - Dom. grain type throughout. 2) Granite: fine-med (trace crs), Qtz-anhedral, clr, gy, wh ~30- 40%; Fld-clr, gy, wh, wthr; anhedral-euhedral 55-65% mica, Biot > Musc ~5%; massive, com wthr. 3) Hornblende Qtz Diorite(?); Hornblende fine-crs grained, euhedral, gen unoriented 30-40% Plag(?) - anhedral-occas euhedral, fine-med grained, com. wthr + Qtz (amount undetermined). 4) Extremely fine grained lt gy - lt(gn)gy, w/ rock wh 1-3% fine Biotite + wthr Flds <5%(?).</p> <p><u>Matrix</u>: variable, includes 1) Blocky calcite; crs grained; occurs throughout but esp com. ~3 ft in middle of core, fills spaces between grains, makes rims up to ¼" thick around grains. 2) Clay: wxy lt-dk (red) brn, com sdy; occurs as veins, space filling between grains, one 2.5" chunk; tr-com. 3) Sand: fine-crs,</p>

Well No.	Run	Footage	Description
#12			gen ang, massive, uncons-(cons): Qtz-clr, gy, wh; Fld, clr, wh, com wthrd and shattered; Mica-Biot & Musc flks & Granite-med-crs-some of this sand appears to be granite which has wthrd in place - ghost of original clast visible.
5		1090'-1100' Rec ~6 ft.	<p>Top 1.5 ft <u>Granite</u>, massive: Qtz, anhedral, clr, gy, wh, gen med-fine grained ~35%; Fld, clr, (gy) wh, wthrd wh, anhedral-euhedral, fine-med, + ~1% crs euhedral K-spar, some <u>wthrd</u> ~60%; Mica, gen fine, Biot < Musc, ~5%; fractures have (yell) gn-(yell) brn stn surfaces; slightly wthrd.</p> <p>Middle 2 ft <u>Wthrd Granite</u> flds much altered; com (yell) gn, (yell) brn, (red) brn stn; lt (yell) gn wxy Cly in some fractures; partially - totally disaggregated.</p> <p>Lower 3 ft <u>Granite</u> identical to top 1.5 ft.</p> <p>Note: total depth 1110 ft.</p>

APPENDIX C

PALYNOLOGY REPORT BY AMOCO PRODUCTION COMPANY

Pollen Analysis of the BFEC Missoula/Bitterroot Drilling Project
Cores from holes MB-2, MB-4, MB-8, and MB-12

by William J. Fritz

The following is an analysis of the assemblage of palynomorphs present in the Missoula/Bitterroot drill holes MB-2, MB-4, MB-8, and MB-12. The samples were collected from cores by Susan Landon and Earl Peterson in March 1979, and were then processed and identified by Earl Peterson of Amoco Production Company.

Pollen and spores were found in all of the holes, although several individual samples were barren. Based on the taxonomic lists given by Peterson, recovery in general appears very poor. In fact, I can draw little paleoenvironmental interpretations or age determinations from these data. This lack of precision can be attributed to the following factors:

1. No quantitative data is given. Paleoenvironmental interpretations and age determinations based on pollen analysis are usually made from information regarding the abundance of particular taxa in the flora. Thus, the mere presence of taxa without information concerning the relative abundance, has little meaning. There is also no information given as to whether the taxonomic lists reflect all taxa present, only those identifiable, or those thought to be significant. This information is needed in making any conclusions.
2. The use of form and organ genera, along with extant generic names, is very confusing. If at all possible, palynomorphs should be identified using one taxonomic system consistently throughout an investigation. Paleoenvironments can not usually be determined from form genera; these refer only to the gross morphology of the grain and do not reflect modern affinities, thus, they are useful only for biostratigraphy and then only when a standard reference section is given using the same nomenclature.
3. The common names given are often misleading. In several cases, a specific extant common name is given for a palynomorph whose scientific name corresponds only to the gross morphology or to a family level. Also the wrong common name appears associated with several genera. For example, Taxodium is bald cypress, not redwood; Pterocarya is the southeast Asian wingnut, not hickory; Momapites is an organ genus and may or may not be a walnut.
4. Good indicator taxa (such as species of Graminae, Compositae, or Liquidamber) are not present. With two exceptions, all palynomorphs are common forms with a range of mid-Eocene to Pliocene.

Because of the above limitations, I can only draw the following conclusions:

1. All samples from MB-2, MB-4, and MB-8 could be of any age from mid-Eocene to Pliocene. I see no paleoenvironmental information to justify ruling out Oligocene as a possibility.

2. Based on the presence of Graminae and Compositae pollen, core #4 in MB-12 is possibly younger than mid-Oligocene.
3. Due to the lack of quantitative data and the wide use of form and organ genera, I believe that no paleoenvironmental conclusions are justified. I see no evidence for restricting the assemblage to warm temperate or for a lacustrine, or even fresh water, environment.
4. The presence of algae in core #8 in MB-12 has little environmental significance without a taxonomic designation and quantitative counts.

Amoco Production Company
Denver, Colorado

June 25, 1979

Don Rasmussen
Room 627 - CF

ATTENTION: SUSAN LANDON

Palynology examination - University of Montana coreholes

On March 22, Susan Landon and I collected samples at Missoula, Montana from five coreholes drilled under the supervision of the Geology Department of the University of Montana.

Fossil recovery was extremely variable in all coreholes although preservation quality was generally quite good when palynomorphs were found. With respect to stratigraphic information, the results from each corehole, such as they are, are discussed below, in their order from north to south:

University of Montana Corehole No. 2
19 - 15N-21W
Missoula County, Montana

812,813,815'

Fossils well preserved, brown-colored, not diagnostic. The general aspect suggests lower Tertiary age. The brown color is not easily explained; it may be from heat from an intrusive, or it may be normal diagenesis.

980'

Fungal spores, brown residue

1073'

Brown palynomorphs, as at 812-15

1237, 1242'

Barren

1257'

Barren

1945'

Barren

2237,2241,2249'

Barren

2320'

Upper Tertiary freshwater assemblage

Possibility: Corehole may have cut a fault

PALYNOLOGY EXAMINATION
JUNE 25, 1979
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University of Montana Corehole No. 4
24 - 14N-20W
Missoula County, Montana

1494'	Barren
1503'	Upper Tertiary, probably Pliocene
2395, 2399'	Brown fossils, possibly lower Tertiary, but none diagnostic (see discussion, Corehole 2, 812-15')
2400'	Barren-brown residue
2403'	Same
2897, 2902'	Barren, residue of black flakes

Possibility: The interval from 2395 to 2902 in Corehole No. 4
might correlate with the interval from 812-1273 in
Corehole No. 2.

University of Montana Corehole No. 6
9 - 9N-20W

472-1109'	All samples barren
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University of Montana Corehole No. 8
26 - 9N-20W
Ravalli County, Montana

1820'	Upper Tertiary - lacustrine
2317, 2321'	Same

Bendix Bitterroot Corehole No. 12
12 - 6N-20W
Ravalli County, Montana

410-15'	Barren
768-71'	Barren
980.5-83'	Barren
984-990.5	Lower Pliocene or upper Miocene

PALYNOLOGY EXAMINATION
JUNE 25, 1979
PAGE THREE

There is no assurance that the brown fossils in Coreholes 2 and 4 are truly lower Tertiary. They may well be middle or upper Eocene, but the Rocky Mountain control we have does not extend higher than lower Eocene. Since the Oligocene is known to be a cold time, we can rule out an Oligocene age simply because the palynomorphs reflect a warm temperate assemblage. I am not particularly willing as yet to call the brown assemblages Miocene, but papers presented at the AAAS meeting in Moscow, Idaho June 3-7 suggest that, at the latitude of Missoula, the brown assemblages might well be Miocene.

Earl T. Peterson

University of Montana Corehole no. 2
Sec. 19, T 15 N, R 21 W, Missoula County, Mt.

812 ft.

Fungal spores

Spores

Leiotriletes

Cyathidites

Verrucosisporites

Conifers

Picea (spruce)

Taxodium ("redwood")

Tsuga (hemlock)

Angiosperms

Caryapollenites ("hickory")

Momipites ("walnut")

Monocolpate pollen

813 ft.

Fungal spores

Spores

Laevigatosporites

Osmundacidites

Perotriletes

Conifers

Picea (spruce)

Angiosperms

Alnipollenites (alder)

815 ft.

Fungal spores

Spores

Acanthotriletes

Verrucosisporites

980 ft.

Fungal spores

1073 ft.

Fungal spores

Spores

Deltoidospora

Laevigatosporites

Cyathidites

Lycopodium

Verrucosisporites

Conifers

Picea (spruce)

Taxodium ("redwood")

Tsuga (hemlock)

Angiosperms

Alnipollenites (? 3 spp.) (alder)

Retitricolpites (? willow)

Caryapollenites (hickory)

Ulmiidites (? elm)

Tilia (linden)

Granitricolpites ("herb")

Triporate pollen

2320 ft.

Dinoflagellate

Algae

Spores

Verrucosisporites

Rugutriletes

Chaenopodium

Lycopodium

Conifers

Picea (spruce)

Pinus (pine)

Taxodium ("redwood")

Angiosperms

Alnipollenites (? 3 spp.) (alder)

Retitricolpites (? willow)

Polyporites (atriplex)

University Of Montana Corehole no. 4
Sec. 24, T 14 N, R 20 W, Missoula County, Mt.

1503 ft.

' Monolete spores
Conifers
 Picea (spruce)
 Taxodium ("redwood")
Angiosperms
 Pterocarya ("hickory")
 Quercoidites ("oak")
 Polyporites (greasewood)
 Polyporites (atriplex)
 Striate pollen
 Tetraporate pollen

2395 ft.

Spores
 Cyathidites
 Laevigatosporites
Conifers
 Picea (spruce)
Angiosperms
 Polyporites (atriplex)

2400 ft.

Spores
 Laevigatosporites
Conifers
 Picea (spruce)

2403 ft.

Fungal spores
Spores
 Osmundacidites
 Laevigatosporites
 Verrucosisporites
 Verrucate spores
Conifers
 Abies (fir)
Angiosperms
 Tetraporate pollen
 Pentaporate pollen

University of Montana Corehole no. 8
Sec. 26, T 9 N, R 20 W, Ravalli County, Mt.

1820 ft.

Algae
Spores
 Laevigatosporites
 Rugutritetes
 Psilamonocolpites
Conifers
 Taxodium ("redwood")

2317 ft.

Conifers
 Taxodium ("redwood")

2321 ft.

Algae
Conifers
 Picea (spruce)
 Pinus (pine)
 Taxodium ("redwood")
 Tsuga (hemlock)
Angiosperms
 Pterocarya ("hickory")

University of Montana Corehole no. 12
Sec. 12, T 6 N, R 20 W, Ravalli County, Mt.

984 - 990,5 ft.

Conifers
 Picea (spruce)
 Abies (fir)
Angiosperms
 Juglans (walnut)
 Polyporites (greasewood)
 Polyporites (atriplex)
 Gnetaceaepollenites (ephedra)
 Echitricolporites (composite)
 Compositae (composite)
 Graminae (grass)
 Multiporopollenites ("herb")
 Monocolpate pollen
 Monoporate pollen

APPENDIX D

ANALYTIC DATA ON CORES

Representative thin sections of the samples submitted were examined using a petrographic microscope in order to identify the major mineral constituents. Clay minerals were separated from the samples and analyzed using X-ray diffraction. Mud/sand ratios were determined by disaggregating each sample and then wet-sieving it through a 230-mesh sieve (U.S. equivalent, 0.0625 mm). The sand-sized portion was then dried and weighed to determine the percent of sand for each sample. Portions of each sample were submitted to an analytic laboratory for emission spectroscopy and organic carbon analyses. Trace element contents can be obtained from the emission spectroscopy data, therefore, no SEM/EDS work was done.

Results of the analyses are included in this appendix. Clay mineral data are presented in Table D-1 and chemical data are shown in Table D-2 and D-3.

Table D-1. Results of clay mineral separation and analysis showing diffraction effects, in percent. (Depth reported in feet; ---, not given.)

Hole no.	Field no.	Sample no.	Depth	Mud	Weight (in percent)			
					Kaolinite	Illite	Montmorillonite	Chlorite
2	MAN-844	43007	814.5	---	73	20	tr	7
2	MAN-845	43008	817	---	63	26	3	8
2	MAN-846	43009	1,073	---	61	36	tr	3
2	MAN-847	43010	1,074.2	---	67	26	tr	7
2	MAU-746	43979	812	---	75	25	tr	tr
4	MAN-850	43011	1,491.5	---	88	8	---	4
4	MIA-576	43012	1,502.5	---	90	10	tr	tr
4	MIA-577	43013	1,503.5	---	60	35	---	5
4	MIA-578	43014	2,396	---	75	25	tr	tr
4	MIA-579	43015	2,399.5	---	72	28	tr	tr
4	MIA-580	43016	2,404	---	69	30	tr	1
4	MIA-581	43017	2,901	---	33	50	tr	12
4	MAU-748	43981	2,899	---	20	80	---	---
4	MAU-479	43982	2,897	---	10	90	tr	tr
8 ¹	MAU-726	36215	1,816.5	93	50	tr	49	tr
8	MAU-727	36216	1,819.5	64	57	11	32	---
8	MAU-728	36217	2,315	20	36	18	46	---
8	MAU-729	36218	2,319.5	58	32	21	46	tr
8	MAU-730	36219	2,321	64	29	30	40	tr
8	MAU-731	36220	2,322	9	tr	50	49	---
9	MIA-586	47661	978	---	---	15	80	5
12	MIA-582	47657	412	---	---	5	90	5
12	MIA-583	47658	768	---	10	5	85	tr
12	MIA-584	47659	770	---	3	5	92	tr
12	MIA-585	47660	776	---	tr	tr	90	10

¹In hole number 8, note how kaolinite decreases and illite increases with depth.

Table D-2. Emission spectroscopy analyses, in parts per million. (Depth reported in feet.)

Hole no.	2	2	2	2	4	4	4	4	4	4	4	8	8	8	8	8	8	8	9	12	12	12	12
Field no.	MAN-844	MAN-845	MAN-846	MAN-847	MAN-850	MIA-576	MIA-577	MIA-578	MIA-579	MIA-580	MIA-581	MAU-726	MAU-727	MAU-728	MAU-729	MAU-730	MAU-731	MAU-732	MIA-586	MIA-582	MIA-583	MIA-584	MIA-585
Depth	814.5	817	1,073	1,074.2	1,491.5	1,502.5	1,503.5	2,396	2,399.5	2,404	2,901	1,816.5	1,819.5	2,315	2,319.5	2,321	2,322	Basement	978	412	768	770	585
ASSAN	43007	43008	43009	43010	43011	43012	43013	43014	43015	43016	43017	36215	36216	36217	36218	36219	36220	36221	47661	47657	47658	47659	47660
Ag	<1	3	<1	<1	<1	<1	<1	<1	<1	<1	<1	5	4	4	5	4	3	5	<0.5	<0.5	<0.5	<0.5	<0.5
Al	45,700	50,500	46,600	48,700	29,100	42,300	28,500	39,200	52,800	45,400	38,700	88,600	77,800	46,400	90,700	86,000	74,000	75,800	7	6	7	7	7
As	77	86	72	99	40	73	30	64	110	73	65	590	500	505	630	570	490	93	<200	<200	<200	<200	<200
B	355	400	360	375	280	300	300	450	340	395	310	170	165	160	165	145	145	20	10	10	20	10	10
Ba	440	410	290	470	490	1,060	530	370	400	480	350	475	670	475	710	470	610	550	700	500	500	700	500
Be	4	4	3	4	1	1	1	6	3	3	3	40	23	27	36	40	20	9	10	10	10	15	7
Ca	5,030	1,050	590	845	40,900	1,650	17,300	3,350	960	2,890	39,200	4,470	4,460	8,670	11,700	9,060	13,000	12,900	1	1	1	1	1
Co	10	12	19	17	4	4	14	15	9	11	14	19	29	17	27	22	12	10	<10	10	10	5	<10
Cr	50	53	56	55	56	120	200	110	73	110	130	38	29	14	18	17	12	9	10	10	20	20	20
Cu	37	28	46	11	5	8	8	<1	14	12	<1	10	6	4	6	1	58	5	7	30	20	15	5
Fe	14,900	22,000	28,100	37,700	12,500	6,720	19,200	69,100	16,300	31,900	28,900	31,800	18,600	21,500	27,600	32,100	16,100	12,900	1.5	2	2	1.5	1.5
La	24	420	15	120	26	36	11	31	34	39	20	16	14	35	19	13	10	9	50	100	20	50	50
Li	30	24	35	30	<10	<10	23	13	20	30	35	50	30	25	45	35	15	15	<100	<100	<100	<100	<100
Mn	205	210	390	380	250	78	440	345	85	145	800	125	105	255	370	330	250	305	700	200	500	100	70
Mo	8	10	9	11	8	17	22	19	12	16	17	27	22	21	27	24	20	12	<10	<10	<10	<10	<10
Na	4,300	6,600	2,850	4,100	1,900	3,600	3,150	1,000	1,200	1,000	4,100	13,800	18,600	19,300	27,400	21,500	32,000	17,100	3	1	1	3	3
Nb	3	3	2	2	1	1	1	2	2	2	1	38	26	27	44	37	15	14	10	10	10	10	10
Ni	18	20	26	25	17	10	35	28	18	22	33	22	22	15	18	18	34	8	<10	<10	<10	<10	<10
Pb	20	32	29	24	13	21	3	35	24	18	17	120	81	84	95	94	88	38	70	10	20	20	30
Sb	45	54	59	48	33	43	29	55	61	49	57	94	81	79	100	88	84	20	<100	<100	<100	<100	<100
Sc	8	10	6	9	3	2	3	10	7	8	6	8	6	6	8	7	3	2	5	10	10	5	5
Sn	25	27	29	28	12	15	12	29	27	23	21	31	27	22	31	32	23	1	<10	<10	<10	<10	<10
Sr	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	500	200	200	300	200
Ti	2,860	3,180	3,150	3,220	980	1,060	950	1,830	2,780	2,090	1,610	3,070	2,280	2,280	3,460	2,960	1,350	1,420	0.15	0.3	0.3	0.2	0.2
V	61	63	78	74	39	18	22	65	63	56	36	65	51	59	59	64	34	41	15	15	15	15	10
W	2	8	6	5	3	3	<1	<1	10	3	6	145	120	115	155	125	120	2	<100	<100	<100	<100	<100
Y	11	80	14	28	11	7	7	20	16	14	14	12	10	25	19	18	9	6	10	20	10	10	10
Zn	71	135	74	85	93	70	170	115	130	81	175	210	83	99	175	140	230	98	<200	<200	<200	<200	<200
Zr	48	100	54	80	17	18	18	64	53	48	28	70	44	100	122	130	19	6	70	200	200	100	70

Table D-3. Organic carbon analyses. (Depth reported in feet.)

Hole no.	Field no.	Sample no.	Depth	Organic carbon
2	MAN-844	43007	814.5	15.6
2	MAN-845	43008	817	.51
2	MAN-846	43009	1,073	<.1
2	MAN-847	43010	1,074.2	<.1
4	MAN-847	43011	1,491.5	<.1
4	MIA-576	43012	1,502.5	<.1
4	MIA-577	43013	1,503.5	.20
4	MIA-578	43014	2,396	.82
4	MIA-579	43015	2,399.5	1.36
4	MIA-580	43016	2,404	<.1
4	MIA-581	43017	2,901	<.1
8	MAU-726	36215	1,816.5	.089
8	MAU-727	36216	1,819.5	.094
8	MAU-728	36217	2,315	.119
8	MAU-729	36218	2,319.5	.112
8	MAU-730	36219	2,321	.052
8	MAU-731	36220	2,322	.053
9	MIA-586	47661	978	.25
12	MIA-582	47657	412	.06
12	MIA-583	47658	768	.06
12	MIA-584	47659	770	.04
12	MIA-585	47660	776	.07

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Subfeldspathic Lithic Wacke

REQUEST NO: 600051
PETROLOGIST: M.O.E.

HOLE NO: 2
FIELD NO: MAU-746

DEPTH: 812 Feet
AASSN: 43979

MINERAL/COMPONENT	%	COMMENTS												
Matrix	31	Clay and sericite.	<p>Medium to very fine sand-sized, angular to subrounded clastics floating in a matrix of clay and sericite. Sand-sized Clastics comprise approximately 69% of the sample. No glass shards were observed in this sample.</p> <table><tr><th><u>Clay Minerals</u></th><th><u>% Diffraction Effects</u></th></tr><tr><td>Kaolinite</td><td>75%</td></tr><tr><td>Illite (sericite)</td><td>25%</td></tr><tr><td>Montmorillonite</td><td>Trace</td></tr><tr><td>Chlorite</td><td>Trace</td></tr></table>		<u>Clay Minerals</u>	<u>% Diffraction Effects</u>	Kaolinite	75%	Illite (sericite)	25%	Montmorillonite	Trace	Chlorite	Trace
<u>Clay Minerals</u>	<u>% Diffraction Effects</u>													
Kaolinite	75%													
Illite (sericite)	25%													
Montmorillonite	Trace													
Chlorite	Trace													
Sand sized clastics	69													
Quartz (dominant)		Metamorphic and plutonic varieties.												
Sedimentary rock fragments (moderate)		Siltstones and shale, many of which are difficult to distinguish from the matrix.												
Metamorphic rock fragments (moderate)		Mostly schists.												
Plagioclase (minor)														
Microcline (minor)														
Muscovite (minor)														
Biotite (minor)		Altering to chlorite												
Opaques (minor)														
Limonite (trace)		Thin stringers.												
Organic carbon (trace)		Thin stringers.												
Tourmaline (trace)														
Zircon (trace)														

PHOTOMICROGRAPH OF SAMPLE 43979 (MAU-746)

Angular to subrounded sand grains floating in a clay and sericite matrix. 16x, crossed polarizers.

(Color microfiche number 1)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Siltstone

REQUEST NO: 600049
PETROLOGIST: M.O.E.

HOLE NO: 2
FIELD NO: MAN-844

DEPTH: 814.5 Feet
AASSN: 43007

MINERAL/COMPONENT	%	COMMENTS	
Silt and clay-sized Material	87	Clay, sericite and quartz	Very fine sand to silt-sized; Angular to subrounded; thinly bedded. Sand-sized clastics comprise approximately 13% of the sample. No glass shards were observed in this sample.
Sand-sized clastic	13		
Quartz (dominant)			
Plagioclase (minor)			
Opagues (minor)			
Chlorite (minor)			
Biotite (trace)			
Epidote (trace)			
Zircon (trace)			
Organic Material (moderate)		Along bedding planes	
Limonite (minor)		Thin stringers and along bedding planes.	

PHOTOMICROGRAPH OF SAMPLE 43007 (MAN-844)

Carbonaceous material following bedding planes in siltstone. 16x, crossed polarizers.

(Color microfiche number 2)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
 ROCK NAME: Sandy Siltstone

REQUEST NO: 600049
 PETROLOGIST: M.O.E.

HOLE NO: 2
 FIELD NO: MAN-845

DEPTH: 817 Feet
 AASSN: 43008

MINERAL/COMPONENT	%	COMMENTS	
Silt and clay-sized Material	67	Clay, sericite and quartz	Fine to very fine sand-sized, subangular to subrounded clastics in a siltstone. Sand sized clastics comprise approximately 33% of the sample. No glass shards were observed in this sample.
Sand-sized clastics	33		
Quartz (dominate)			
Opagues (moderate)			
Sedimentary rock fragments (minor)		Limestone, siltstones and shales	
Plutonic rock fragments(minor)			
Muscovite (minor)			
Chlorite (minor)			
Plagioclase (trace)			
Zircon (trace)			
Epidote (trace)			
Secondary quartz (trace)			
Microcline (trace)			
Organic Carbon (minor)		With limonite in this stringers	
Limonite (minor)			

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
 ROCK NAME: Subfeldspathic Lithic Wacke

REQUEST NO: 600051
 PETROLOGIST: M.O.E.

HOLE NO: 2
 FIELD NO: MAU-747

DEPTH: 1072 Feet
 AASSN: 43980

MINERAL/COMPONENT	%	COMMENTS	
Matrix	43	Ferruginous clay and sericite	Angular to subrounded; fine- to very fine-sand-sized and coarse- silt sized clastics along with a few coarse sand-sized rock fragments floating in a ferruginous clay matrix. The ferruginous matrix invades many of the sand grains. Sand-sized clastics comprise approximately 57% of the sample. The clay in a few areas of the rock is much less ferruginous than that in the majority of the rock. No glass shards were observed in this sample.
Sand-sized grains	57		
Quartz (dominate)			
Sedimentary rock fragments (moderate)		Shale, siltstones and very fine-grained sandstones.	
Metamorphic rock fragments (moderate)		Schists and quartzites.	
Limonite (minor)		Open space filling.	
Plagioclase (minor)			
Microcline (minor)			
Chlorite (minor)			
Muscovite (minor)			
Opaques (minor)			
Zircon (minor)			

PHOTOMICROGRAPH OF SAMPLE 43980 (MAU-747)

General view showing ferruginous and non-ferruginous areas of the sample. 40x, crossed polarizers.

(Color microfiche number 3)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Sandy Siltstone

REQUEST NO: 600049
PETROLOGIST: M.O.E.

HOLE NO: 2
FIELD NO: MAN-846

DEPTH: 1073 Feet
AASN: 43009

MINERAL/COMPONENT	%	COMMENTS	
Clay and silt-sized sized Material	85	Clay, sericite and quartz.	Fine to very fine sand-sized, subangular to subrounded clastics in a siltstone. Ragged grain boundaries common. Sand-sized clastics comprise approximately 15% of the sample. No glass shards were observed in this sample.
Sand-sized clastics Quartz (dominant) Biotite (minor) Opaques (minor) Chlorite (minor) Muscovite (trace) Epidote (trace) Sedimentary rock fragments (trace)	15		

PHOTOMICROGRAPH OF SAMPLE 43009 (MAN-846)

General view of sandy siltstone showing variable concentrations of sand-sized clastics. 16x, crossed polarizers.

(Color microfiche number 4)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Conglomeratic Siltstone

REQUEST NO: 600049
PETROLOGIST: M.O.E.

HOLE NO: 2
FIELD NO: MAN-847

DEPTH: 1074.2 Feet
AASSN: 43010

MINERAL/COMPONENT	%	COMMENTS	
Clay and silt-sized material	72	Ferruginous clay, sericite and silt sized clastics (mostly quartz)	A few rounded pebbles (to 1 cm) and coarse sand-sized rock fragments and quartz with fine sand-sized, subangular to subrounded clastics in a ferruginous siltstone. Some ferruginous clay invades the clastics. Sand-sized clastics comprise approximately 27% of the sample. No glass shards were observed in this sample.
Sand-sized clastics	28		
Quartz (dominant)		Single and composite; few strongly undulose	
Metamorphic rock fragments (moderate)		Schists	
Sedimentary rock fragments (minor)		Shale, fine-grained sandstones	
Plutonic rock fragments (minor)		Granitic	
Muscovite (minor)			
Microcline (minor)			
Plagioclase (minor)			
Opaques (minor)			
Chlorite (trace)			
Biotite (trace)		Altering to limonite	
Epidote (trace)			
Zircon (trace)			

PHOTOMICROGRAPH OF SAMPLE 43010 (MAN-847)

Sedimentary rock fragment and various quartz grains in a ferruginous clay matrix. 40x, crossed polarizers.

(Color microfiche number 5)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Subfeldspathic Arenite

REQUEST NO: 600049
PETROLOGIST: M.O.E.

HOLE NO: 4
FIELD NO: MAN-850

DEPTH: 1491.5 Feet
AASSN: 43011

MINERAL/COMPONENT	%	COMMENTS	
Cement/matrix	32	Carbonate cement and clay matrix	Fine sand-sized angular to subrounded clastics cemented by carbonate and clay. Sand-sized clastics comprise approximately 68% of the sample. No glass shards were observed in this sample.
Sand-sized clastics	68		
Quartz (dominate)			
Plagioclase (minor)			
Sedimentary rock fragments (minor)		Siltstones	
Microcline (minor)			
Muscovite (minor)			
Opaques (minor)		Limonite stained	
Chert (trace)			
Biotite (trace)		Altered to chlorite and limonite	
Zircon (trace)			

PHOTOMICROGRAPH OF SAMPLE 43011 (MAN-850)

Angular to subrounded clastics in a carbonate cement. 40x, crossed polarizers.

(Color microfiche number 6)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Lithic Conglomerate

REQUEST NO: 600049
PETROLOGIST: M.O.E.

HOLE NO: 4
FIELD NO: MIA-576

DEPTH: 1502.5 Feet
AASSN: 43012

MINERAL/COMPONENT	%	COMMENTS	
Matrix/cement	23	Clay and sericite with a trace of carbonate cement.	Subrounded to subangular lithic pebbles (to 2 cm) and very coarse to fine sand-sized clastics in a clay/sericite matrix with a trace of carbonate cement. Sand sized clastics and pebbles comprise approximately 77% of the rock. No glass shards were observed in this sample.
Pebbles and sand-sized clastics	77		
Sedimentary rock fragments (dominant)		Quartz arenites, quartz wackes and shales.	
Plutonic rock fragments (subdominant)		Granitic, granitic-cataclastic and granophyric some vein rock.	
Quartz (moderate)		Plutonic, stretched metamorphic and volcanic.	
K-feldspar (minor)		Microcline and sanadine.	
Volcanic rock fragments (minor)			
Muscovite (minor)			
Plagioclase (minor)			
Chalcedony (trace)			
Secondary Quartz (trace)			

PHOTOMICROGRAPH OF SAMPLE 43012 (MIA-576)

General view showing different types of rock fragments and quartz. 16x, crossed polarizers.

(Color microfiche number 7)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
 ROCK NAME: Quartz Arenite

REQUEST NO: 600049
 PETROLOGIST: M.O.E.

HOLE NO: 4
 FIELD NO: MIA-577

DEPTH: 1503.5 Feet
 AASSN: 43013

MINERAL/COMPONENT	%	COMMENTS	
Matrix/cement	29	Mostly carbonate cement with lesser clay matrix. Some carbonate occurs as space filling.	Angular to subrounded, fine to very fine sand-sized clastics cemented by carbonate with small amounts of clay matrix. Sand-sized clastics comprise approximately 71% of the rock. No glass shards were observed in this sample.
Sand sized clastics	71		
Quartz (dominant)			
Muscovite (moderate)			
Sedimentary rock fragments (minor)			
Opaques (trace)			
Epidote (trace)			
Zircon (trace)			
Organic carbon (minor)		Thin slivers	
Limonite		Stain and fracture filling	

PHOTOMICROGRAPH OF SAMPLE 43013 (MIA-577)

General view showing fine sand-sized clastics in a carbonate cement. 40x, crossed polarizers.

(Color microfiche number 8)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Subfeldspathic Lithic Wacke

REQUEST NO: 600049
PETROLOGIST: M.O.E.

HOLE NO: 4
FIELD NO: MIA-578

DEPTH: 2396 Feet
AASSN: 43014

MINERAL/COMPONENT	%	COMMENTS	
Matrix/cement	35	Clay and sericite matrix with lesser carbonate cement.	Medium to very fine sand-sized, subangular to subrounded clastics in a clay/sericite matrix. Sand-sized clastics comprise approximately 65% of the sample. No glass shards were observed in this sample.
Sand-sized clastics	65		
Quartz (dominant)			
Metamorphic rock fragments (moderate)		Schists	
Sedimentary rock fragments (moderate)		Shales and arenite; many are inconspicuous and appear as part of matrix.	
Plagioclase (minor)			
Muscovite (minor)			
Biotite (minor)			
Chert (minor)			
Microcline (trace)			
Epidote (trace)			
Opaques (trace)			
Organic carbon (minor)			
Limonite (trace)		As stain and with organic carbon.	

PHOTOMICROGRAPH OF SAMPLE 43014 (MIA-578)

Various rock fragments and quartz in a clay matrix.
Note how inconspicuous some of the fragments are.
40x, crossed polarizers.

(Color microfiche number 9)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Subfeldspathic Lithic Wacke

REQUEST NO: 600049
PETROLOGIST: M.O.E.

HOLE NO: 4
FIELD NO: MIA-579

DEPTH: 2399.5 Feet
AASSN: 43015

MINERAL/COMPONENT	%	COMMENTS	
Matrix	30	Sericite clay, chlorite and opaques (some of the clay is ferruginous).	Fine to silt-sized clastics with a few medium to coarse sand sized rock fragments in a clay/sericite/chlorite matrix. Sand sized clastics comprise approximately 70% of the sample. No glass shards were observed in this sample.
Sand-sized clastics	70		
Quartz (dominant)			
Sedimentary rock fragments (moderate)		Inconspicuous and appears as part of the matrix.	
Metamorphic rock fragments (moderate)		Schists	
Opaques (moderate)			
Microcline (minor)			
Plagioclase (minor)			
Muscovite (minor)			
Chert (trace)			
Zircon (trace)			
Organic carbon (moderate)		Mostly in lenses.	
Limonite (minor)		Open space filling and stain.	

PHOTOMICROGRAPH OF SAMPLE 43015 (MIA-579)

General view showing inconspicuous rock fragments and partially ferruginous matrix. Note lenses of organic material. 16x, crossed polarizers.

(Color microfiche number 10)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
 ROCK NAME: Lithic Conglomerate

REQUEST NO: 600049
 PETROLOGIST: M.O.E.

HOLE NO: 4
 FIELD NO: MIA-580

DEPTH: 2404 Feet
 AASSN: 43016

MINERAL/COMPONENT	%	COMMENTS	
Matrix	40	Clay and silt-sized quartz (some secondary quartz cement)	Rounded pebble-sized rock fragments and fine sand-sized quartz in a silty/clayey matrix. Some secondary quartz also supports the pebbles. Clastics, sand-sized and larger, comprise approximately 60% of the sample. No glass shards were observed in this sample
Pebble and sand-sized clastics	60		
Sedimentary rock fragments (dominant)		Arenites, wackes and shales	
Metamorphic rock fragments (moderate)		Schists and gneisses	
Quartz (minor)			

PHOTOMICROGRAPH OF SAMPLE 43016 (MIA-580)

Pebbles of sedimentary and metamorphic rock fragments in clayey matrix. Gray boarder around one of the pebbles is balsam and not part of the rock. 16x, crossed polarizers.

(Color microfiche number 11)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600051

HOLE NO: 4

DEPTH: 2897 Feet

ROCK NAME: Calcareous Siltstone (May also be sandy limestone)

PETROLOGIST: M.O.E.

FIELD NO: MAU-749

AASSN: 43982

MINERAL/COMPONENT	%	COMMENTS	
Micritic lime, spar- ritic calcite and clay	59		A very fine sand and coarse silt-sized clastics floating in a micritic lime. Some carbncate is sparry and fills open spaces. Small amounts of secondary quartz also support sand grains. Secondary quartz also occurs in veins and thin stringers through- out the rock. Sand-sized clastics and secondary quartz comprise approximately 41% of the rock. No glass shards were observed in this sample.
Clastics	31	Argular to subrounded.	
Quartz (dominant)			
Muscovite (minor)			
Sedimentary rock fragments (trace)			
Microcline (trace)			
Opaques (trace)			
Secondary Quartz	10	In veins and thin stringers.	

PHOTOMICROGRAPH OF SAMPLE 43982 (MAU-749)

Secondary quartz vein in calcareous siltstone.
40x, crossed polarizers.

(Color microfiche number 12)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600057

HOLE NO: 4

DEPTH: 2899 Feet

ROCK NAME: Bedded siltstone, sandy silt- stone, calcareous shale and fine-grained quartz arenite.

PETROLOGIST: M.O.E.

FIELD NO: MAU-748

AASSN: 43981

MINERAL/COMPONENT	%	COMMENTS		
Silt-sized grains and clay	70		Soft sediment deformation has caused the bedding to be deformed. The quartz arenite is cemented by calcite. Sand-sized clastics comprise approximately 20% of the sample. No glass shards were observed in this sample.	
Carbonate cement	10			
Sand-sized clastics	20	Fine- to very fine sand-sized; subangular to sub-rounded.		
Quartz (dominant)			<u>Clay minerals</u>	<u>% Diffraction Effects</u>
Opagues (moderate)		Some in stringers.	Illite (sericite)	80
Muscovite (minor)			Kaolinite	20

Soft sediment deformation forming unusual bedding.
16x, crossed polarizers.

(Color microfiche number 13)

Siltstone and carbonate cemented arenite. 40x,
crossed polarizers.

(Color microfiche number 14)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
 ROCK NAME: Sandy Limestone

REQUEST NO: 600049
 PETROLOGIST: M.O.E.

HOLE NO: 4
 FIELD NO: MIA-581

DEPTH: 2901 Feet
 AASSN: 43017

MINERAL/COMPONENT	%	COMMENTS	
Carbonate	60	Micrite and sparry calcite	Angular to subangular, fine to very fine sand-sized clastics in a limestone. Thinly bedded and folded. Sand-sized clastics comprise approximately 40% of the sample. No glass shards were observed in this sample.
Sand sized clastics	40		
Quartz (dominant)			
Muscovite (minor)			
Plagioclase (trace)			
Opaques (trace)			
Limonite (minor)		Along bedding planes	
Secondary quartz (trace)		Open space filling	

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Mylonite Gneiss

REQUEST NO: 600051
PETROLOGIST: M.O.E.

HOLE NO: 6
FIELD NO: MAU-745

DEPTH: 1732 Feet
AASSN: 43978

MINERAL/COMPONENT	%	COMMENTS	
Porphyroclasts Plagioclase (60)	60	Strongly altered to clay and sericite.	Cataclastic rock with fluxion structure; medium- to coarse-grained porphyroclasts in a cataclastic mortar that has been partially recrystallized; secondary calcite veins cut throughout the sample and fills most fractures.
Quartz (40)		Strongly undulose and fractured into subgrains.	
Cataclastic mortar	30	Partially recrystallized plagioclase and quartz with lesser sericite and clay	
Calcite	10	Secondary vein and fracture filling	
Opaques	tr	Limonite stained; scattered.	
Zircon	tr

PHOTOMICROGRAPHS OF SAMPLE 43978 (MAU-745)

General view showing altered plagioclase and quartz porphyroclasts. 16x, crossed polarizers.

(Color microfiche number 15)

Secondary calcite veins. 160x, crossed polarizers.

(Color microfiche number 16)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600035

HOLE NO: 8

DEPTH: 1816.5 Feet

ROCK NAME: Mudstone

FIELD NO: MAU-726

AASSN: 36215

GENERAL TEXTURE AND FEATURES: Fine to very fine angular to subangular grains floating in a clay matrix; poorly sorted. Most grains have a random orientation.

MINERAL/COMPONENT	%	TEXTURE	CHARACTERISTICS	ALTERATION/REPLACEMENT
Matrix	85	Extremely fine-grained.	Consists of clay, silt sized quartz and small amounts of chlorite.	
Quartz	10	Fine- to very fine-grained; angular to subangular.	Plutonic and volcanic varieties; Mostly straight extinction.	
Muscovite	2	Fine- to very fine-grained flakes.	Random orientation.	Few fresh flakes; many altering to clay.
Sanadine	1	Fine- to very fine-grained; angular to subangular.		Mostly fresh.
Plagioclase	tr	Fine- to very fine-grained; angular to subangular.		Few slightly argillized grains; some grains totally altered to clay.
Chlorite	tr	Fine- to very fine-grained flakes.		May be altered biotite.
Zircon	tr	Fine- to very fine-grained; subangular.		
Opakes	tr	Fine- to very fine grains and aggregates; subangular to subrounded.	Mostly occurs as part of matrix; some occurs as fracture fillings; few individual grains.	

PHOTOMICROGRAPH OF SAMPLE 36215

Shows general texture and features. Note the abundance of clay and angular texture of quartz grains. 40x, crossed polarizers.

(Color microfiche number 17)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula Bitterroot

REQUEST NO: 600035

HOLE NO: 8

DEPTH: 1819.5 Feet

ROCK NAME: Sandy Mudstone

FIELD NO: MAU-727

AASSN: 36216

GENERAL TEXTURE AND FEATURES: Medium to very fine angular grains floating in a clay matrix; poorly sorted; some of the clay also occurs as rounded clay galls.

MINERAL/COMPONENT	%	TEXTURE	CHARACTERISTICS	ALTERATION/REPLACEMENT
Matrix	50	Extremely fine-grained.	Consists of clay and silt-sized quartz, some limonite staining.	
Quartz	22	Medium- to very fine-grained; angular to subangular.	Plutonic with few volcanic varieties; mostly straight extinction, few composite grains; few inclusions of zircon.	
Sanadine	17	Medium- to very fine-grained; angular to subangular.		Mostly fresh; few grains slightly argillized.
Muscovite	7	Fine to very fine flakes.	Random orientation.	Some fresh grains; many flakes altering to clay.
Plagioclase	1	Fine- to very fine-grained; angular to subangular.		Slightly to strongly argillized.
Opaques	1	Fine angular grains and very fine aggregates	Very fine aggregates occur as part of matrix.	
Rock fragments	1	Medium- to fine-grained subangular.	Plutonic? Composed of quartz, plagioclase, and muscovite.	

(Continued on next page)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600035

HOLE NO: 8

DEPTH: 1819.5 Feet

ROCK NAME: Sandy Mudstone

FIELD NO: MAU-727

AASSN: 36216 (cont.)

GENERAL TEXTURE AND FEATURES: Medium to very fine angular grains floating in a clay matrix; poorly sorted; some of the clay also occurs as rounded clay galls.

MINERAL/COMPONENT	%	TEXTURE	CHARACTERISTICS	ALTERATION/REPLACEMENT
Chlorite	tr	Fine to very fine flakes		Some may be altered biotite.
Epidote	tr	Fine to very fine-grained; subangular	Associated with altered feldspars.	
Sphene	tr	Fine-grained; angular.		

PHOTOMICROGRAPHS OF SAMPLE 36216

Shows general texture and features. Note the size range of the grains. 40x, crossed polarizers.

(Color microfiche number 18)

Shows sanidine grains. 160x, crossed polarizers.

(Color microfiche number 19)

PHOTOMICROGRAPH OF SAMPLE 36216

Shows fresh muscovite. 160x, crossed polarizers.

(Color microfiche number 20)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600035

HOLE NO: 8

DEPTH: 2315 Feet

ROCK NAME: Lithic Wacke

FIELD NO: MAU-728

AASSN: 36217

GENERAL TEXTURE AND FEATURES: Medium to very fine, angular to subangular grains floating in a clay matrix; very poorly sorted; some of the matrix appears to form rounded clay galls.

MINERAL/COMPONENT	%	TEXTURE	CHARACTERISTICS	ALTERATION/REPLACEMENT
Matrix	56	Extremely fine-grained.	Consists of clay and silt sized quartz.	
Quartz	20	Medium to very fine-grained; angular to subangular.	Mostly plutonic, few volcanic grains; mostly straight extinction.	
Rock Fragments	13	Medium to very fine-grained; angular to subangular; few coarse grains.	Plutonic; (K-feldspar, quartz, plagioclase, muscovite and some epidote) some myrmekite in the feldspars.	
K-feldspar	5	Medium to very fine-grained; angular to subangular.	Microcline.	Slightly argillized.
Plagioclase	5	Medium to very fine-grained; angular to subangular.	Some moderately zoned grains.	Mostly fresh; few sericitized and argillized grains.
Chlorite	tr	Medium to very fine-grained; books and flakes.	Opaques along cleavages.	May be altered biotite
Epidote	tr	Fine to very fine-grained; anhedral.	Mostly associated with rock fragments and altered feldspars.	

(Continued on next page)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600035

HOLE NO: 8

DEPTH: 2315 Feet

ROCK NAME: Lithic Wacke

FIELD NO: MAU-728

AASSN: 36217 (cont.)

GENERAL TEXTURE AND FEATURES: Medium to very fine, angular to subangular grains floating in a clay matrix; very poorly sorted; some of the matrix appears to form rounded clay galls.

MINERAL/COMPONENT	%	TEXTURE	CHARACTERISTICS	ALTERATION/REPLACEMENT
Muscovite	tr	Fine to very fine-grained flakes.	Mostly associated with rock fragments.	Fresh in rock fragments; altering to clay in matrix.
Opakes	tr	Fine to very fine subangular to subrounded grains and aggregates.

Shows general texture and features. Note size range and angularity of the grains. 16x, crossed polarizers.

(Color microfiche number 21)

Shows granite rock fragment. 40x, crossed polarizers.

(Color microfiche number 22)

PHOTOMICROGRAPH OF SAMPLE 36217

Shows zoned plagioclase grain. 160x, crossed polarizers.

(Color microfiche number 23)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600035

HOLE NO: 8

DEPTH: 2319.5 Feet

ROCK NAME: Arkosic Wacke

FIELD NO: MAU-729

AASSN: 36218

GENERAL TEXTURE AND FEATURES: Fine to very fine angular to subangular grains floating in a clay matrix; poorly sorted; some of the clay appears to flow around some grains.

MINERAL/COMPONENT	%	TEXTURE	CHARACTERISTICS	ALTERATION/REPLACEMENT
Quartz	41	Fine to very fine-grained; angular to subangular.	Plutonic and volcanic varieties; straight slightly undulose extinction.	
Matrix	31	Extremely fine-grained.	Consists of clay, silt-sized quartz and small amounts of chlorite; some limonite staining.	
Plagioclase	10	Fine- to very fine-grained; angular to subangular.	Few pericline twins.	Mostly fresh.
Chlorite	6	Fine to very fine-grained flakes and books.	Some grains have opaques along cleavages.	May be altered biotite altering to clay.
K-feldspar	5	Fine to very fine-grained; angular to subangular.	Microcline.	Mostly fresh; few grains slightly argillic.
Muscovite	5	Fine to very fine-grained flakes.	Random orientation.	Many fresh grains; some grains altering to clay.
Zircon	tr	Fine to very fine-grained; subangular to subrounded.		

(Continued on next page)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600035

HOLE NO: 8

DEPTH: 2319.5 Feet

ROCK NAME: Arkosic Wacke

FIELD NO: MAU-729

AASSN: 36218 (cont.)

GENERAL TEXTURE AND FEATURES: Fine to very fine angular to subangular grains floating in a clay matrix; poorly sorted; some of the clay appears to flow around some grains.

MINERAL/COMPONENT	%	TEXTURE	CHARACTERISTICS	ALTERATION/REPLACEMENT
Opakes	tr	Fine to very fine, subangular to subrounded grains and aggregates.	Finer grains are part of matrix; few grains along cleavages in chlorite.	

PHOTOMICROGRAPH OF SAMPLE 36218

Shows general texture and features. Note that most of the quartz is very fine-grained. 16x, crossed polarizers.

(Color microfiche number 24)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600035

HOLE NO: 8

DEPTH: 2321 Feet

ROCK NAME: Sandy Mudstone

FIELD NO: MAU-730

AASSN: 36219

GENERAL TEXTURE AND FEATURES: Medium to very fine, angular to subangular grains floating in a clay matrix; very poorly sorted.

MINERAL/COMPONENT	%	TEXTURE	CHARACTERISTICS	ALTERATION/REPLACEMENT
Matrix	72	Extremely fine-grained.	Consists of clay, silt-sized quartz and small amount of chlorite.	
Rock Fragments	10	Medium- to fine-grained; angular to subangular.	Plutonic (quartz, microcline, plagioclase and muscovite).	Feldspars are fresh to slightly argillic.
Quartz	10	Medium to very fine-grained; angular to subangular.	Plutonic variety; mostly straight extinction.	
Plagioclase	5	Fine to very fine-grained; angular to subangular.	Few untwinned grains.	Fresh to slightly argillic.
K-feldspar	1	Medium to very fine-grained; angular to subangular.	Microcline; probably from rock fragments.	Fresh to slightly argillic.
Muscovite	1	Fine to very fine flakes.	Random orientation, mostly in rock fragments.	Mostly fresh; few grains altering to clay.
Opaques	tr	Fine to very fine-grained; angular.	Disseminated.	
Zircon	tr	Fine to very fine-grained; subrounded.		

PHOTOMICROGRAPH OF SAMPLE 36219

Shows general texture and features. Note the size range and angularity of the grains (rock fragments, quartz, muscovite, etc.). 16x, crossed polarizers.

(Color microfiche number 25)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600035

HOLE NO: 8

DEPTH: 2322 Feet

ROCK NAME: Arkosic Wacke

FIELD NO: MAU-731

AASSN: 36220

GENERAL TEXTURE AND FEATURES: Coarse to fine-grained, angular to subangular floating grains with many point contacts; poorly sorted.

MINERAL/COMPONENT	%	TEXTURE	CHARACTERISTICS	ALTERATION/REPLACEMENT
Quartz	28	Coarse to fine-grained; angular to subangular.	Plutonic; mostly straight extinction; few composite grains.	
Rock Fragments	20	Coarse to fine-grained; angular to subangular.	Plutonic (quartz, K-feldspar, plagioclase and muscovite) some myrmekite in feldspars.	Feldspars are fresh to slightly argillic.
Matrix	19	Extremely fine-grained.	Consists of clay and silt-sized quartz.	
Plagioclase	17	Coarse to fine-grained; angular to subangular.	Few zoned grains.	Fresh to slightly argillic.
K-feldspar	11	Coarse to fine-grained; angular to subangular.	Microcline.	Fresh to slightly argillic.
Chlorite	3	Medium to fine-grained books and flakes.	Opakes along cleavages; many books squeezed between clastics.	Altering to clay.
Muscovite	1	Medium to fine-grained books and flakes.	Mostly associated with rock fragments.	Fresh in rock fragments.
Opakes	tr	Fine to very fine-grained; subangular to subrounded.	Mostly occurs along cleavages in chlorite.

(Color microfiche number 26)

Both photomicrographs show general texture and features. Note size range and angularity of grains (rock fragments, quartz, feldspars, etc.). Top photo: 40x, crossed polarizers. Bottom photo: 16x, crossed polarizers.

(Color microfiche number 27)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600035

HOLE NO: 8

DEPTH: 2722 Feet

ROCK NAME: Quartz Monzonite

FIELD NO: MAU-732

AASSN: 36221

GENERAL TEXTURE AND FEATURES: Medium to fine-grained; allotriomorphic.

MINERAL/COMPONENT	%	TEXTURE	CHARACTERISTICS	ALTERATION/REPLACEMENT
Plagioclase	33	Medium to fine-grained; anhedral.	Many zoned grains; some myrmekite.	Slightly argillic; some grains moderately altered to sericite, epidote, and small amounts of calcite.
Quartz	32	Medium to fine-grained; anhedral.	Slightly undulose; various inclusions.	
K-feldspar	26	Medium to fine-grained; anhedral.	Microcline; various inclusions.	Fresh to slightly argillic.
Biotite/chlorite	6	Medium to fine-grained books and flakes.	Penninite; brown to green; opaques along some cleavages; some epidote associated.	Biotite altering to chlorite.
Epidote	1	Medium to fine-grained; anhedral.	Commonly associated with altered feldspars and chlorite.	
Opaque	1	Fine-grained subhedral to euhedral (cubic) to very fine grained anhedral.	Larger grains commonly occur in clusters; very fine grains occur along cleavages in chlorite.	
Zircon	tr	Very fine-grained; euhedral.	As inclusions.	

(Continued on next page)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot

REQUEST NO: 600035

HOLE NO: 8

DEPTH: 2722 Feet

ROCK NAME: Quartz Monzonite

FIELD NO: MAU-732

AASSN: 36221 (cont.)

GENERAL TEXTURE AND FEATURES: Medium to fine-grained; allotriomorphic.

MINERAL/COMPONENT	%	TEXTURE	CHARACTERISTICS	ALTERATION/REPLACEMENT
Allanite	tr	Medium to fine-grained; anhedral to subhedral.	Slightly zoned with epidote rims.	Minor alteration to leucoxene.
Apatite	tr	Very fine-grained; euhedral.	As inclusions.	
Calcite	tr	Fine-grained; anhedral.	Occurs as patches in altered plagioclase.	
Sphene	tr	Fine-grained; euhedral to anhedral.	Disseminated.

PHOTOMICROGRAPHS OF SAMPLE 36221

Shows microcline grain. Note calcite, epidote, and opaques. 40x, crossed polarizers.

(Color microfiche number 28)

Shows zoned plagioclase and microcline. Note myrmekite. 40x, crossed polarizers.

(Color microfiche number 29)

Shows alteration of plagioclase. 40x, plane polarized light.

(Color microfiche number 30)

Shows chlorite (penninite). Note epidote and sphene. 40x, crossed polarizers.

(Color microfiche number 31)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Granite

REQUEST NO: 600062
PETROLOGIST: M.O.E.

HOLE NO: 9
FIELD NO: MIA-586

DEPTH: 978 Feet
AASSN: 47661

MINERAL/COMPONENT	%	COMMENTS	
K-feldspar	40	Microcline and perthite.	Coarse to medium grained allotriomorphic granular; most grains have been broken; the plagioclase is strongly sauceritized; biotite is moderately altered to chlorite. Since this is an igneous rock, no sand/mud ratio was determined.
Quartz	33	Straight extinction.	
Plagioclase	17	Many subhedral grains; strongly sauceritized.	
Biotite	7	Medium-grained flakes.	
Epidote	1	Medium-to fine-grained anhedral; associated with plagioclase and altered biotite.	
Copaques	1	Fine-grained; subhedral.	
Sphene	tr	Fine-grained; subhedral.	
Zircon	tr	Fine-grained; euhedral.

General view of granite showing broken grains and altered plagioclase and biotite. 16x, crossed polarizers.

(Color microfiche number 32)

General view showing microcline, biotite, and epidote. 16x, crossed polarizers.

(Color microfiche number 33)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
 ROCK NAME: Sandy Mudstone

REQUEST NO: 600062
 PETROLOGIST: M.O.E.

HOLE NO: 12
 FIELD NO: MIA-582

DEPTH: 412 Feet
 AASSN: 47657

MINERAL/COMPONENT	%	COMMENTS	
Matrix (mud)	89	Clay, silt sized components, and chlorite. Limonite stained.	Fine-to very fine sand-sized angular grains floating in a matrix of mostly iron stained clay and silt sized grains; very few contacts; abundant glass shards were observed.
Sand-sized grains	11	Angular to subangular; fine sand-sized to very fine sand-sized; largest grains are less than 0.25 mm.	
Altered rock fragments (dominant)		Strongly stained by limonite.	
Glass shards (subdominant)			
Muscovite (subdominant)		Rotted flakes.	
Plagioclase (subdominant)			
Sanidine ? (minor)			
Opaques (subdominant)		Strongly altered to limonite.	
Chlorite (minor)			
Quartz (trace)			
Zircon (trace)

General view of limonite stained mudstone. Note glass shard in lower center of photo. 160x, plane polarized light.

(Color microfiche number 34)

Same view with crossed polarizers.

(Color microfiche number 35)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Sandy Mudstone

REQUEST NO: 600062
PETROLOGIST: M.O.E.

HOLE NO: 12
FIELD NO: MIA-583

DEPTH: 768 Feet
AASSN: 47658

MINERAL/COMPONENT	%	COMMENTS	
Matrix (mud)	71	Clay and sericite with a trace of chlorite; some areas have a concentrated limonite stain; many areas appear to swirl.	Coarse to fine sand-sized grains floating in a clayey matrix; very few contacts; few areas have a concentrated limonite stain; most grains have rotted edges and are strongly altered. No glass shards were observed in this sample.
Sand-sized grains	29	Coarse to fine sand-sized; angular to subangular.	
Quartz (dominant)		Mostly composite; undulose.	
Rock fragments (subdominant)		Plutonic.	
Muscovite (subdominant)		Bent flakes; moderately altered.	
K-feldspar (minor)		Microcline and perthite.	
Plagioclase (minor)			
Opaques (minor)		Altering to limonite.	
Biotite (minor)		Altering to limonite.	
Zircon (trace)			

PHOTOMICROGRAPH OF SAMPLE 47658 (MIA-583)

Area of sample with high limonite concentration.
40x, plane polarized light.

(Color microfiche number 36)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
 ROCK NAME: Feldspathic Wacke

REQUEST NO: 600062
 PETROLOGIST: M.O.E.

HOLE NO: 12
 FIELD NO: MIA-584

DEPTH: 770 Feet
 AASSN: 47659

MINERAL/COMPONENT	%	COMMENTS	
Matrix	38	Clay, sericite, and silt-sized grains.	Very coarse- to fine sand-sized clastics floating in a clay-sericite matrix; few point contacts; poorly sorted; no glass shards were observed in this sample.
Sand-sized grains	62	Very coarse to fine sand-sized; angular to sub-angular.	
Quartz (dominant)		Undulose; plutonic.	
Rock fragments (sub-dominant)		Plutonic.	
Muscovite (subdominant)		Bent flakes.	
K-feldspar (minor)		Perthite and microcline.	
Plagioclase (minor)		Some altering to limonite.	
Opakes (minor)			
Epidote (trace)			
Sphene (trace)			
Zircon (trace)			
Chlorite (trace)

Angular clastics of quartz, feldspar, and muscovite in a clay/sericite matrix. 40x, plane polarized light.

(Color microfiche number 37)

Same view with crossed polarizers.

(Color microfiche number 38)

PETROGRAPHIC DESCRIPTION

PROJECT: Missoula/Bitterroot
ROCK NAME: Meta-Sandstone

REQUEST NO: 600062
PETROLOGIST: M.O.E.

HOLE NO: 12
FIELD NO: MIA-585

DEPTH: 776 Feet
AASSN: 47660

MINERAL/COMPONENT	%	COMMENTS	
Quartz	64	Fine-grained mosaic of anhedral grains.	Fine-grained; granoblastic; thermally metamorphosed rock that has not reached a stable hornfels assemblage; since this rock has been metamorphosed no sand/mud ratio has been determined.
Carbonate	14	Interstitial patches.	
Epidote	6	Fine-grained; anhedral patches.	
Chlorite	5	Patches and individual anhedral flakes.	
Clay	4	Patches; could be totally altered feldspar.	
K-feldspar	2	Microcline.	
Plagioclase	1	Fine-grained.	
Muscovite	1	Fine-grained flakes.	
Zircon	1	Fine-grained; euhedral.	
Opakes	tr	Scattered anhedral.	
Limonite	tr	Grain coating.	

PHOTOMICROGRAPH OF SAMPLE 47660 (MIA-585)

General view showing mosaic of fine-grained quartz and carbonate. 40x, crossed polarizers.

(Color microfiche number 39)