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MASTER

FAVORABILITY FOR URANIUM IN TERTIARY SEDIMENTARY ROCKS, SOUTHWESTERN MONTANA

BENDIX FIELD ENGINEERING CORPORATION
Grand Junction Operations
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SUMMARY

Tertiary sedimentary rocks in the basins of southwestern Montana were studied to determine their favorability for potential uranium resources. Three major age groups of Tertiary rocks were studied: the Beaverhead Conglomerate, which was deposited during Late Cretaceous through early Eocene time as a result of Laramide tectonism, and two sedimentary sequences which filled the intermontane basins after the basins were formed. The older of these two basin-fill sequences is the lower Tertiary sequence, which contains rocks of late Eocene, Oligocene, and, locally, early Miocene age. The upper Tertiary sequence includes rocks of late Miocene and Pliocene age, and is separated from the lower sequence by an unconformity of middle Miocene age. Of the three groups, the lower Tertiary sequence is the most favorable and the Beaverhead Conglomerate is the least favorable for potential uranium resources.

Uranium in the Tertiary sedimentary rocks was probably derived from the Boulder batholith and from silicic volcanic material. The batholith contains numerous uranium occurrences and is the most favorable plutonic source for uranium in the study area. Silicic volcanic material is incorporated in the Tertiary rocks as air-fall tuff. This tuffaceous material is abundant throughout both basin-fill sequences, and contains up to 17 ppm equivalent uranium where it is not diluted by detrital sediments.

Subjective favorability categories of good, moderate, and poor, based on the number and type of favorable criteria present, were used to classify the rock sequences studied. Rocks judged to have good favorability for uranium deposits are (1) Eocene and Oligocene strata and undifferentiated Tertiary rocks in the western Three Forks basin and (2) Oligocene rocks in the Helena basin. Rocks having moderate favorability consist of (1) Eocene and Oligocene strata in the Jefferson River, Beaverhead River, and Lower Ruby River basins, (2) Oligocene rocks in the Townsend and Clarkston basins, (3) Miocene and Pliocene rocks in the Upper Ruby River basin, and (4) all Tertiary sedimentary formations in the eastern Three Forks basin, and in the Grasshopper Creek, Horse Prairie, Medicine Lodge Creek, Big Sheep Creek, Deer Lodge, Big Hole River, and Bull Creek basins. The following have poor favorability: (1) the Beaverhead Conglomerate in the Red Rock and Centennial basins, (2) Eocene and Oligocene rocks in the Upper Ruby River basin, (3) Miocene and Pliocene rocks in the Townsend, Clarkston, Smith River, and Divide Creek basins, (4) Miocene through Pleistocene rocks in the Jefferson River, Beaverhead River, and Lower Ruby River basins, and (5) all Tertiary sedimentary rocks in the Boulder River, Sage Creek, Muddy Creek, Madison River, Flint Creek, Gold Creek, and Bitterroot basins. No favorability rating was assigned to Tertiary rocks in the Silver City, Deep Creek, Blackfoot, Douglas Creek, Avon, Rock Creek, and Philipsburg basins because available data are insufficient to provide a basis for a meaningful evaluation.

INTRODUCTION

This report presents results of a study of Tertiary and related sedimentary rocks in intermontane basins of southwestern Montana. The study was conducted by Bendix Field Engineering Corporation for the Grand Junction Office of the U.S. Energy Research and Development Administration (ERDA).

PURPOSE AND SCOPE

The objective of the study was to evaluate the favorability for potential uranium resources in Tertiary and related strata. Past studies indicate that the Tertiary basins in southwestern Montana are worthy of further investigation because (1) several basins contain a thick sequence of continental sedimentary rocks, (2) several basins are near possible granitic source rocks that have known uranium occurrences, and (3) some of the Montana basins are geologically similar to basins in Wyoming that are host to important sandstone-type deposits.

This study focuses on sedimentary rocks of Tertiary age, but includes some rocks of Late Cretaceous and Pleistocene ages. In some areas only a portion of the total Tertiary sedimentary section could be studied because of poor surface exposures and limited subsurface information.

AREA STUDIED

The area studied includes parts of 13 counties (Fig. 1) in southwestern Montana and contains 34 named basins which range in size from 50 to 800 sq mi. The total area of the basins within the project area is about 5,000 sq mi.

GENERAL GEOLOGY

Geologic Setting

The project area, which is part of the Northern Rocky Mountains, is characterized by subparallel mountain ranges and intermontane basins that trend generally northwestward. The area of Tertiary basins lies between the Idaho batholith on the west and the Montana disturbed belt on the east and north; the basins terminate to the south against flows and associated volcanic rocks of the Snake River Plain and Yellowstone-Absaroka volcanic region (Pl. 1).

Floors of the intermontane basins (valleys) are 3,500 to 7,000 ft above sea level and range from a few to as much as 20 mi in width. Although the basins are filled mostly with Tertiary sedimentary rocks, Holocene materials are widespread at the surface and mask much of the older basin fill. The mountain ranges that separate the basins rise to elevations of 6,500 to 10,000 ft and are principally made up of metasedimentary rocks of Precambrian age; marine sandstones, shales, and carbonate rocks of Paleozoic and Mesozoic age; continental strata of Jurassic and Cretaceous age; and andesitic volcanic

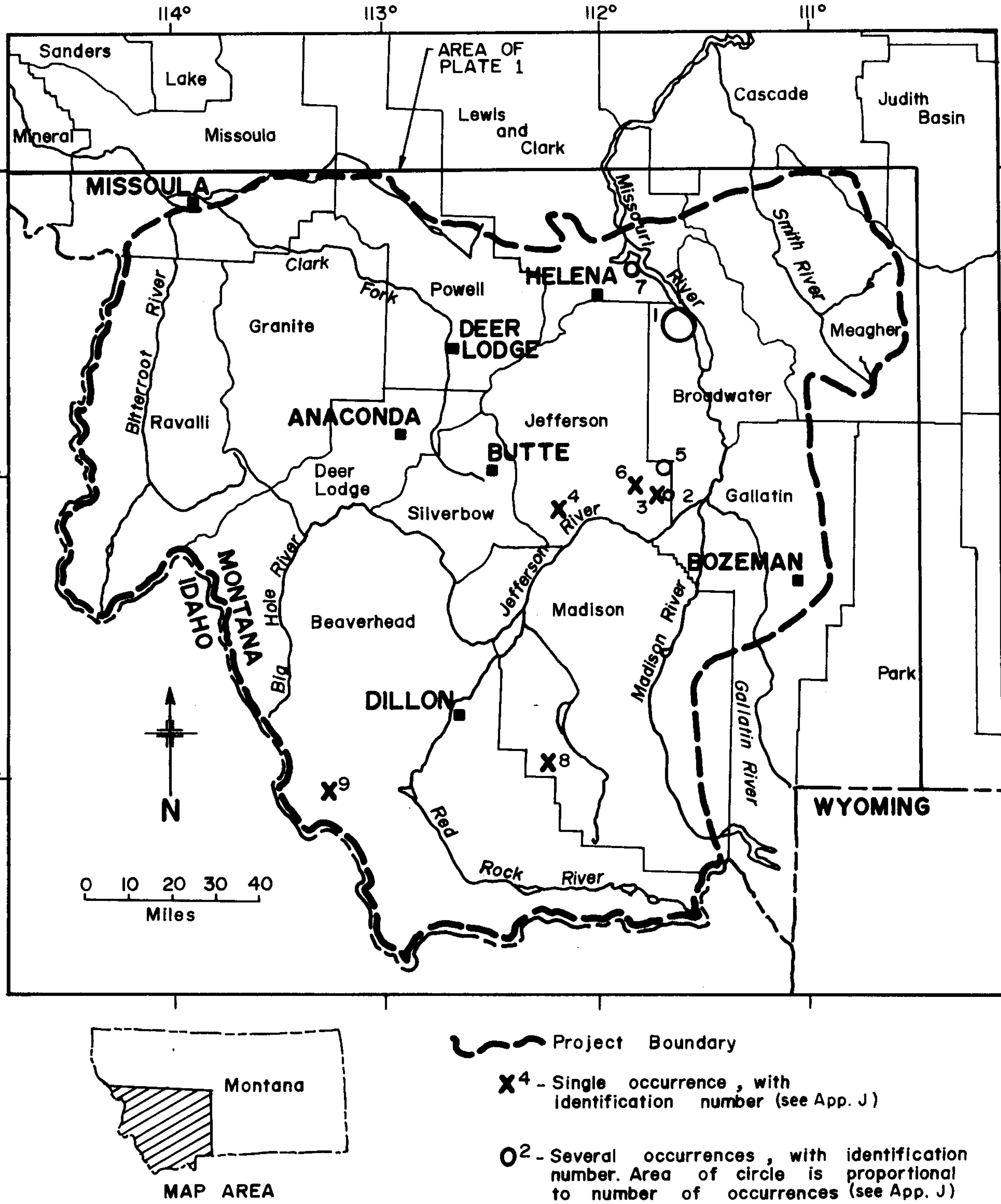

Figure 1. Southwestern Montana project area and known uranium occurrences in Tertiary basins.

rocks of Late Cretaceous age. The Boulder batholith, which consists mostly of quartz monzonite of Cretaceous age, forms a prominent positive feature near the center of the study area and was an important provenance for sediment deposited in some of the adjacent intermontane basins during Tertiary time.

The geology is further complicated by folding, thrusting, and normal faulting. Major structural complexities are confined mostly to pre-Tertiary rocks. Tertiary strata in the intermontane basins are only mildly deformed.

Tertiary Sedimentary Rocks

The Tertiary sedimentary rocks within the project area comprise three unconformable groups: the Beaverhead Formation and two basin-fill depositional sequences called the "lower" and "upper" Tertiary sequences. The Beaverhead Formation ranges from Late Cretaceous to early Eocene in age, and was deposited as a synorogenic conglomerate in response to Laramide tectonism (Ryder and Scholten, 1973). In later orogenic phases, the Beaverhead was tilted, folded, and faulted.

Block faulting and erosion during Paleocene and Eocene time determined the configuration of the Tertiary basins and adjacent mountain ranges. During late Eocene through early Miocene time, material that was eroded from the uplifted ranges was deposited in the basins along with silicic air-fall tuff and formed the lower Tertiary sequence. Deposition of this sequence was accompanied or, possibly, followed by eastward tilting of many of the basins. An episode of erosion in middle Miocene time removed an indeterminate thickness of previously deposited Tertiary sediments and resulted in the development of an extensive unconformity that now separates the lower Tertiary sequence from the upper Tertiary sequence. Recurrent movement along mountain-bordering faults during late Miocene to middle Pliocene time uplifted the ranges. The rejuvenated streams that drained the uplifted ranges deposited the thick upper Tertiary sequence of coarse sediments interbedded with pyroclastic material and some lacustrine beds upon the mid-Tertiary erosion surface. Varying quantities of the Tertiary sediments were removed from the basins during the present erosional episode, which was initiated in late Pliocene time.

As a result of the history described above, most of the mountain ranges and adjacent Tertiary basins are tilted to the east. The lower and upper Tertiary depositional sequences, separated by the mid-Tertiary unconformity, are lithologically distinct and can be identified in most of the Tertiary basins.

Possible Sources of Uranium

Uranium in the Tertiary sedimentary rocks was probably derived from the Boulder batholith and from silicic pyroclastic material. The Boulder batholith contains numerous uranium occurrences and is the most favorable source for uranium of any of the plutonic rocks in and near the study area. Arkosic and feldspathic sediments derived from the batholith were deposited in several basins adjacent to the batholith during late Eocene to Pliocene time. In some basins, uranium occurrences and radioactivity anomalies are associated with these sediments. Other nearby plutons, although less favorable, are also possible sources of uranium.

Silicic pyroclastic material is a prominent component of both the upper and lower Tertiary sequences and probably originated from eruptive centers throughout the region. These centers include those of the post-Lowland Creek volcanics, the Challis volcanics, the volcanics associated with the Yellowstone Plateau, and several local volcanic centers mapped within the project area. Some of the flows from these eruptive centers contain higher-than-average amounts of uranium. The rhyolitic post-Lowland Creek volcanics of post-early Eocene age, which crop out in and around the northern part of the Boulder batholith, contain an average of 6.1 ppm uranium and, locally, contain as much as 18 ppm uranium (Tilling and Gottfried, 1969, p. E11). In nearby parts of east-central Idaho, some silicic flows of the Challis volcanics of Eocene age are highly enriched in uranium. Tuffaceous beds throughout the basin-fill sequences in the project area are more radioactive than are the enclosing sedimentary beds and contain up to 17 ppm equivalent uranium where not diluted by sediments.

METHODS OF INVESTIGATION

To facilitate field investigations, the 34 basins in the study area were arbitrarily divided into three groups: northeastern basins, south-central basins, and western basins (Pl. 2). Responsibility for field work, data interpretation, and report preparation was assigned to one geologist for each group of basins.

Field Work

Field work was conducted over a four-month period in 1975. Effort was concentrated on sedimentary rocks that were considered to be most favorable for potential uranium deposits on the basis of information collected from the literature and from field reconnaissance. Samples were collected from beds of potential host rocks and, wherever possible, from beds of fine-grained rocks adjacent to the potential host rocks. Stratigraphic and lithologic information based upon field and petrographic studies is recorded in Appendix A.

Chemical Analyses

All bulk rock samples were analyzed by gamma-ray spectrometry for equivalent uranium, thorium, and potassium (App. C), except for samples in which the uranium content was too high to be analyzed by this method. Thirty-nine rock samples with higher-than-average uranium values and (or) higher-than-average uranium-to-thorium ratios were chemically analyzed for uranium (App. D). Forty rock samples from sequences characterized by higher-than-average radioactivity and (or) favorable stratigraphic and lithologic characteristics were analyzed by emission spectroscopy (App. E). Six rock samples were analyzed for total and organic carbon (App. A). Fourteen water samples were analyzed for uranium by the fluorometric method (App. F).

Petrographic Studies

Fifty-eight rock samples were selected for petrographic study because of their high radioactivity or uncertain origin, classification, or composition. Petrographic studies included rock and mineral identifications, semiquantitative modal analyses, textural descriptions, and descriptions of alteration. Basic results from these studies are included in Appendix A.

Subsurface Studies

Numerous well logs were examined by the authors. The logs selected for use in this report were those which directly supplemented surface studies or which supplied information where no surface information was available.

Well logs from 13 petroleum test wells (App. G; Pl. 2) were obtained from the Montana Oil and Gas Conservation Commission, Billings; the Rocky Mountain Well Log Service, Denver; and the American Stratigraphic Company, Denver. Lithologic logs were available for 8 wells, electric logs for 4 wells, and gamma-ray neutron logs for 3 wells.

Logs of 24 uranium exploration drill holes were obtained from Western Nuclear, Inc. (through ERDA), and from the Montana Oil and Gas Conservation Commission. Lithologic and gamma-ray logs were available for 23 drill holes, and electric logs were available for 20 drill holes. Drill cuttings from 4 holes were also used (App. I; Pl. 2).

Lithologic logs for 42 water wells (App. H; Pl. 2) were obtained from the Montana Bureau of Mines and Geology, Butte, and from Hackett and others (1960, Table 33). Most data available from these well logs were limited to rock type, color, and thickness. However, some logs, particularly those from Hackett and others, contained detailed lithologic descriptions.

Favorability Evaluation

Determination of the favorability for uranium was made by comparison of observed lithologic, stratigraphic, and structural characteristics of rocks in the Tertiary basins with characteristics in similar geologic settings where sandstone-type uranium deposits are known to occur. Favorability categories of good, moderate, and poor (Table 1) were subjectively selected to classify rock sequences that occupy the basins. Most of the criteria used to judge the favorability of the rock sequences are those given by Grutt (1972, Tables 2, 3).

TABLE 1. RELATIVE FAVORABILITY RATING SYSTEM

Favorability rating	Favorable sedimentary rock sequence[a]	Uranium occurrences and (or) radioactivity anomalies[b]	Samples with anomalous chemical composition[c]	Evidence of reducing condition[d]
good	yes	numerous	numerous	yes
moderate	yes	few	few	yes
poor	yes	none	none	no
	no	none	some or none	yes or no

[a] More than 1,000 ft thick, contains 30-80 percent sandstone and (or) conglomerate, contains one or more beds of medium- to coarse-grained sandstone or conglomerate between 20 and 200 ft thick, and generally contains tuffaceous material.

[b] Surface and (or) subsurface.

[c] (1) Anomalously high equivalent uranium content relative to equivalent thorium or (2) above average equivalent uranium content relative to equivalent thorium accompanied by one or more other possible chemical indicators.

[d] Potential host rock and (or) adjacent fine-grained rocks contain direct (carbonaceous material, pyrite) or indirect (petrified wood) evidence of reducing conditions.

Favorability is indicated by the following:

1. Thick (1,000 ft or more) sequence of Tertiary sedimentary rocks derived from granitic and silicic volcanic provenances;

2. 30-80 percent sandstone and (or) conglomerate, some beds of which are 20 to 200 ft thick, light colored (where indicative of a reducing environment), feldspathic to arkosic, poorly sorted, medium to coarse grained, and (or) permeable;

3. Carbonaceous material or pyrite in or adjacent to potential host rocks and presence of a reducing fluid or gas in wells that penetrate such rocks;

4. Uranium occurrences, radioactivity anomalies, and favorable geochemical indicators[a/] in Tertiary strata;

5. Pervasive postdepositional alteration (for example, iron staining) of potential host rocks;

6. Unconformities that bound or are within the rock sequence;

7. Siliceous, tuffaceous rocks superjacent to potential host rocks; and

8. Gentle dips (1° to 5°) and presence of faults.

ACKNOWLEDGEMENTS

The authors are indebted to Western Nuclear, Incorporated, and to the Montana Power Company for providing subsurface logs and other information; to the Montana Bureau of Mines and Geology and the Oil and Gas Commission of the State of Montana for permission to make copies of pertinent subsurface logs and other information; to Dr. Robert Lankston, Gulf Research Laboratories, Houston, for providing geophysical data for the Bitterroot Basin; and to U.S. Geological Survey personnel of the Public Information Office in Spokane for general assistance in literature research. Field assistance during the study was provided by Michael Berry, Deborah Highley, Peter Kurisoo, and Kevin Sylvester.

[a/] Favorable geochemical indicators are high concentrations of the elements U (or eU), As, B, Cr, Cu, Ga, Li, Mn, Mo, Nb, P, Se, Sn, V, and Zn (Marjaniemi and Robins, 1975a, 1975b; Grutt, 1972, p. 53) and high ratios of eU/eTh in potential host rocks, in argillaceous interbeds, and in waters that may have passed through these rocks. The significance of a high equivalent uranium content of an individual rock sample was determined by comparing the uranium content to both (1) the equivalent thorium content of the sample (using the ratio eU/eTh or a plot of eU versus eTh for a control group of samples) and (2) the mean equivalent uranium content of a control group of samples. The significance of a high uranium content in a specific water sample was determined by comparison of its uranium content with the mean uranium content of all water samples analyzed for the project.

NORTHEASTERN BASINS

by

M. A. Wopat

The seven northeastern basins (Fig. 2) contain some of the best exposures and some of the most favorable rocks in the project area. These basins are discussed in an approximate south-to-north order. The large Three Forks basin has been divided into an eastern and a western part because the favorability characteristics significantly differ between the two parts.

WESTERN THREE FORKS BASIN

Eocene and Oligocene Rocks

Data were obtained from surface studies of 18 localities (301-306, 308-315, 324-326, 364, Pl. 2); analyses of 53 rock samples and 1 water sample from these localities (App. A); logs of 4 water wells, 6 petroleum test wells, and 7 uranium exploration drill holes (Pl. 2; Fig. I-1); 3 measured sections described in the literature (App. B); and cited references.

Eocene and Oligocene rocks have been mapped as four lithologically distinct formations in the Three Forks quadrangle (Robinson, 1963) and in the northern part of the contiguous Norris quadrangle (Feichtinger, 1970). These formations, from oldest to youngest, are: (1) the Sphinx Conglomerate of Eocene age, (2) the Milligan Creek Formation of Eocene age, (3) the Climbing Arrow Formation of the late Eocene and early Oligocene age, and (4) the Dunbar Creek Formation of Oligocene age.

The Sphinx Conglomerate is principally a limestone conglomerate with a porous earthy matrix. It crops out only near the basin edges, but it may occur in subsurface as a widespread basal unit in pre-Tertiary valleys in the western part of the basin. A few coal layers were penetrated in the upper part of the Sphinx by a petroleum test well (no. 1) in the Madison Valley (Hackett and others, 1960, p. 35).

The Milligan Creek Formation is thin (0-300 ft), of limited areal extent, and composed of fine-grained tuffaceous lacustrine deposits, with minor zones of intertonguing fluvial conglomerate and sandstone. The formation crops out only in the Jefferson River valley.

The Climbing Arrow Formation is as much as 1,500 ft thick, 35 percent of which is composed of fluvial sandstone and conglomerate. This formation is the most extensively exposed of the four that form the Eocene-Oligocene sequence; for this reason, most of the data from which favorability of the western Three Forks basin is determined were derived from the Climbing Arrow Formation.

The Dunbar Creek Formation comprises 15 percent fluvial sandstone and conglomerate, 80 percent thick-bedded tuffaceous siltstone and sandstone, and 5 percent limestone and claystone. Much of the fine constituent is airborne volcanic ash (Robinson, 1963, p. 121), which could be a source of uranium.

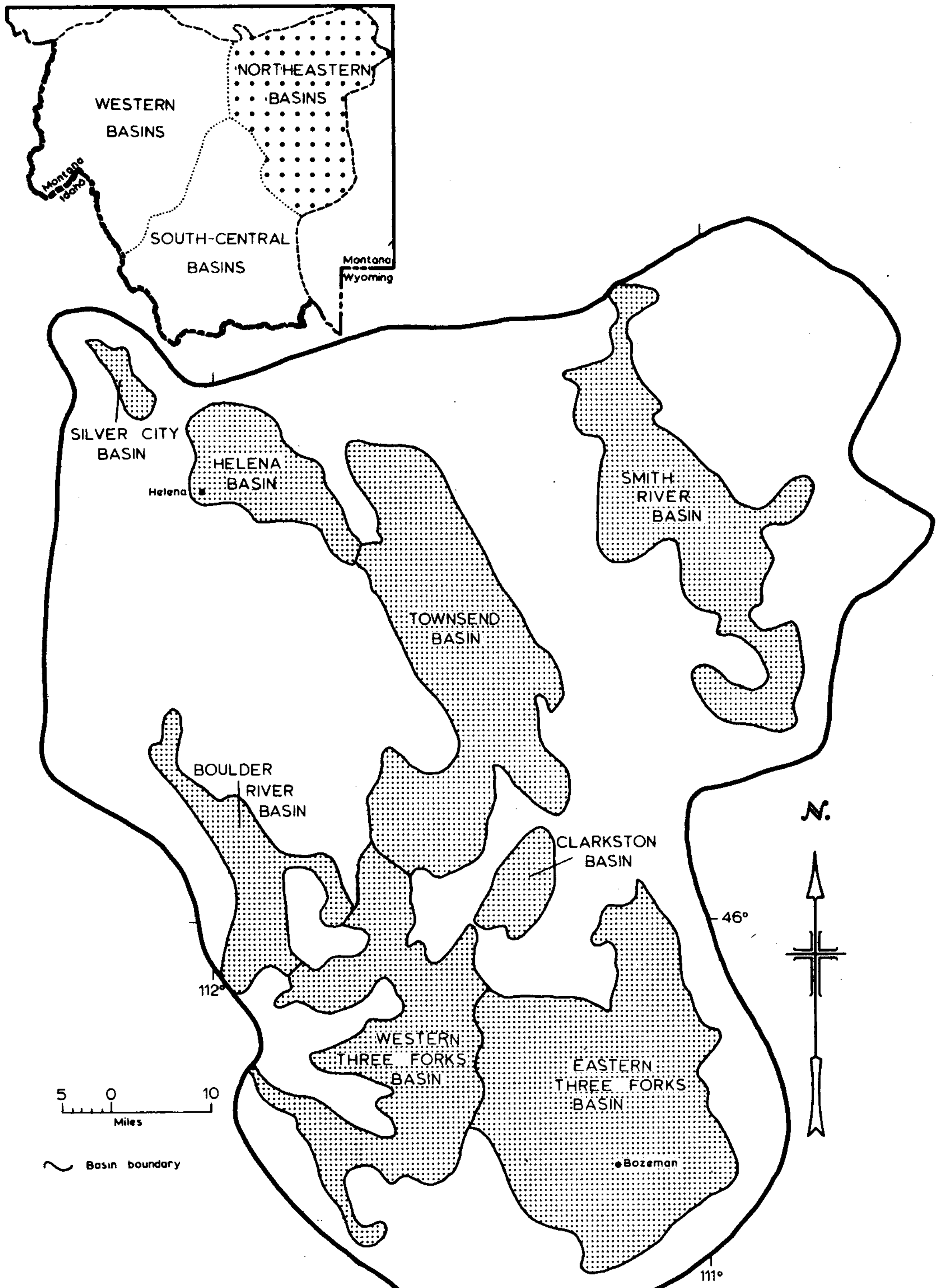

Figure 2. Locations and names of Tertiary basins in the northeastern part of the study area.

Favorability Characteristics. Robinson (1963, p. 60) reported that the Tertiary sedimentary rocks in the Three Forks quadrangle are generally less than 1,000 ft thick, but locally may be as much as 2,500 ft thick. In the contiguous Jefferson Island quadrangle to the west, these rocks probably have a maximum thickness of about 400 ft (Richard, 1966, Pl. 5). The thickness of the lower Tertiary rocks in six locations is shown by the wells and drill holes that bottom in the pre-Tertiary rocks (Table 2). Geophysical evidence (Davis and others, 1965b) indicates that the Tertiary basin deposits near the town of Three Forks may be as much as 3,000 ft thick on the west side of the Madison River valley, but are probably less than 1,000 ft thick within the Jefferson River valley. The rocks are bounded by an erosion surface of Late Cretaceous to early Eocene age below and an unconformity of middle Oligocene to middle Miocene age above (Robinson, 1963, p. 61).

Sandstone and conglomerate average 25 percent of measured sections and 38 percent of subsurface intervals (Table 2). Between 35 and 45 percent may be a more representative estimate because most of the measured sections and wells for which sandstone percentages were calculated are in the fine-grained sedimentary facies away from the basin edges. Also, a thick basal conglomerate, which is believed to underlie most of the basin, was penetrated by only two deep petroleum test wells (nos. 1, 5) and was not measured during surface investigations; it is therefore poorly represented in the calculated sandstone percentages. Robinson's (1963, p. 60) value of 45 percent for the proportion of sandstone and conglomerate in early Tertiary rocks of the Three Forks quadrangle further indicates that the percentages measured are minimum ones.

Potential host rocks range from medium-grained sandstone to conglomerate. The sandstone is poorly sorted and is arkosic or feldspathic in most localities. Some of the beds penetrated by petroleum test well 5 are feldspathic. The potential host rocks generally are permeable, and iron staining is common. These rocks form beds which average less than 10 ft in thickness, although beds as much as 25 ft thick in outcrop (Apps. A, B) and as much as 120 ft thick in the subsurface (Table 2) are known. The basal conglomerate, which is as much as 100 ft thick in outcrop (Robinson, 1963, p. 1), is 300 to 400 ft thick in the subsurface and contains beds that range from 5 to 105 ft thick and average 51 ft thick (petroleum test well 5).

Except for localized concentrations of petrified wood and lesser amounts of petrified bone, organic material is present only in trace amounts in outcrop. A few layers and seams of coal and a trace of carbonaceous shale were intercepted in the subsurface (Table 2).

Tuffaceous material is common throughout the section (Robinson, 1963, p. 60). Most beds contain some Tertiary volcanic ash, and many strata are composed wholly of such material (for example, loc. 304, units 11 and 12, App. A). The Dunbar Creek Formation in the western part of the basin is formed mostly of airborne ash (Robinson, 1963, p. 121).

TABLE 2. SUMMARY OF DATA FROM SUBSURFACE INTERVALS OF EOCENE AND OLIGOCENE ROCKS IN THE WESTERN THREE FORKS BASIN

Type of well and well no.	Depth of logged interval (ft)	Total thickness of lower Tertiary rocks (ft)	Sandstone and conglomerate: Percent of interval[a]	Sandstone and conglomerate: Average bed thickness (ft)	Sandstone and conglomerate: Maximum bed thickness (ft)	Comments
Petroleum test wells (App. G, Pl. 2)						
1, 2, 3, 4[b]	95-1,650	2,300	31[c]	--	25[c]	d/
5	5-1,661	1,656	48	33	120	e/
7	0-1,214(?)[f]	1,214(?)[f]	--	--	--	
Water wells (App. H, Pl. 2)						
1	0-200(TD)	--	0	0	0	
7	18-160(TD)	--	26	--	5	
8	40-195(TD)	--	19	--	10	
43	0-446(TD)	--	56	--	84	
Uranium exploration drill holes (App. I)						
2	0-700(TD)	--	--	--	--	
3	0-720(TD)	--	--	--	--	
4	0-470	470	--	--	--	
10	5-240	235	--	--	--	
11	10-535	525	--	--	--	
12	0-724(TD)	--	--	--	--	
13	40-300(TD)	--	--	--	--	

TD = total depth
-- = information not available

a/ Units described as composed of sandstone interbedded with finer sediments are assumed to contain 50 percent sandstone.

b/ Because these wells are clustered in a very small area, the information from their logs is combined.

c/ The 300- to 400-ft-thick basal conglomerate at a depth of 2,000 ft in well 1 (Hackett and others, 1960, p. 34-35; Robinson, 1963, p. 63) is not included because it lies below the interval for which well logs were available.

d/ A few coal layers were present in well 1 (Hackett and others, 1960, p. 34-35), and a few thin coal seams were found in well 4.

e/ Trace of carbonaceous shale was reported. Beds of a basal conglomerate make up 95 percent of the bottom 321 ft of the Tertiary interval.

f/ Log is of poor quality; total thickness does not agree with the interpretation of Richard (1966, Pl. 5).

Several uranium occurrences (nos. 2, 3, 5, 6, Fig. 1, App. J) have been reported northwest of the town of Three Forks, and meta-autunite and coffinite were found nearby at locality 325. "Slight mineral" was reported on the log of uranium exploration drill hole 11, and numerous subsurface radioactivity anomalies (Table I-2) were recorded on gamma-ray logs from the uranium exploration drill holes that are also near the reported uranium occurrences. Petroleum test well 3, southeast of the town of Three Forks, penetrated a 6-ft-thick anomalously radioactive (2 to 3 times background) bed at a depth of 742 ft.

Rock sample 325-5 contains 0.94 percent uranium (App. D). Equivalent uranium values of the rest of the samples of these rocks are generally much higher than those of the western and south-central basins (Fig. 3). Furthermore, the mean equivalent uranium value and the mean eU/eTh ratio of these samples are higher than those from most other basins in this study (exceptions are the Townsend, Clarkston, and Helena basins) (Table 3). Sixteen rock samples (301-2, 301-6, 302-1, 302-6, 305-2, 312-1, 312-2, 314-2, 324-1, 324-2, 324-3, 325-2, 325-3, 325-4, 326-1, 326-2) from eight study localities are anomalously high[a/] in equivalent uranium (App. C). Three samples (301-6, 324-1, 326-1) also contain anomalously high concentrations of other favorable geochemical indicators (App. E). Of the sixteen rock samples for which both equivalent and chemical uranium analyses were available, four (302-6, 303-1, 324-1, 324-3) are in disequilibrium (Fig. K-1). One water sample (308-1) is anomalously high in U_3O_8 (40 ppb, App. F).

These chemical characteristics do not indicate uniform favorability throughout the area underlain by these rocks, but rather reflect the favorability of each of the four lower Tertiary formations. The sample containing 0.94 percent U_3O_8 is from the Climbing Arrow Formation. The 39 other rock samples from this formation contain an average of 59 ppm equivalent uranium, and the 1 water sample, taken from a spring that rises from the Climbing Arrow, contains 40 ppb U_3O_8. In contrast, the 2 rock samples collected from the most favorable outcrop of the Milligan Creek Formation contain an average of 32 ppm equivalent uranium, and the 9 rock samples from the Dunbar Creek Formation have an average equivalent uranium content of 6 ppm. The Sphinx Conglomerate was not sampled.

Dips commonly are 5° to 10° and rarely are as much as 25° (Robinson, 1963, p. 61). Post-Tertiary faults have been mapped only near the southern margin of the western Three Forks basin, near the Madison River (Feichtinger, 1970, p. 37, Pls. I, III). Evidence of late- or post-Tertiary movement on the eastern extension of the Willow Creek fault zone (Robinson, 1963,

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[a/] The equivalent uranium (eU) content of a rock sample from the northeastern basins is considered to be anomalously high if the eU/eTh ratio of the sample is 1.0 or more and the eU value is 8.7 ppm or more. The 8.7 ppm value is the mean (3.3 ppm eU) plus two standard deviations (1 std dev = 2.7 ppm eU) of the eU values of the rock samples from the south-central and western basins. A meaningful cutoff value cannot be derived from the eU values of the rock samples from the northeastern basins because the distribution of these values is greatly skewed (Fig. 3).

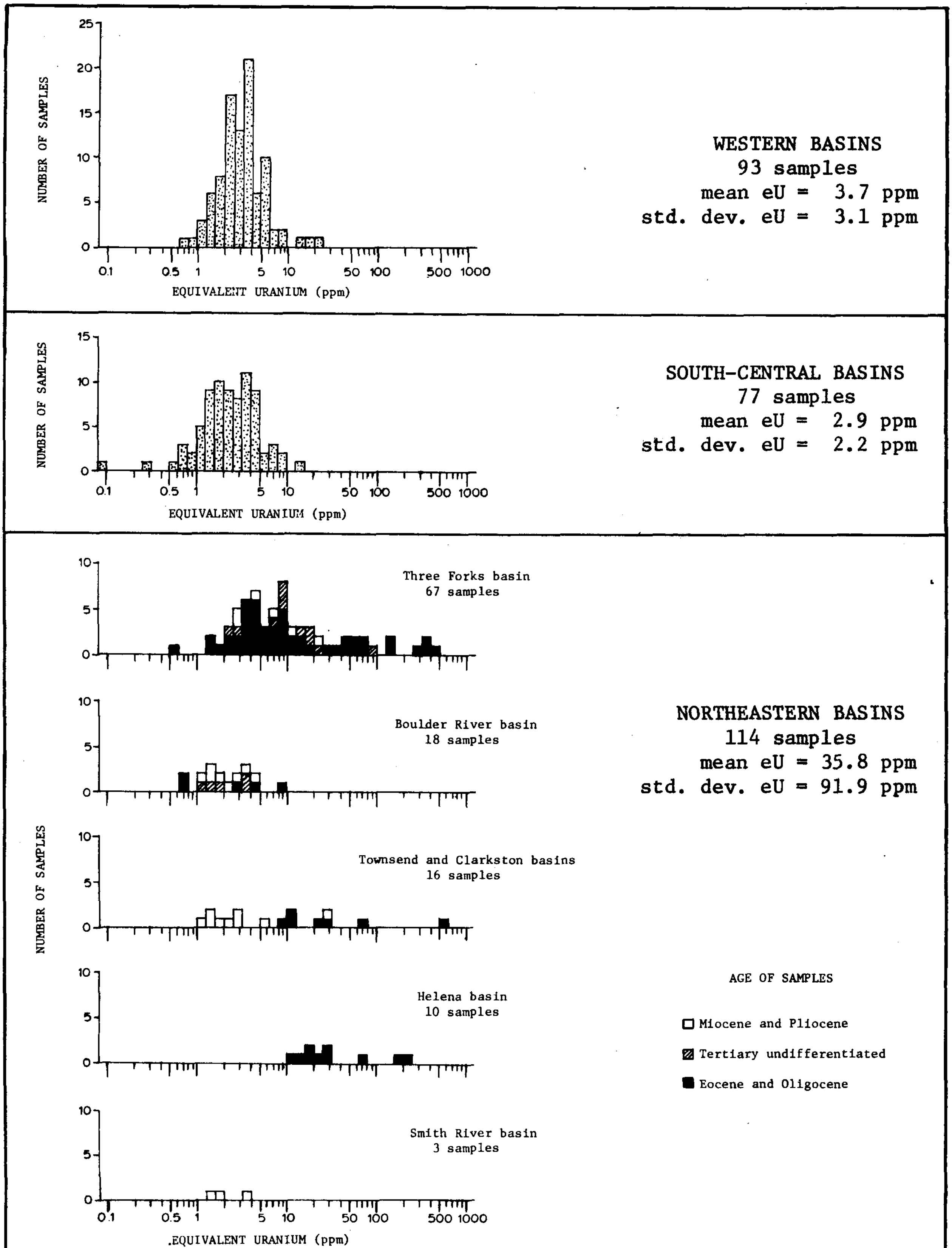

Figure 3. Distribution of equivalent uranium content of samples from individual northeastern basins compared with distributions for the south-central basins and the western basins. (Includes all samples used in Table 3)

TABLE 3. MEAN EQUIVALENT URANIUM AND THORIUM CONTENT OF ALL ROCK SAMPLES[a], BY BASIN AND AGE

Region	Sample Group		Number of samples	eU (ppm) mean	eU (ppm) std dev	eTh (ppm) mean	eTh (ppm) std dev	eU/eTh mean	eU/eTh std dev
NORTHEASTERN BASINS	Three Forks basin, western part	Undifferentiated Tertiary	11	18.1	23.4	11.6	6.7	1.35	0.90
		Eocene and Oligocene	50	48.0	103.4	16.3	11.9	3.00	6.00
		All samples	61	42.6	94.7	15.5	11.2	2.71	5.47
	Three Forks basin, eastern part - Miocene and Pliocene		6	8.4	7.6	7.5	1.6	1.20	1.14
	Boulder River basin	Miocene and Pliocene	8	2.3	1.1	10.4	3.6	0.22	0.06
		Undifferentiated Tertiary	5	2.3	1.2	12.5	3.5	0.17	0.05
		Eocene and Oliogcene	5	3.5	3.4	18.5	9.2	0.17	0.10
		All samples	18	2.6	2.0	13.3	6.4	0.19	0.07
	Townsend and Clarkston basins	Miocene and Pliocene	9	5.0	7.7	11.6	6.2	0.98	2.32
		Oligocene	7	107.7	220.0	34.9	15.2	3.05	5.20
		All samples	16	49.9	148.9	21.8	16.0	1.89	3.85
	Helena basin - Oligocene		10	57.7	70.6	28.8	12.8	2.69	4.03
	Smith River basin - Miocene and Pliocene		3	2.2	1.1	17.7	15.6	0.16	0.07
SOUTH-CENTRAL BASINS	Jefferson River, Beaverhead River, Lower Ruby River, and Divide Creek basins		32	3.4	2.4	12.9	7.9	0.28	0.16
	Upper Ruby River and Sage Creek basins		24	2.8	1.5	12.7	8.2	0.23	0.07
	Red Rock and Centennial basins		3	0.6	0.3	2.7	1.9	0.37	0.35
	Grasshopper Creek, Horse Prairie, Muddy Creek, Medicine Lodge Creek, and Big Sheep Creek basins		12	3.1	2.9	7.9	8.3	0.59	0.58
	Madison River basin		6	1.9	1.2	7.6	4.9	0.26	0.08
WESTERN BASINS	Deer Lodge, Flint Creek, and Gold Creek basins		34	3.2	1.5	9.6	4.4	0.37	0.18
	Big Hole, Bull Creek, and Deep Creek basins		30	4.4	4.7	9.6	4.1	0.47	0.41
	Wise River, Blackfoot, Douglas Creek, Avon, and Rock Creek basins		13	3.0	1.5	9.5	4.8	0.35	0.17
	Bitterroot River basin		16	4.0	3.0	13.4	8.9	0.32	0.16

[a] Includes all samples analyzed by gamma-ray spectrometry except those of probable pyroclastic origin and those which are hydrothermally altered (140-1, 140-2, 222-1, 224-1, 230-1, 231-1, 238-1, 239-1, 245-1, 250-1, 254-1, 304-3, 304-4, 333-1, 335-2, 336-1, and 336-2).

page 13, Pl. 3) was observed just east of the Madison River (Schneider, 1970, p. 36; Hackett and others, 1960, p. 51-55). Although this movement most likely affected the Tertiary sedimentary rocks west of the Madison River, Robinson (1963, p. 61) did not map any faults that cut the Tertiary rocks in the Three Forks quadrangle.

The western part of the Three Forks basin is approximately 25 mi from the Boulder batholith. Eastward drainage from the batholith in early Tertiary time transported batholithic detritus through, and perhaps across, the ancient Boulder River and northern Jefferson River valleys into the Three Forks basin. Most of the lower Tertiary sediments in the basin were deposited by eastward- and, perhaps, northeastward-flowing streams. The Climbing Arrow Formation, for example, comprises sediment derived from the ancestral Elkhorn, Madison, and Tobacco Root Mountains and from the Boulder batholith (Robinson, 1963, p. 95, 121).

Conclusions. Favorability for uranium in Eocene and Oligocene rocks of the western Three Forks basin is judged to be good because of the presence of a favorable sedimentary rock sequence (Table 1), several uranium occurrences, numerous radioactivity anomalies, and high concentrations of uranium in 17 of the 53 rock samples and in 1 water sample. Abundant tuffaceous material, ample evidence of reductants, and proximity of the area to the Boulder batholith further enhance the favorability. In addition, the Eocene-Oligocene sequence is bounded by unconformities. The favorability rating is adequately supported by the large volume of data from the surface and subsurface geologic studies.

Although no specific attempt was made during the study to separately evaluate the four formations that make up the Eocene and Oligocene rocks, results indicate that the rocks are not uniformly favorable. The Climbing Arrow Formation is the most favorable of the four formations; 15 of 17 rock samples that contain anomalously high uranium concentrations are from Climbing Arrow beds. The Dunbar Creek Formation, although not as favorable as the subjacent Climbing Arrow Formation, contains units with anomalous uranium concentrations (sample 314-2) and warrants further evaluation. Because of its volcanic ash content, the Dunbar Creek could be a source of uranium for underlying rocks. The Sphinx Conglomerate is lithologically unfavorable as a uranium host rock, and no radioactivity anomalies were found to warrant sampling or further examination of the formation. The Milligan Creek Formation contains possible host rocks (loc. 305), but the limited thickness, the limited areal extent, and the dominance of unfavorable lithology indicate generally poor favorability for potential uranium deposits.

Undifferentiated Tertiary Rocks

Data were obtained from surface studies of 7 localities (318, 319, 340-342, 377, 378, Pl. 2), analyses of 12 rock samples and 1 water sample from these localities (App. A), and cited references.

Favorability Characteristics. Maximum thickness of the undifferentiated Tertiary sequence is about 1,500 ft near the Willow Creek Reservoir, east of Harrison (Davis and others, 1965b); the sequence is at least 711 ft thick in

Antelope Creek valley, northwest of Harrison (Richard, 1966, p. 40). The sandstone percentage of the sequence is unknown, but small outcrops examined near Harrison and Norris contain a larger proportion of coarse sediments than the overlying limestone and tuffaceous siltstone unit mapped east of Harrison by Feichtinger (1970). Andretta and Alsup (1960, p. 185) indicate that the Tertiary sedimentary rocks in the valley between Harrison and Norris are mainly siltstone and sandstone.

Potential host rocks range from conglomerate to medium-grained sandstone and are feldspathic to arkosic. The sandstone is moderately to poorly sorted and is medium to very coarse grained. The potential host rocks form beds that average 12 ft thick and that attain a maximum thickness of 25 ft. These rocks range from soft, where not cemented, to very hard, where cemented by silica; permeability varies inversely with hardness. The rocks are iron stained at three localities but are very light colored (reduced?) at localities 341 and 378. The pervasive hematitic staining of rocks at locality 318 may be due to hot-springs activity (Andretta and Alsup, 1960, p. 186). Traces of petrified wood were found in both the fine and coarse sedimentary rocks northwest of Harrison. Traces of petrified wood containing carnotite were found at localities 341 and 378.

The siltstone beds at localities 318 and 342 are tuffaceous. The finer sedimentary rocks that are inferred to overlie the rocks of the study localities include the tuffaceous siltstone described by Feichtinger (1970, p. 21, 79-81). Glass shards are common in the Tertiary sedimentary rocks that underlie the valley between Harrison and Norris (Andretta and Alsup, 1960, p. 185).

Rock sample 341-1, which is petrified wood, contains the highest concentration of uranium (2.58 percent) of all samples collected for this study. Even discounting this sample, the equivalent uranium values of the remaining samples are generally higher than values recorded from the western and south-central basins (Fig. 3). Furthermore, the mean equivalent uranium value and the mean eU/eTh ratio are higher in the undifferentiated Tertiary sequence of the western Three Forks basin than in the western and south-central basins (Table 3). A total of five rock samples (318-1, 340-1, 341-4, 341-5, 342-4) from four localities are anomalously high in equivalent uranium content. The three samples (318-1, 342-2, 343-3) analyzed for other favorable geochemical indicators all contained anomalously high concentrations of one or more of the indicators (App. E). The high concentrations support the anomalously high uranium content of sample 318-1, and are in agreement with other characteristics that suggest a high favorability rating for locality 342.

The undifferentiated Tertiary rocks unconformably overlie all older rocks, which have experienced various degrees of deformation; however, no dips steeper than 10° were found in the Tertiary rocks. Evidence of post-Tertiary faulting has been observed only east of the town of Norris, where shear and drag folds in the Tertiary sedimentary rocks indicate movement along the Warm Springs Fault Zone (Andretta and Alsup, 1960, p. 188). Although evidence of post-Tertiary movement on the northwest-trending Cherry Creek and Elk Creek faults has been observed only near the Madison River

(Feichtinger, 1970, p. 37, Pls. I, III), this movement may have affected Tertiary sedimentary rocks that overlie the faults (Davis and others, 1965b) northwest of Harrison.

Eastward drainage from the Boulder batholith transported batholithic detritus to the western Three Forks basin in Tertiary time. The Tobacco Root batholith contributed detritus to Tertiary sedimentary rocks that underlie the valley between Norris and Harrison and was also the source of feldspathic sediments east of Norris (Andretta and Alsup, 1960, p. 185, 186).

Conclusions. Favorability for uranium deposits in the undifferentiated Tertiary rock sequence in the western Three Forks basin is rated good to moderate. The rating is based on the presence of feldspathic to arkosic potential host rocks, abundant tuffaceous material, anomalously high uranium content in six rock samples, and petrified wood with carnotite. Furthermore, an unconformity separates the sequence from subjacent older rocks; and the area is proximal to the uraniferous Boulder batholith, from which some of the sediment in the sequence was probably derived.

The available information is limited because outcrops are sparse and subsurface information is lacking. Most of the data were derived from surface studies of the best exposed outcrops, which are clustered in two small areas (Pl. 2). Therefore, the favorability rating is considered valid only for rocks in and near the areas of outcrop.

EASTERN THREE FORKS BASIN

Data were obtained from surface studies of four localities (Pl. 2); analyses of six rock samples from the study localities (App. A); logs of nine water wells, one petroleum test well, and one uranium exploration drill hole (Pl. 2); examination of the rocks in six measured sections described in the literature (App. B); published descriptions of two other sections not examined during this study; and cited references.

Tertiary rocks that underlie the eastern Three Forks basin are predominately of Miocene and Pliocene age (Pl. 1). Also, rocks of Oligocene age (Klemme, 1949, p. 68; Verrall, 1955, p. 172-173; loc. 362) and of undifferentiated Tertiary age (Hackett and others, 1960, p. 39) underlie part of the basin. These three age groups are distinguished on the map of the basin (Pl. 1). However, they are not treated separately in the favorability discussion because (1) little information is available for rocks of Oligocene and undifferentiated Tertiary age and (2) age subdivisions of the Tertiary section are not readily distinguishable on the well logs.

Favorability Characteristics

The maximum thickness of Tertiary rocks is 6,000 ft in the southernmost of three bedrock depressions that underlie the Cenozoic sediments east of longitude 111°15' W. (Davis and others, 1965a; Burfeind, 1967). In the central depression the rocks are about 5,000 ft thick, and in the northernmost depression the rocks are 3,000 ft thick or less. These thick sequences are separated from the 2,300-ft-thick Tertiary sequence near the Madison River by a north-trending bedrock high over which the Tertiary rocks thin to less than 1,000 ft. Tertiary strata unconformably overlie all older rocks throughout the basin.

Sandstone and conglomerate make up about 30 percent of the Tertiary section. The coarser sedimentary rocks average 40 percent in measured section and make up 22 percent of the Tertiary sedimentary rocks penetrated by the nine water wells.

The sandstone and conglomerate form beds that average 20 to 25 ft thick; beds as thick as 40 ft are common. Feldspar content is generally low; feldspathic sands were found only in measured sections 51 and 55 (App. B). Sandstones are medium to very coarse grained, very poorly to well sorted, and permeable where not cemented or claybound. All measured sections, wells, and study localities (except measured section 53 and locs. 317 and 361) contain some calcite-cemented rocks. In many places calcite appears to have been deposited penecontemporaneously as a caliche horizon (Mifflin, 1963, p. 22; Glancy, 1964, p. 21, 22); thus, some of the possible host rocks may have been relatively impermeable since the time of deposition. Iron staining generally is uncommon and was found only in locality 316 and in measured sections 48 and 51 (App. B).

Traces of carbonaceous dendrites, bone fragments, and petrified wood were found in outcrop (App. B). Beds containing petrified wood and (or) bone were penetrated by water wells 48 and 49. Water wells 4, 45, and 48 penetrated beds of pyritic sand and clay. The pyritic rocks in these wells range in thickness from 39 ft (well 48) to 191 ft (well 45) and are found near the base of the Tertiary sequence just above Precambrian basement rocks in which all three wells bottom. Individual sand beds in the pyritic section are 20 to 26 ft thick.

Pyroclastic material probably makes up more than half of the rock. Ash beds, 15 to 35 ft thick, are found both near the Madison River valley (Schneider, 1970, p. 23) and near Bozeman (Glancy, 1964, p. 24; loc. 361, this report).

Although five of the six rock samples are from one locality (316) near the western part of the basin, the mean equivalent uranium content and mean eU/eTh ratio of the six samples are higher than those from most other basins in this study (exceptions are the Helena, Townsend, Clarkston, and western Three Forks basins) (Table 3). Rock samples 316-2 and 316-4 are anomalously high in equivalent uranium content.

Tertiary strata generally dip 1° to 5° to the east. However, local variations are numerous, and dips up to 35° have been recorded. Evidence of post-Tertiary movement has been observed both along the trace of the Willow Creek fault (Schneider, 1970, p. 36; Hackett and others, 1960, p. 51-55), which extends eastward from the Jefferson River canyon (Robinson, 1963, p. 13, Pl. 3) to the Bridger Range (Davis and others, 1965a), and along the trace of a small north-trending fault mapped in the bluffs just east of the Madison River and north of the Willow Creek fault (Schneider, 1970, p. 38, Pls. I, II). Other evidence of possible faulting is presented by Robinson (1961, p. 1009-1010) and Hackett and others (1960, p. 50).

Detrital sediments in the bluffs just east of the Madison River were deposited by northeastward-flowing streams and were derived from mountains to the west and southwest of the basin (Schneider, 1970, p. 14). Near the eastern edge of the basin, coarse sediments were derived from sources to the south and east (McMannis, 1955, p. 1413; Glancy, 1964, p. 30).

Eocene and Oligocene rocks, which are rated as having good favorability for uranium deposits in the contiguous western part of the basin, dip under the younger Tertiary rocks in the eastern part of the basin. Although the easternmost subsurface extent of the favorable older Tertiary rocks is not known, these rocks may be present in deep bedrock depressions and may underlie much of the younger strata in the eastern part of the basin. The probable existence of older Tertiary rocks in the subsurface enhances the favorability of the eastern Three Forks basin.

Conclusions

Favorability for uranium deposits in Tertiary rocks of the eastern Three Forks basin is rated moderate. Favorability is not uniform across the eastern part of the basin, but increases from poor, east of the Gallatin River, to moderate, west of the river. West of the Gallatin River, the sandstone content increases westward, evidence of reductant is found both in outcrop and in the subsurface, the favorable lower Tertiary rocks dip under the less favorable upper Tertiary rocks, and anomalously high concentrations of uranium are found in two rock samples. East of the Gallatin River, the Tertiary sequence is very thick in bedrock depressions, the favorable lower Tertiary rocks may be present at depth, and evidence of reductant material was found in one well.

The conclusions are based upon data that vary in type and quality across the basin. Most of the surface data were obtained from excellent outcrops in the Madison Bluffs, near the western part of the basin. Five of the eight sections described in the literature are in the bluffs, and five of the six rock samples were collected from there. East of the bluffs, the basin has few outcrops and was evaluated mainly on the basis of data obtained from well logs and from previous geophysical investigations. Deep wells are evenly spaced in the eastern part of the basin and the quality of well logs is good. Geophysical investigations provided additional information about total thickness of the Cenozoic sedimentary sequence and topography of subjacent pre-Tertiary rocks.

BOULDER RIVER BASIN

Data were obtained from surface studies of 11 localities (Pl. 2), analyses of 18 rock samples and 4 water samples from these localities (App. A), 2 published measured sections (App. B), and cited references.

Favorability Characteristics

The maximum thickness of the Tertiary sequence, in the southern part of the Boulder River basin, is 1,100 ft (Richard, 1966, Table 1, Pls. 5, 6); the average thickness is less than 1,000 ft. The Tertiary rocks lie unconformably on all older rocks, and an unconformity of middle Tertiary age separates Oligocene rocks from Miocene rocks (Richard, 1966, p. 51-54).

Approximately 15 to 30 percent of the sequence is sandstone and conglomerate. Coarse-grained sedimentary rocks average 17 percent (30 percent maximum) of the upper Tertiary measured sections and appear to make up a larger percentage of lower Tertiary rocks. Individual sandstone and conglomerate beds are up to 8 ft thick, but most beds are less than 5 ft thick.

Most sandstones are poorly sorted, medium to very coarse grained, feldspathic to arkosic, and along with the conglomerates, generally permeable. The sandstones and conglomerates contain lithic fragments mainly derived from the Elkhorn Mountains Volcanics, assorted intrusive rocks, and to a lesser extent, quartzitic rocks (Weeks, 1974).

Fine-grained rocks in the sequence are composed mostly of glass shards, and thin beds of volcanic ash were found at locality 347. Iron staining was found in localities 346, 347, and 348; and traces of petrified wood and bones were found at locality 346.

No rock samples from the Tertiary strata contained anomalous equivalent uranium, nor was anomalous radioactivity detected in the Boulder River basin. In addition, none of the water samples analyzed have above average uranium.

The dip of the Tertiary rocks ranges from 0° to 40°. Dips of about 10° are most common, but steeper dips are not unusual. Sedimentary rocks at locality 347 exhibit evidence of several feet of post-Oligocene movement along one or more normal faults.

The Boulder River basin lies between the Boulder batholith and the highly favorable western Three Forks basin. It extends into and receives drainage from a part of the batholith that has many uranium occurrences. The basin was a conduit for eastward transportation of batholithic detritus during Tertiary time.

Conclusions

Favorability for uranium deposits in sedimentary rocks of the Boulder River basin is rated poor because the rocks average less than 1,000 ft thick, sandstone percent is low, sandstone and conglomerate beds are thin, and none of the rock and water samples have anomalous uranium. Proximity of the basin to the Boulder batholith and to the highly favorable part of the Three Forks basin is deemed insufficient to justify a higher rating.

Unfortunately, data obtained from surface studies are representative of only a small part of the Tertiary sedimentary rocks. In the northern part of the basin, Tertiary rocks are not exposed (Pl. 1) and the thickness of Cenozoic rocks is not known.

In the southern part of the basin, only rocks of Miocene and Pliocene age are well exposed. Older Tertiary rocks, which have good favorability in the adjacent Three Forks basin, are poorly exposed and not well represented in the data. The only available subsurface information are thicknesses obtained from geophysical investigations. Consequently, the favorability rating could be applied only to exposures of Tertiary rocks in the southern Boulder River basin.

TOWNSEND AND CLARKSTON BASINS

Oligocene Rocks

Older Tertiary rocks crop out in the western part of the Townsend basin, in the northern part of the Clarkston basin, and along the lower part of Sixmile Creek east of Toston. A small wedge of undifferentiated Tertiary rocks (Pl. 1) contains some rocks of Oligocene age along its western edge (Nelson, 1963, p. J45). No Eocene rocks were identified in either the Townsend or the Clarkston basins.

Data were obtained from surface studies of seven localities (321, 323, 330, 331, 355, 356, 366, Pl. 2), analyses of eight rock samples and one water sample from the study localities (App. A), logs of two water wells (Pl. 2) and five uranium exploration drill holes (Fig. I-2), two measured sections described in the literature (App. B), and cited references.

Favorability Characteristics. In the northern part of the Townsend basin near Winston, Oligocene rocks are more than 2,800 ft thick (Pardee, 1925, p. 27); and in the southeastern part of the basin east of Toston, the Oligocene section may be as much as 2,400 ft (Klemme, 1949, p. 64), or possibly 4,100 ft thick (combined maximum thicknesses of Oligocene formation mapped by Robinson, 1967). In the Townsend basin southwest of Toston, Oligocene rocks have a maximum thickness of 1,000 ft (Freeman and others, 1958, p. 507), although the average thickness is much less. Rocks of equivalent age in the northern part of the Clarkston basin are probably less than 250 ft thick (Robinson, 1967, cross section CC').

Geophysical data (Davis and others, 1963; Kinoshita and others, 1964, 1965) indicate that the Townsend basin is shallow southwest of Toston and deepens northward. Cenozoic sedimentary rocks are as much as 6,300 ft thick under the southern part of Canyon Ferry Lake (Lake Sewell) and have a maximum thickness of about 8,500 ft northeast of Winston. The maximum thickness of rocks that are exclusively of Oligocene age has not been ascertained.

Potential host rocks are mostly tuffaceous or pumiceous, contain less than 10 percent feldspar, range from medium-grained sandstone to conglomerate, and are poorly to moderately sorted. These rocks average approximately 23 percent of the Oligocene section and generally form beds less than 10 ft thick, although beds exposed along Sixmile Creek east of Toston are as much as 70 ft thick (App. B). Although most of the Oligocene beds are relatively impermeable because they are well cemented (loc. 321) or partly clogged with clay (possibly derived from devitrification of volcanic glass), a few beds are clean and permeable (Pardee, 1925, p. 48). Iron staining was found only in locality 330, near Winston.

Organic material is common in the lower part of the section. A few thin lignitic coal beds were found east of Toston near Sixmile Creek (Pardee, 1925, p. 23; Robinson, 1967; loc. 321). Carbonaceous claystone and siltstone were found near Sixmile Creek (Klemme, 1949, p. 193) and in the Clarkston basin (loc. 355). Northeast of Winston, lignites and carbonaceous shales constitute less than 1 percent of the Oligocene section; nonetheless, they form beds up to 18 in. thick (Becraft, 1958, p. 154) and are associated with about 20 radioactivity anomalies (Becraft, 1958, p. 155; Fig. I-2; sample 330-2).

Tuffaceous material ranges from 0 to 100 percent and commonly accounts for more than 50 percent of individual beds. Most of the tuffaceous material is fine grained; a significant exception is a thick lens of coarse eruptive volcanic material near Winston (Pardee, 1925, p. 23). This lens is at least 2,700 ft thick (Pardee, 1925, p. 26) and is composed of tuff or tuffaceous material except for a few thin beds of carbonaceous shale and chert (Becraft, 1958, p. 153).

The Oligocene section rests unconformably on all older rocks. Oligocene rocks are separated from Miocene and younger strata by a disconformity (Pardee, 1925, p. 41; Klemme, 1949, p. 62, 65; Freeman and others, 1958, p. 511, 531; and Robinson, 1967).

The area northeast of Winston contains numerous uranium occurrences (Becraft, 1958, p. 152-159, Pl. 3), and secondary uranium minerals (carnotite and metatorbernite) were identified at five localities. According to Becraft (1958, p. 155-159), attempts were made to strip mine uranium from one of the occurrences. Subsurface occurrences may be indicated by 37 radioactivity anomalies recorded on gamma-ray logs from three nearby uranium exploration drill holes (Table I-3; Fig. I-2).

The equivalent uranium contents of the seven bulk rock samples from Oligocene strata of the Townsend and Clarkston basins generally are much higher than those from the western and south-central basins (Fig. 3); both the mean equivalent uranium value and the mean eU/eTh ratio of these samples are higher than those of any other sample group in the project (Table 3). Two samples (321-1, 330-2), both lignites, contain anomalously high amounts of equivalent uranium. The other carbonaceous sample (355-1), a claystone, contains 12 ppm equivalent uranium, but its eU/eTh ratio (0.97) is less than 1.0. One carbonaceous sample (321-1) is low in equivalent uranium relative to chemical uranium and may be in disequilibrium (Fig. K-1). The other four samples (303-1, 330-3, 330-4, 331-1) are from tuffaceous and pumiceous sedimentary rocks. Three are samples of sandstone that is considered to be potential host rock. Although the equivalent uranium content of the four samples is high (mean eU = 17 ppm), the values are attributed to the large proportion of silicic volcanic material in these rocks. The high uranium contents are not believed to be evidence of secondary enrichment in uranium because the eU/eTh ratios of these samples are not correspondingly high. Sample 330-4 is high in equivalent uranium relative to chemical uranium and may be in disequilibrium (Fig. K-1).

Possible disequilibrium indicated by two samples and the obvious concentration of uranium in carbonaceous rocks are evidence of the mobility of uranium in the Oligocene rocks but do not indicate secondary concentration of uranium in the coarser sedimentary rocks which are generally considered to be potential host rocks for uranium deposits. Chemical data indicate that uranium was leached from tuffs and pyroclastic sedimentary rocks and was concentrated in carbonaceous rocks.

The Oligocene sediments generally dip 15° to 30°. Normal faults are common in the Tertiary section east of Toston (Pardee, 1925, p. 32, Fig. 4; Klemme, 1949, p. 111-114; Lorenz and McMurtrey, 1956, Fig. 35) and northeast of Winston, along the east side of the Spokane Hills (Mertie and others, 1951, p. 35; Becraft, 1958, p. 154; loc. 366).

The Elkhorn Mountains, which separate the Townsend basin from the Boulder batholith to the west, have formed a barrier to eastward drainage from the batholith since early Tertiary time. Detrital material found in outcrops of Tertiary rocks in the basin was not eroded from the batholith but was derived from sources within and immediately adjacent to the basin. For example, Oligocene sedimentary rocks east of Toston are derived predominantly from Belt Series rocks (Klemme, 1949, p. 64; Robinson, 1967), and the nonvolcanic rocks east and north of Winston are composed of detritus from Elkhorn Mountain volcanics and from pre-Tertiary rocks of the Spokane Hills (Mertie and others, 1951, p. 32, 33; Freeman and others, 1958, p. 510). In most localities, evidence indicates that detritus in the Oligocene sedimentary rocks was deposited by easterly-flowing streams.

Conclusions. Favorability for uranium deposits in Oligocene rocks of the Townsend and Clarkston basins is rated moderate. A favorable sedimentary sequence (Table 1) was not found, and the sandstone and conglomerate show little evidence of secondary enrichment in uranium. Nevertheless, a moderate rating has been assigned because of many uranium occurrences, numerous radioactivity anomalies, and a few uranium minerals in and near the lignites and other carbonaceous beds. Uranium probably was leached from siliceous tuffs and tuffaceous and pumiceous sedimentary rocks and was concentrated in the lignites and other carbonaceous beds. Although permeability of near-surface sandstone and conglomerate is generally low, thick and permeable beds of potential host rocks may be downdip in the deeper parts of the Townsend basin. The possibility of permeable beds in the subsurface and the demonstrated mobility of uranium in Oligocene rocks suggest that uranium deposits may occur at depth in coarse-textured strata even though no direct evidence of such deposits has been found.

With the exception of thickness estimates based on geophysical investigations and subsurface radiometric information from uranium exploration drill holes northeast of Winston, little is known of Oligocene rocks in the subsurface. These conclusions are, therefore, valid only for outcrops of Oligocene rocks in the Townsend and Clarkston basins.

Miocene and Pliocene Rocks

Rocks of Miocene and Pliocene age underlie the eastern two-thirds of the Clarkston basin and most of the Townsend basin east of the Missouri River. Rocks of undifferentiated Tertiary age that crop out between Winston and the Missouri River are probably of Miocene and Pliocene age (Freeman and others, 1958, p. 512).

Data were obtained from surface studies of seven localities (320, 322, 327, 328, 329, 354, 381, Pl. 2), analyses of nine rock samples from the study localities (App. A), two measured sections described in the literature (App. B), and cited references.

Favorability Characteristics. Miocene and Pliocene rocks are predominantly fanglomerate near the east edge of the basin and become finer basinward (Robinson, 1967; Nelson, 1963, p. J41). The rocks also seem to become finer grained downward, although gravel is abundant in the basal 200 ft (Freeman and others, 1958, p. 531). The proportion of sandstone and conglomerate in measured sections ranges from 4 percent (loc. 328) to 65 percent near the east edge of the basin (sec. 61, App. B). Coarser sedimentary rocks form beds that are generally less than 50 ft thick except near the edge of the basin where the beds are as thick as 470 ft (sec. 61).

Sandstones and gravels, although mostly calcareous, are generally open textured and permeable (Pardee, 1925, p. 48). The sandstones are medium to coarse grained and are moderately to well sorted. Feldspar generally makes up less than 10 percent of the detrital sedimentary rocks. Detrital material in these rocks was predominantly derived from nearby pre-Tertiary rocks in the Big Belt Mountains to the east (Pardee, 1925, p. 24, 26; Klemme, 1949, p. 65, 131; Mertie and others, 1951, p. 37; Nelson, 1963, p. J42; Robinson, 1967).

The finer-grained rocks are tuffaceous throughout the Miocene and Pliocene section. Traces of fossilized bones were found in two localities and iron staining was found in one locality.

Miocene rocks are as much as 2,000 ft thick in the Clarkston basin, 4,000 ft thick east of Toston, and farther north may be as much as 6,000 ft thick (Robinson, 1967). Miocene and Pliocene sediments lie disconformably on all older formations (Pardee, 1925, p. 41; Klemme, 1949, p. 65; Freeman and others, 1958, p. 511; Robinson, 1967).

Of the nine rock samples, only sample 320-1 is anomalously high in equivalent uranium content. The mean equivalent uranium value and the mean eU/eTh ratio are slightly higher in these samples than in those from most of the basins (Table 3). If sample 320-1, which is from a vein of banded chalcedony in siltstone and which is not representative of potential host rocks, is excluded, the mean equivalent uranium value and the mean eU/eTh ratio of the remaining samples are lower than those from most of the basins.

Younger Tertiary strata generally dip 10° to 20° (Pardee, 1925, p. 31, 32; Freeman and others, 1958, p. 527; Nelson, 1963, p. J49; Robinson, 1967). Normal faulting is common in the Tertiary section east of Toston and at locality 328.

Conclusions. Favorability for uranium deposits in Miocene and Pliocene rocks in the Townsend and Clarkston basins is rated poor because the rocks contain no known uranium occurrences or radioactivity anomalies; only one sample contained anomalously high concentrations of uranium; and detrital feldspar, iron staining, and reductants are rare.

HELENA BASIN

The Helena basin (also known as the Prickly Pear basin) is underlain by Tertiary sedimentary rocks that form a benchland in the eastern one-third of the basin. Drilling indicates that these rocks underlie alluvium in the central and western parts of the basin (Pardee and Schrader, 1933).

Outcrops of Tertiary sedimentary rocks between Hauser Lake and Lake Helena are of Oligocene age (Lorenz and Swenson, 1951, p. 16). The outcrop at locality 322 (Pl. 2) is presumed to be of Oligocene age because it is lithologically similar to lower Oligocene rocks near Winston.

Data were obtained from surface studies of four localities (Pl. 2), analyses of ten rock samples from these localities (App. A), analysis of one water sample from a fifth locality (357), and published reports.

Favorability Characteristics

Sandstone and conglomerate, which constitute 56 percent of the rocks at locality 359, form beds that average about 10 ft thick and reach a maximum thickness of more than 40 ft. The sandstone ranges from medium to coarse grained and is poorly to very poorly sorted. Artesian and flowing wells indicate that permeability is high in the northern half of the basin where coarser sedimentary rocks commonly lie between impermeable beds. At the south margin of the valley, however, Tertiary beds yield only meager amounts of water (Lorenz and Swenson, 1951, p. 1, 28) and are probably relatively impermeable.

Where not pumiceous, the coarser sediments are feldspathic or arkosic. The finer sediments are tuffaceous throughout the Tertiary section (Lorenz and Swenson, 1951, p. 16; Becraft, 1958, p. 160-161). Petrified wood, carbonaceous shale, and lignite are found at localities 359 and 360. Iron staining is found at all surface study localities, but unit 2 of locality 358 appears to be bleached (reduced?) where the radioactivity is highest.

Tertiary sedimentary rocks between Hauser Lake and Lake Helena are probably less than 1,000 ft thick (Davis and others, 1963, Sheet 1, cross section AA'; Burfeind, 1967, Pl. 3, cross section KK'), but gradually thicken to the south and rapidly thicken to the west. The deepest part of the basin, 3 to 4 mi north of East Helena, is filled with 4,000 ft (Burfeind, 1967, p. 69) to 6,000 ft (Davis and others, 1963, p. 3) of Cenozoic sediments, most of which are Tertiary in age.

Four uranium occurrences (no. 7, Fig. 1), reported by Becraft (1958, p. 160-161), are radioactivity anomalies in carbonaceous shales that crop out between Lake Helena and Hauser Lake. During this study, several radioactivity anomalies were found in sandstones that were sampled in the same general area.

Equivalent uranium contents of the ten rock samples from the Helena basin are high compared with those of the other basins in the project area (Fig. 3). The mean equivalent uranium content of these samples is the highest of any of the basins (Table 3). Four samples (358-1, 359-3, 359-4, 360-1) from three localities contain anomalously high amounts of uranium. Furthermore, three samples (359-1, 359-3, 360-3) from two localities contain anomalously high concentrations of one or more favorable geochemical indicators.

Oligocene sedimentary rocks generally dip basinward at 8° to 15°. Between Hauser Lake and Lake Helena, the beds are gently folded along an axis which strikes slightly east of north and plunges gently to the south. Evidence of small-scale faulting in Tertiary beds was observed both at locality 332 and in outcrops between Lake Helena and Hauser Lake.

The Helena basin lies immediately north of the Boulder batholith. Prickly Pear and Tenmile Creeks, which flow north into the Helena basin, drain much of the northern third of the batholith where numerous uranium occurrences are located. This north-flowing drainage has probably transported batholithic detritus into the Helena basin since, perhaps, late Eocene time, when the streams unroofed the batholith. The batholithic detritus probably was an important source of the uranium found in Oligocene sedimentary rocks of the Helena basin.

Conclusions

Favorability for uranium deposits in Oligocene rocks of the Helena basin is rated good because of the favorable character of the sedimentary rocks, proximity to and drainage from the Boulder batholith, and the presence of several radioactivity anomalies, ample reductant, abundant tuffaceous material, and anomalously high concentrations of uranium in four samples.

The favorability rating is mainly based upon data collected from the study localities, four of which are clustered in the belt of outcrops between Lake Helena and Hauser Lake (Pl. 2). Tertiary rocks are covered by Holocene alluvium in the western two-thirds of the basin and are poorly exposed in the eastern third of the basin. The only useful subsurface data were thickness estimates based upon geophysical investigations. Consequently, the favorability rating is applicable only to exposed or near-surface Oligocene rocks.

SILVER CITY BASIN

The Silver City basin (also known as the Little Prickly Pear basin or the Silver basin) is presumably filled with Tertiary sedimentary rocks that are covered by Holocene alluvium (Pardee and Schrader, 1933, p. 14). No outcrops of Tertiary rocks and no radioactivity anomalies were found. The only available data were from the log of a single water well (Pl. 2), which may or may not have penetrated Tertiary rocks. The 168-ft water well penetrated only 3 ft of potential host rocks and bottomed in 4 ft of ash. For these reasons a meaningful favorability rating cannot be assigned.

SMITH RIVER BASIN

Data were obtained from surface studies of 15 localities (Pl. 2), analyses of 7 rock samples and 2 water samples (App. A), logs of 1 water well and 1 petroleum test well (Pl. 2), and cited references.

Favorability Characteristics

The Tertiary rocks that underlie the Smith River basin are of Miocene age and are predominantly composed of buff-colored tuffaceous siltstone and vitric tuff. Rhyolitic glass shards, which make up 80 to 85 percent of the rock, appear to have been deposited as ash that was reworked locally by mud flows and streams. The ash was probably derived from volcanic vents in the basin and in the Castle Mountains east of the basin (Koerner, 1939; Tanner, 1949; Wolfe, 1964; Birkholz, 1967; Phelps, 1969).

A few ash-flow tuffs and stream deposits are interbedded with the tuffaceous siltstone and tuff. The ash-flow tuffs are pumiceous and contain high concentrations of uranium. However, the eU/eTh ratio is low and the uranium is believed to be of primary origin. These tuffs are permeable and form beds that average less than 8 ft thick. Although the ash-flow tuffs could serve as potential host rocks, they make up less than 1 percent of Miocene strata. No evidence of secondary enrichment in uranium was found.

Fluvial deposits are the only other possible host rocks of Tertiary age in the Smith River basin. These rocks, predominantly conglomerate and sandstone, make up less than 5 percent of the outcrops of Miocene age. The conglomerate generally is carbonate cemented in outcrop and forms resistant beds that range from 1 to 27 ft in thickness but that average less than 5 ft thick. Clasts in the conglomerate are derived from

Precambrian and Paleozoic rocks that crop out in the surrounding mountains. The sandstones are poorly to well indurated, poorly to moderately sorted, medium to very fine grained, and locally calcareous. They form beds that range from 0.5 to 5 ft in thickness.

The sandstones and conglomerates are generally permeable, contain little feldspar, and are not iron stained. No organic material or reductant was found in the coarse-grained rocks, but vertebrate fossils are common in impermeable tuffaceous siltstone and tuff, which make up most of the sequence.

The Miocene section is probably less than 500 ft thick in most parts of the basin but is about 1,000 ft thick in the broadest part of the basin west of the town of White Sulphur Springs (petroleum test well 6, App. G; Wolfe, 1964, p. 496; Groff, 1965, p. 13). The Tertiary rocks lie unconformably on all older rocks and are divided by an unconformity of middle Miocene age (Koerner, 1939, p. 1).

Samples 334-1 and 339-1, of potential host rocks, and sample 335-1, of tuffaceous siltstone, all have low equivalent uranium contents and eU/eTh ratios (Fig. 2; Table 3; App. C). Rock sample 335-1, however, contains an anomalously high concentration of niobium (App. E), a favorable geochemical indicator.

Miocene rocks generally dip 3° to 10°, although Birkholz (1967, p. 28) recorded dips as much as 14°. A few post-Miocene faults are known to cut the Tertiary rocks (Klemme, 1949, p. 50; Birkholz, 1967, p. 46-48).

The Smith River basin contains no Tertiary rocks known to be older than early Miocene age and is far removed from intrusives known to contain significant amounts of uranium.

Conclusions

Favorability is poor for potential uranium deposits in Tertiary rocks of the Smith River basin. The sedimentary rock sequence is not favorable, no nearby plutonic source of uranium can be identified, and analyses of rock samples reveal low eU/eTh ratios.

Data upon which the rating is based are mostly derived from the northern part of the basin (Pl. 2). Outcrops are rare and very small elsewhere in the basin. However, other geologic studies (McGrew, 1974a, 1974b, 1974c, 1974d) indicate that Miocene rocks in the southern part of the basin are thin and do not significantly differ in character from those in the northern part.

SOUTH-CENTRAL BASINS

by

J. W. Robins

The south-central part of the project area has 14 basins (Fig. 4), which are discussed in an approximate north-to-south order. Some basins have been grouped together for discussion.

JEFFERSON RIVER, BEAVERHEAD RIVER, AND LOWER RUBY RIVER BASINS

Tertiary rocks in the Jefferson River, Beaverhead River, and Lower Ruby River basins are the best exposed and the most completely studied rocks of the south-central basins. In addition, the Tertiary section is thick; geophysical investigations indicate that the maximum thickness of Cenozoic basin deposits is about 4,000 ft in the Beaverhead River and Lower Ruby River basins, is between 4,000 and 5,500 ft in the Jefferson River basin, and increases to 7,800 ft at the junction of the three basins south of Twin Bridges (Burfeind, 1967, p. 51-54). The following favorability discussions are organized on the basis of recently established age subdivisions for Tertiary rocks in these basins.

Eocene and Oligocene Rocks

Eocene and Oligocene sedimentary rocks in the Jefferson River, Beaverhead River, and Lower Ruby River basins were called the Renova Formation and mapped by Kuenzi and Fields (1971), Petkewich (1972), and Hoffman (1972). Data were obtained from surface studies of 8 localities (201, 203, 205, 206, 219, 224, 230, 231, Pl. 2), analyses of 12 rock samples from these localities (App. A), a lithologic log of 1 petroleum test well (no. 9, App. G, Pl. 2), 15 measured sections described in the literature (App. B), and cited references.

Favorability Characteristics. Rocks of the lower Tertiary sequence have a maximum stratigraphic thickness of 3,500 ft in the Jefferson River basin (Kuenzi and Fields, 1971, p. 3385) and 2,400 ft in the Lower Ruby River basin (Petkewich, 1972, p. 24). In the northern part of the Beaverhead River basin, a petroleum test well (no. 9, App. G) penetrated 1,725 ft of sedimentary rocks that are believed to be of Eocene and Oligocene age. Angular unconformities bound the sequence above and below.

Estimations of sandstone percent for the rocks in this group of basins are: less than 30 percent in the Jefferson River basin (Kuenzi and Fields, 1971, p. 3379), 18 percent in the Lower Ruby River basin (Petkewich, 1972, p. 30), 25 percent in part of the Beaverhead River basin (Hoffman, 1972, p. 19), and 28 percent in petroleum test well 9. The lower Tertiary section also contains fine-grained permeable sandstones that are not represented in the estimated sandstone percent values.

Potential host rocks range from medium-grained sandstone to conglomerate. The rocks are generally arkosic or feldspathic, are poorly sorted, and form beds that average about 19 ft in thickness and range from 0 to 47 ft thick.

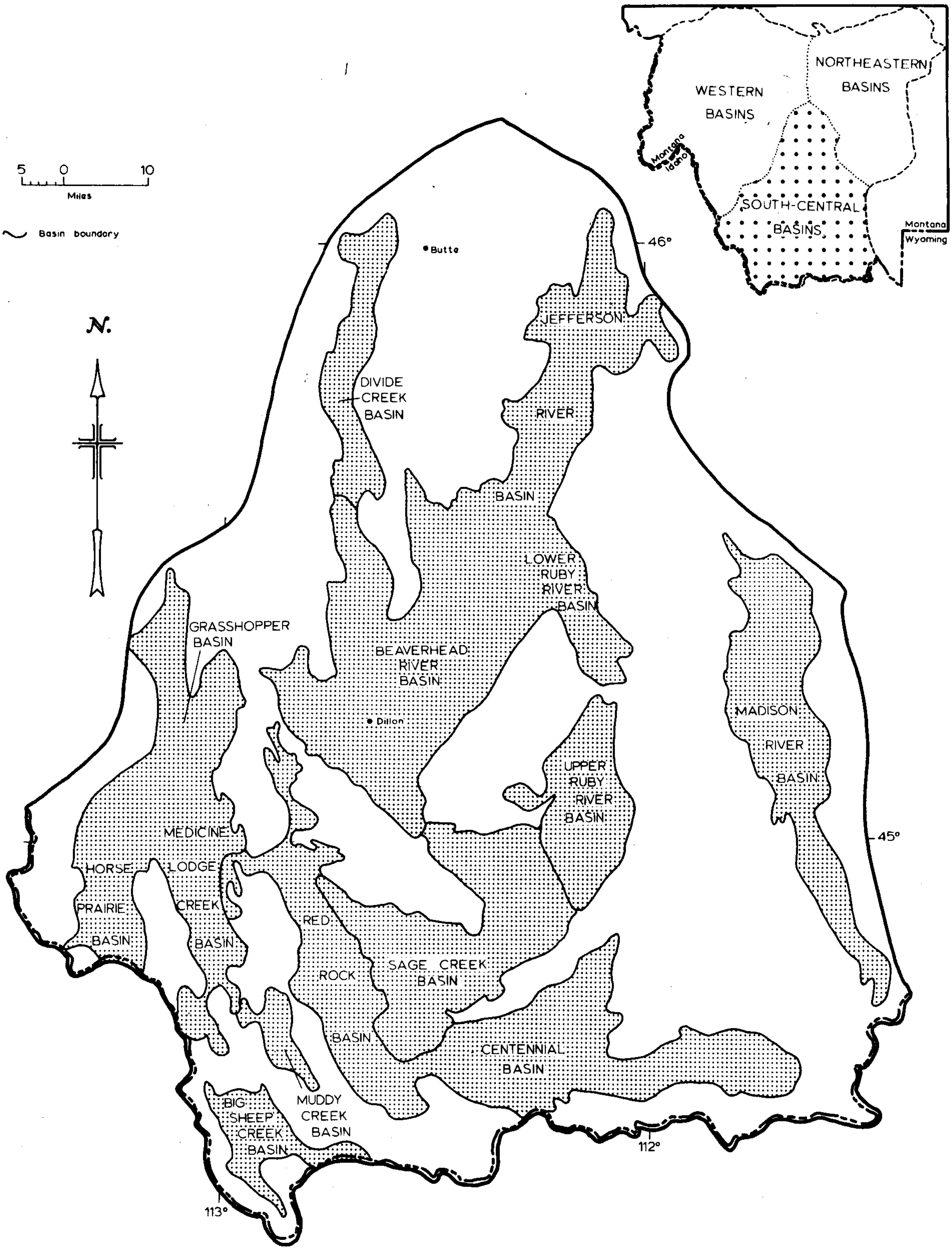

Figure 4. Locations and names of Tertiary basins in the south-central part of the study area.

In some areas the beds are permeable and in most areas the beds are iron stained. Carbonaceous material was found in trace amounts at two localities. Tuffaceous rocks commonly overlie the potential host rocks.

One uranium occurrence (no. 4, Fig. 1; loc. 205, Pl. 2) is known in this group of basins. No uranium minerals were identified at this occurrence.

The mean equivalent uranium content (5.3 ppm) of the rock samples from the three basins (excluding volcanic samples 224, 250, 231, App. A) is more than one standard deviation higher than the mean content (2.9 ppm, Fig. 3) of all rock samples from the south-central basins. Two samples (205-2, 219-1, Fig. 5) contain anomalous equivalent uranium. These values are supported by higher-than-average (more than one standard deviation above mean) concentrations of gallium, lithium, and yttrium in sample 205-1, and an anomalous (more than two standard deviations above mean) amount of vanadium in sample 219-1 (App. E).

The uraniferous Boulder batholith is the major source of sediment for the Tertiary rocks in the northern part of the Jefferson River basin. Tertiary sedimentary rocks in the southern part of the Jefferson River basin and in the Lower Ruby River and Beaverhead River basins are derived mainly from gneisses and schists of Archean age which have a lower mean uranium content than the granitic rocks of the Boulder batholith.

Conclusions. The favorability for uranium deposits in Eocene and Oligocene rocks in the Jefferson River, Beaverhead River, and Lower Ruby River basins is rated moderate because the sandstone content is adequate, both the characteristics of the potential host rocks and the chemical characteristics are favorable, and carbonaceous material is present. The lower Tertiary rocks are more favorable in the northern Jefferson River basin than in the remainder of the south-central basins. Paleodrainage in the northern part of the basin was from the Boulder batholith, which has an unusually high number of uranium occurrences. In the remainder of these basins, the paleodrainage was from Precambrian schists and gneisses, which are less favorable as source rocks than the batholith.

Miocene and Pliocene Rocks

Kuenzi and Fields (1971) named the Miocene and Pliocene rocks in the Jefferson River basin the Sixmile Creek Formation. Data were obtained from surface studies of 12 localities (202, 204, 214-218, 220, 237, 259-261, Pl. 2), analyses of 15 rock samples and 2 water samples from these localities (App. A), logs of 2 water wells and of 2 petroleum test wells (nos. 9, 10, Pl. 2), 13 measured sections described in the literature (App. B), and cited references.

Favorability Characteristics. The maximum stratigraphic thickness of Miocene and Pliocene rocks is estimated to be 2,400 ft in the Jefferson River basin (Kuenzi and Fields, 1971, p. 3385) and 3,100 ft in the Lower Ruby basin (Petkewich, 1972, p. 59). Neither water wells nor petroleum test wells penetrated more than 558 ft of these rocks.

Sandstone and conglomerate constitute approximately 79 percent of the Miocene and Pliocene sequence in the Jefferson River basin (Kuenzi and Fields, 1971, p. 3383) and 78 percent in the Lower Ruby River basin (Petkewich, 1972, p. 62-63). Tuffaceous material generally is present throughout the section.

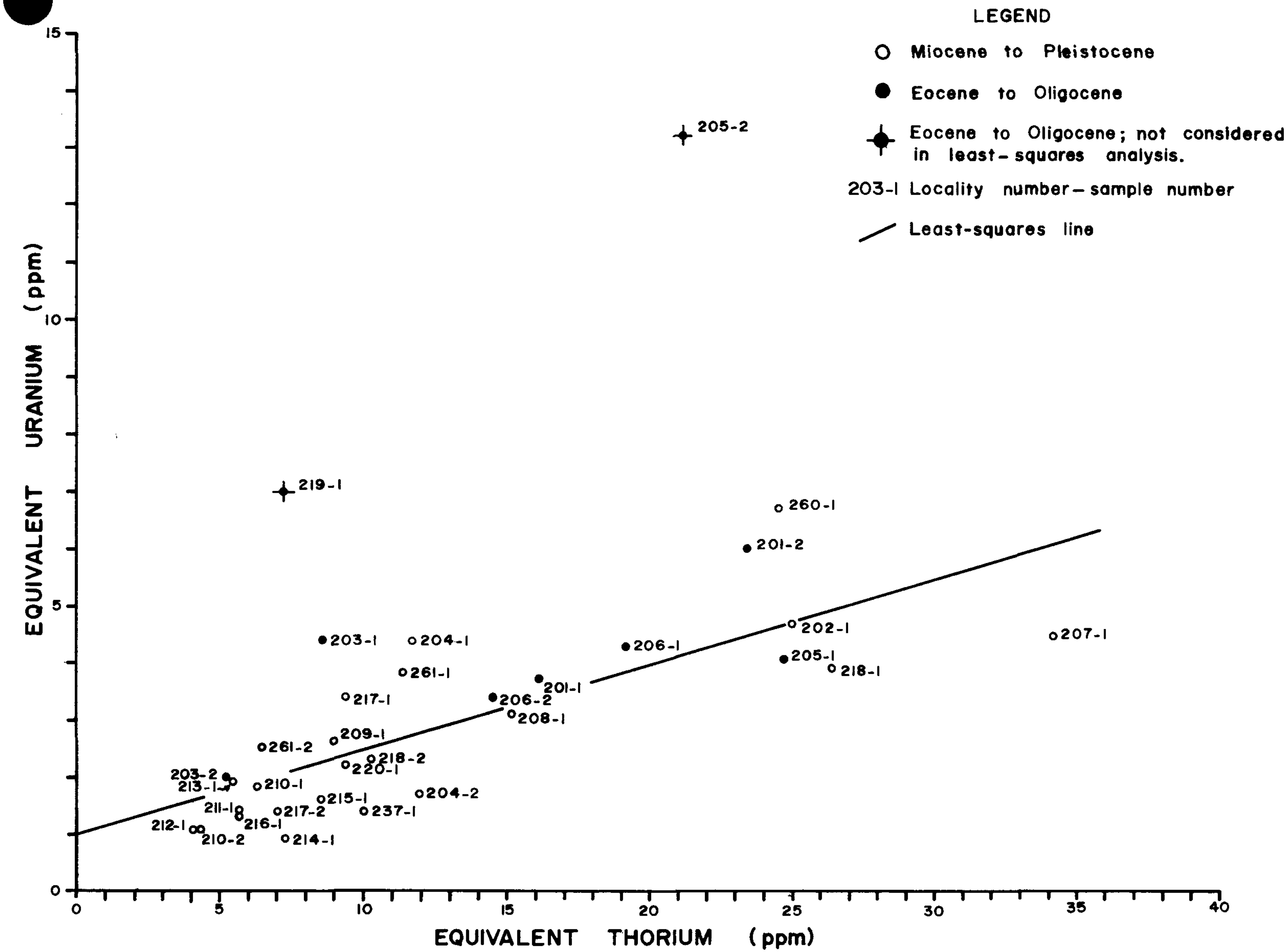

Figure 5. Plot of equivalent uranium versus equivalent thorium for samples from selected central basins. (Includes samples from Jefferson River, Beaverhead River, Lower Ruby River, and Divide Creek basins; excludes volcanic samples 224-1, 230-1, and 231-1)

Potential host rocks are medium-grained sandstone to conglomerate, feldspathic or arkosic in most localities, predominantly poorly sorted, and very permeable. (In fact, the Sixmile Creek Formation may be too permeable to have impeded any fluids that may have moved through it, and few permeability barriers bound the potential host rocks.) The potential host rocks have relatively low dips, which average 10° (Kuenzi and Fields, 1971, p. 3385).

Trace amounts of carbonaceous material were found in two localities and were reported in one published measured section.

Chemical data yield no positive indications of favorability. Equivalent uranium contents of two samples (204-1, 260-1) are slightly high relative to equivalent thorium, when compared to the contents of all other samples in the sample group (Fig. 5). Sample 260-1 is high in equivalent uranium primarily because of abundant tuffaceous detritus. Water sample 259-1, from the same vicinity as sample 260-1, has a U_3O_8 value of 10 ppb. Although this is the highest value obtained from a water sample in the south-central basins, it is not considered anomalously high when compared to the mean (7 ppb) of all samples (App. F).

The Boulder batholith supplied most of the detrital sediments deposited in the northern Jefferson River basin during Miocene and Pliocene time. The southern Jefferson River basin, the Lower Ruby River basin and the Beaverhead River basin, however, received detrital sediments from gneisses and schists of Archean age.

Conclusions. Favorability for uranium deposits in Miocene and Pliocene rocks in the Jefferson River, Beaverhead River, and Lower Ruby River basins is rated poor because the rocks are very permeable, are mostly sandstone, have no positive chemical indicators, and contain little carbonaceous material.

Pliocene and Pleistocene Rocks

Data were obtained from surface studies of four localities (207, 211, 212, 213, Pl. 2), analyses of four rock samples from these localities (App. A), one petroleum test well log (no. 11, Pl. 2), and cited references.

Because deposition was continuous from Miocene to Pleistocene time in the Jefferson River and contiguous basins, the Pliocene-Pleistocene boundary cannot be readily delineated; therefore Pliocene and Pleistocene rocks are treated here as one sequence. The Pliocene-Pleistocene sedimentary sequence is unconsolidated and very permeable; uranium-bearing solutions would have passed directly into underlying rocks. The average uranium values of samples from three localities is less than 2 ppm (locs. 211, 212, 213; App. C). A sample from locality 207 (Pl. 2) has an equivalent uranium content of 4.5 ppm, but the unusually high equivalent thorium content (34.3 ppm) indicates a probable local concentration of heavy minerals. On the basis of these findings, the favorability for uranium deposits in these rocks is rated poor.

DIVIDE CREEK BASIN

Data were obtained from surface studies of three localities (Pl. 2), analyses of four rock samples from these localities (App. A), logs of two water wells (Pl. 2), and cited references.

Tertiary sedimentary rocks in the Divide Creek basin are predominantly of Miocene and Pliocene age (Smedes, 1967). Oligocene rocks crop out locally along the western edge of the basin (R. W. Fields, 1976, personal commun.) and may underlie most of the younger Tertiary sequence.

Favorability Characteristics

Basin-fill deposits are indicated by geophysical investigations to be at least 2,800 ft thick (Burfeind, 1967, Pls. 1, 2, cross section GG'). The 400 ft of deposits penetrated by the two water wells contains about 25 percent sandstone and conglomerate. Potential host rocks at two localities range from medium-grained sandstone to conglomerate and are poorly sorted, feldspathic, permeable, and iron stained. Detrital material in a third locality (210) is primarily limestone and quartzite. Possible host rocks form beds that are generally 5 to 10 ft thick and rarely more than 20 ft thick. Tuffaceous material is interbedded with the potential host rocks. The Tertiary rocks examined contain no reductants and, because few impermeable barriers are above or below the beds of potential host rocks, are generally too permeable to have retained uraniferous fluids. The average equivalent uranium content (2 ppm) of rock samples from the Divide Creek basin is below the mean (2.9 ppm) for all rock samples from the south-central basins. No anomalous uranium values were found (Fig. 5).

Conclusions

Favorability for uranium deposits in Tertiary rocks of the Divide Creek basin is rated poor because the rocks are too permeable, contain no reductants, and have no favorable chemical indicators. The data upon which the rating is based represent only the upper few hundred feet of Miocene and Pliocene rocks in the basin. In neighboring basins, Eocene and Oligocene rocks are more favorable than younger Tertiary rocks. Although the presence of Oligocene sedimentary rocks in the basin and the proximity of the basin to the Boulder batholith both enhance the favorability rating, the available evidence is not adequate to warrant a rating of moderate.

UPPER RUBY RIVER BASIN

The Upper Ruby River basin contains Tertiary sedimentary rocks that range in age from Paleocene[a/] to Pliocene. The rocks have a maximum total thickness of 7,000 ft (Burfeind, 1967, p. 71), are cut by post-Tertiary

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[a/] Locality 241 in this basin contains rocks of Upper Cretaceous and Paleocene age and is discussed with the rocks of this age range in the section on the Red Rock and Centennial basins.

faults near the edges and the center of the basin, and dip 0° to 15°. Although these rocks are subdivided on the basis of age for the following discussion, the maximum thickness of the rocks in each subdivision has not been determined.

Eocene and Oligocene Rocks

Sedimentary rocks of Eocene and Oligocene age were named the Passamari Formation by Dorr and Wheeler (1964). Data were obtained from surface studies of one locality (242, Pl. 2), analyses of two rock samples from this locality (App. A), logs of two uranium exploration drill holes (nos. 19, 21, Fig. I-3), one measured section described in the literature (sec. 38, App. B), and published reports.

Favorability Characteristics. Exposures of the Passamari Formation are predominantly composed of lacustrine sediments. Sandstone content of these rocks is low. The few potential host rocks in outcrops of the formation are medium-grained sandstones that are moderately sorted, permeable, and commonly iron stained. They form beds that range from 2 to 13 ft in thickness. Traces of carbonaceous material are found in both fine- and coarse-grained sedimentary rocks, and tuffaceous beds overlie beds of potential host rocks. Although no feldspar was found in outcrop, two beds of medium-grained feldspathic sandstone, each approximately 20 ft thick, were identified from examination of drill cuttings from the interval between 300 and 450 ft in uranium exploration test well 21 (Fig. I-3).

No anomalous chemical values were found in the two rock samples collected from locality 242 (samples 242-1, 242-2, Fig. 6), but a highly anomalous radioactive interval was detected in the gamma-ray log of uranium exploration drill hole 21 (Table I-4). The anomalous interval may not be representative of the subsurface portions of the Passamari Formation throughout the basin, however, because hole 21 is near a late Cenozoic rhyolite plug, which may have caused the alteration and secondary enrichment in uranium of the adjacent upper Tertiary sedimentary rocks.

The Passamari Formation was deposited unconformably on all older rocks. Detrital sediments in the formation were derived from Precambrian gneiss and schist, which surround the Upper Ruby River basin. These Precambrian rocks have a low uranium content (mean eU_3O_8 content = 2.1 ppm, Malan and Sterling, 1970, Table 6) and are not favorable sources for uranium.

Conclusions. Favorability for uranium deposits in outcrops of the Passamari Formation (Eocene and Oligocene) of the Upper Ruby River basin is rated poor because the sandstone content is low and no favorable chemical indicators were identified. An anomalously radioactive interval and some feldspathic beds, which are found in the subsurface and which normally indicate favorability, are not deemed sufficient to raise the favorability rating.

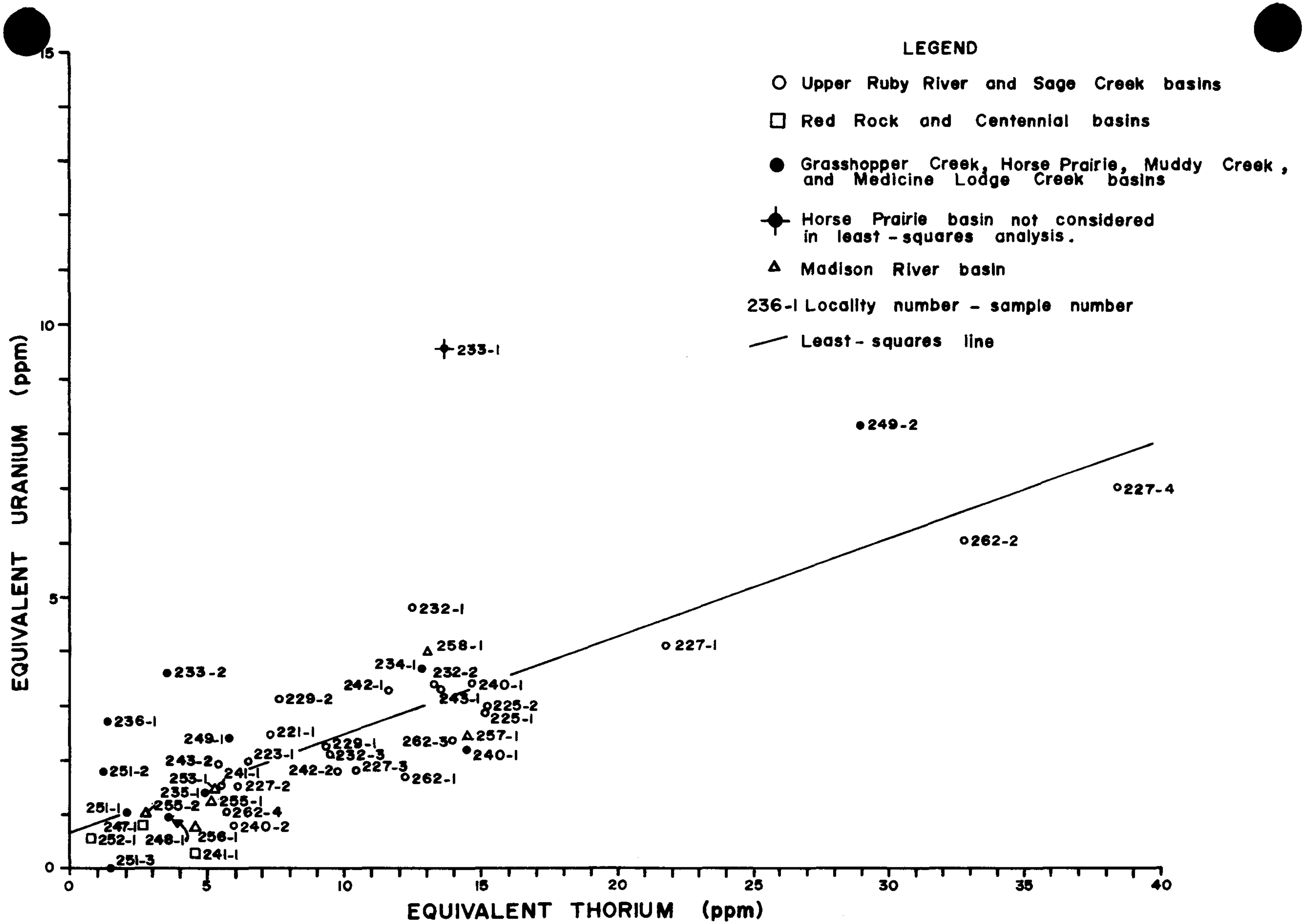

Figure 6. Plot of equivalent uranium versus equivalent thorium for samples from selected southern basins. (Includes samples from Upper Ruby River, Sage Creek, Red Rock, Centennial, Grasshopper Creek, Horse Prarie, Medicine Lodge Creek, Muddy Creek, and Madison River basins; excludes hydrothermally-altered samples and samples of probable volcaniclastic origin [222-1, 238-1, 239-1, 245-1-250-1, and 254-1])

Miocene and Pliocene Rocks

Miocene and Pliocene sedimentary rocks in the Upper Ruby River basin were called the "Madison Valley equivalent" by Dorr and Wheeler (1964, p. 308). Data were obtained from surface studies of six localities (221, 222, 223, 238, 239, 240, Pl. 2), analyses of seven rock samples from these localities (App. A), logs of eight uranium exploration drill holes (nos. 15-18, 20, 22-24, Fig. I-3), four measured sections described in the literature (secs. 37, 39-41, App. B), and published reports.

Favorability Characteristics. Potential host rocks range from medium-grained sandstone to conglomerate, which together make up 38 percent (lower member of the Madison Valley equivalent, sec. 39, App. B) to 83 percent of the Miocene and Pliocene sections. The sandstones contain little feldspar, are poorly sorted and permeable, and, along with the conglomerates, are iron stained in some places. Many potential host rock beds are more than 20 ft thick. Impermeable barriers are present between some sandstone and conglomerate beds. Tuffaceous material is abundant in the upper member of the Madison Valley equivalent (Dorr and Wheeler, 1964, p. 305), and carbonaceous material was found between the depths of 600 and 635 ft in uranium exploration drill hole 15.

One uranium occurrence (no. 8, Fig. 1) and four surface radioactivity anomalies (Fig. I-3) have been reported for these rocks. Four subsurface radioactivity anomalies were recorded on gamma-ray logs of uranium exploration drill holes 16, 20, and 23 (Table I-4).

Miocene and Pliocene sedimentary rocks are altered near their contact with rhyolite and basalt extrusives of post-early Pliocene age. The uranium occurrence, two study localities at the occurrence (222, 238), and one locality nearby (239) are within the zone of alteration. Although all three rock samples from these localities contain anomalously high amounts of uranium (up to 107 ppm eU), the data from these samples are not considered representative of the Miocene and Pliocene rocks in the Upper Ruby River basin and were not used to evaluate favorability. Other samples from the Madison Valley equivalent contain no anomalous chemical values.

Conclusions. Favorability for uranium deposits in Miocene and Pliocene rocks in the Upper Ruby River basin is rated moderate because the sand percent is favorable, potential host rocks are present, and a few surface and subsurface radioactivity anomalies have been reported.

SAGE CREEK BASIN

Tertiary sedimentary rocks in the Sage Creek basin range from Eocene to Pliocene in age, but, because of their similarity, they are treated as a group in the following discussion. Data were obtained from studies of 7 localities (Pl. 2), analyses of 18 rock samples and 2 water samples from the study localities (App. A), logs of 2 water wells (Pl. 2), 1 measured section described in the literature (sec. 42, App. B), and published reports.

Favorability Characteristics

The maximum aggregate thickness of the three Tertiary formations mapped in the Sage Creek basin by Scholten and others (1955, Pl. 1, p. 369) is 3,400 ft. The total thickness of these rocks in any single place within the basin is unknown. Neither of the two water wells completely penetrates the Tertiary section.

Potential host rocks are conglomerates and medium- to coarse-grained sandstones that make up 10 to 61 percent of the Tertiary section. Individual beds generally are more than 20 ft thick and commonly are iron stained. Siltstones predominate in the lower Tertiary section.

Tuffaceous material was found above potential host rocks throughout the sequence and is most abundant in Miocene and Pliocene sedimentary rocks. Trace amounts of carbonaceous material were found at two localities. None of the sources of detrital sediments are granitic.

Four rock samples contain more than 4 ppm equivalent uranium. Only sample 232-1 is high in equivalent uranium compared to equivalent thorium (Fig. 6). The sample was collected from a locality adjacent to the rhyolitic Cook Ranch volcanics of Oligocene age (Scholten and others, 1955, Pl. 1) and may be slightly enriched in uranium but is not anomalous. Samples 227-1, 227-4, and 262-2 are tuffaceous sandstones and contain relatively high levels of both thorium and uranium (Fig. 6). The uranium and thorium contents of these three samples probably result from a high content of silicic volcanic detritus in the sandstones and are not evidence of secondary enrichment in uranium.

Conclusions

Favorability for uranium deposits in Tertiary rocks of the Sage Creek basin is rated poor. Although the sandstone percent is favorable and potential host rocks are present, the poor rating is assigned because granitic source rocks, anomalously high equivalent uranium values, and uranium occurrences are lacking in the basin and reductants are scarce.

RED ROCK AND CENTENNIAL BASINS

Data were obtained from surface studies of two localities (Pl. 2), analyses of two rock samples from the study localities (App. A), and cited references.

The central parts of the Red Rock and Centennial basins are covered by a thick sequence of unconsolidated Quaternary sediments (Pl. 1). The only Tertiary sedimentary rock known to crop out in the basins is the Beaverhead Conglomerate of Late Cretaceous to early Eocene age (Lowell and Klepper, 1953).

The Beaverhead Conglomerate has poor favorability for uranium deposits. This formation has an estimated thickness of 9,700 ft (Lowell and Klepper, 1953, p. 238). Seventy-three percent of the formation consists of quartzite and limestone conglomerates; the remainder is limestone, siltstone, and sandstone. The conglomerate, sandstone, and siltstone are all strongly cemented, generally dark red, and contain no known reductants. The bedding generally is massive, and the formation has undergone considerable deformation. The mean equivalent uranium content of two samples from these basins and one sample of the Beaverhead Conglomerate (the "Red Conglomerate" of Dorr and Wheeler, 1964, p. 302) from the Upper Ruby River basin was 0.6 ppm (Table 3; Fig. 6). This is more than one standard deviation below the mean (2.9 ppm) for all samples from the south-central basins.

GRASSHOPPER CREEK, HORSE PRAIRIE, MEDICINE LODGE CREEK, AND BIG SHEEP CREEK BASINS

Rocks in the Grasshopper Creek, Horse Prairie, Medicine Lodge Creek, and Big Sheep Creek basins were named the "Medicine Lodge" beds by Scholten and others (1955). Data were obtained from surface studies of seven localities (Pl. 2), analyses of nine rock samples from the study localities (App. A), logs of three water wells and one petroleum test well (Pl. 2), two measured sections described in the literature (App. B), and cited references.

The favorability discussion and conclusions apply to most of the Miocene and Pliocene sedimentary section in the Horse Prairie and Medicine Lodge Creek basins. The conclusions are less applicable to the Grasshopper Creek and Big Sheep Creek basins because information is limited for these areas. The four basins, which are contiguous and contain rocks of similar age, are discussed as a group.

Favorability Characteristics

The estimated maximum thickness of the Tertiary rocks ranges from 4,130 to 6,700 ft (M'Gonigle, 1965, p. 50; petroleum test well 12, App. G). The sandstone content in these rocks ranges from 4 to 10 percent overall (secs. 43, 44, App. B; petroleum test well 12, App. G). Lower portions of the sections may contain as much as 60 percent sandstone and conglomerate (loc. 233, App. A; water well 39, App. H). Nearby granitic rocks, such as the Dillon Granite Gneiss which underlies the upland between the Horse Prairie and Medicine Lodge Creek basins (M'Gonigle, 1965, Pl. 1), and the quartz monzonitic pluton which underlies the Pioneer Mountains to the north (Myers, 1952, Pl. 1), provided detritus for Tertiary sedimentary rocks in these basins.

Potential host rocks in beds greater than 20 ft thick were found in several localities (App. A) and were described in published measured sections (App. B) and in water well logs (wells 38, 39, 40, App. H). These rocks are conglomerates and medium- to coarse-grained sandstones that are poorly sorted, permeable, and iron stained. Most of these rocks are arkosic or feldspathic. Medicine Lodge shale beds above the potential host rocks contain abundant carbonaceous material, and some carbonaceous material is present within the possible host beds. Tuffaceous rocks were mapped on the west side of Medicine Lodge Creek basin by M'Gonigle (1965, Pl. 1) and were studied at locality 267. Tuffaceous detritus is a constituent of the potential host rocks.

One uranium occurrence (no. 9, Fig. 1; loc. 250, Pl. 2) is reported for the Horse Prairie basin. Sample 250-1, from this locality, is a volcanic tuff that contains anomalous equivalent uranium (26.6 ppm), although no uranium minerals were identified. Sample 233-1 is anomalously high in equivalent uranium (Fig. 6). (Sample 250-1 is excluded from consideration because of its volcanic origin.) Samples 236-1 and 249-2 contain higher-than-average equivalent uranium accompanied by anomalous concentrations of other chemical indicators (lead and tin in sample 236-1, manganese in sample 249-2). One other sample (233-2) contains higher-than-average equivalent uranium.

Miocene and Pliocene rocks lie unconformably on the older Tertiary strata. The Tertiary section is cut by minor faults.

Conclusions

The Tertiary section as a whole has moderate favorability for uranium deposits because of the presence of potential host rocks, carbonaceous material, favorable chemical characteristics, and nearby favorable source rocks. The lower part of the section contains more potential host rocks than the upper and is, therefore, considered to be more favorable.

MUDDY CREEK BASIN

Data were obtained from surface studies at three localities (Pl. 2), analyses of five rock samples collected from the study localities (App. A), and the cited references. Only the upper portion of the Tertiary sedimentary rocks in the basin were studied.

Rocks in the Muddy Creek basin are of Oligocene age and were called the "Muddy Creek" beds by Scholten and others (1955, p. 369). The rocks have a maximum thickness of more than 1,000 ft (Scholten and others, 1955, p. 369). Potential host rocks are conglomerates and medium- to coarse-grained sandstones that are permeable, iron stained, and form beds greater than 20 ft thick in one locality (loc. 251). The fine-grained sedimentary rocks contain some carbonaceous material (loc. 246) and thick beds of tuff crop out in the basin (loc. 245). Most of the section, however, consists of fine-grained sandstone, siltstone, and mudstone. The sandstones are neither feldspathic nor arkosic, no favorable chemical indicators were found in rock samples (except sample 245-1, which is excluded because of its volcanic origin), and no granitic source rocks are nearby.

Tertiary sedimentary rocks of the Muddy Creek basin have poor favorability for uranium deposits because sandstone content is low, chemical characteristics are unfavorable, and both granitic source rocks and known uranium occurrences are lacking.

MADISON RIVER BASIN

Data were obtained from surface studies of six localities (Pl. 2), analyses of seven rock samples from the study localities (App. A), logs of three water wells (Pl. 2), and the cited references.

The Tertiary sedimentary sequence in the Madison River basin consists of a poorly exposed basal gravel of Oligocene age overlain by a thick sequence of volcanic flows and tuffs, freshwater limestone of Miocene and Pliocene age, and a thick cover of Pleistocene gravel and sand (Hadley, 1969a; 1969b). Samples show no anomalous chemical characteristics.

The basin has a maximum depth of 5,000 ft, on the basis of geophysical data presented by Burfeind (1967, p. 66). Information from three water wells is available for only the upper few hundred feet of the total section. Well 300 penetrated 193 ft of strata, well 37 penetrated 105 ft before bottoming in limestone, and well 50 penetrated material described as "ash" from 88 to 188 ft and continued to 339 ft in "clay" of unknown age.

On the basis of limited information, Tertiary sedimentary rocks of the Madison River basin have poor favorability for uranium deposits. None of the samples contain anomalously high equivalent uranium values, no uranium occurrences are known, and no reductants were seen in the exposed section. However, owing to the large size of the basin, the possible widespread existence of the lower Tertiary sequence in the subsurface, and regional geologic similarities to other favorable basins, the Madison River basin may be more favorable than the data indicate. Much more subsurface information is required to adequately evaluate the favorability.

WESTERN BASINS

by

W. E. Curry

The 13 basins (Fig. 7) in the western part of the project area are discussed in an approximate east-to-west order. Several smaller basins are grouped for discussion.

DEER LODGE BASIN

Data were obtained from surface studies of 12 localities (Pl. 2), analyses of 22 rock samples from these localities (App. A), the log of one petroleum test well (Pl. 2), and the cited references. Tertiary sedimentary rocks in the Deer Lodge basin range from Eocene to Pliocene in age (Konizeski and others, 1968, Pl. 1) but, with few exceptions, are not subdivided by age for discussion of favorability.

Favorability Characteristics

According to gravity profiles, the maximum thickness of valley fill ranges from 2,300 ft near the town of Deer Lodge to more than 5,500 ft in the southern part of the basin (Konizeski and others, 1968, p. 29). Thickness in the central part of the basin interpreted from gravity data is substantiated by petroleum test well 8, which penetrated 2,516 ft of Tertiary strata without reaching the underlying pre-Tertiary rocks. The section penetrated by petroleum test well 8 contains 23 percent sandstone and conglomerate; at locality 150 the section is entirely conglomerate.

Potential host rocks range from medium-grained sandstone to conglomerate. The rocks are feldspathic or arkosic, iron stained in many areas, and poorly sorted. They vary in permeability and form beds that average less than 20 ft thick and have a maximum thickness of 81 ft (loc. 106). Minor to trace amounts of carbonaceous material are present in the sandstones and conglomerates and in adjacent fine-grained beds.

Tertiary sedimentary rocks in the Deer Lodge basin contain volcanic detritus eroded from the Lowland Creek Volcanics and some interbedded volcanic ash (Konizeski and others, 1968, p. 14-16).

The mean equivalent uranium content (3.2 ppm) for the samples from the Deer Lodge basin is close to the mean for all samples from the western basin sample group (Fig. 3). Sample 101-1 contains anomalous equivalent uranium relative to equivalent thorium (Fig. 8). Sample 106-1 contains a higher-than-average enrichment of equivalent uranium relative to equivalent thorium (Fig. 8) as well as anomalous concentrations of Cu, Mn, Sn, V, and Zn (App. E).

The Deer Lodge basin is fault-bounded (Konizeski and others, 1968, p. 27-29, Pl. 2) and thus is similar to other large fault-bounded basins in which the favorable lower sequence has been preserved in the subsurface. Most of the

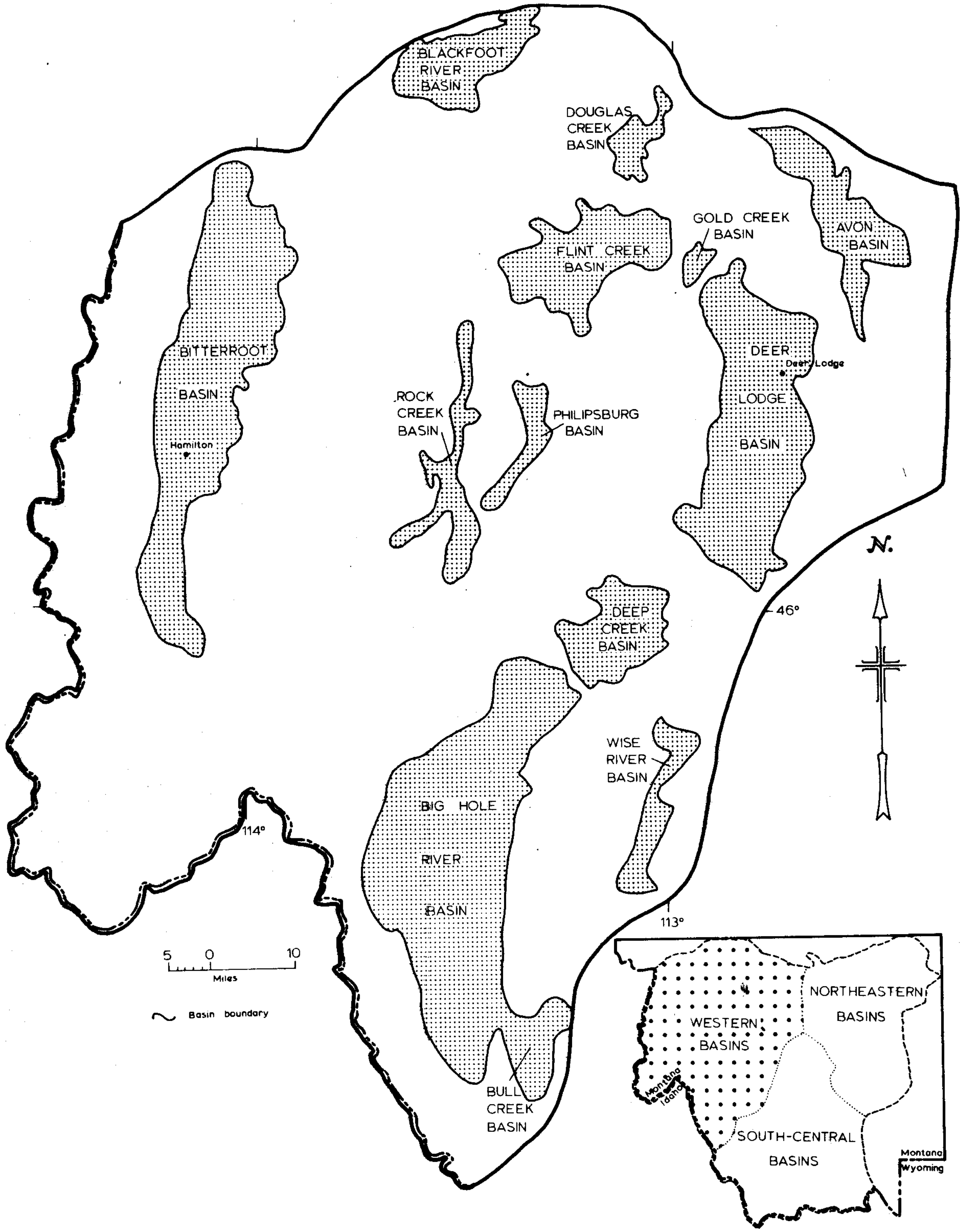

Figure 7. Locations and names of Tertiary basins in the western part of the study area.

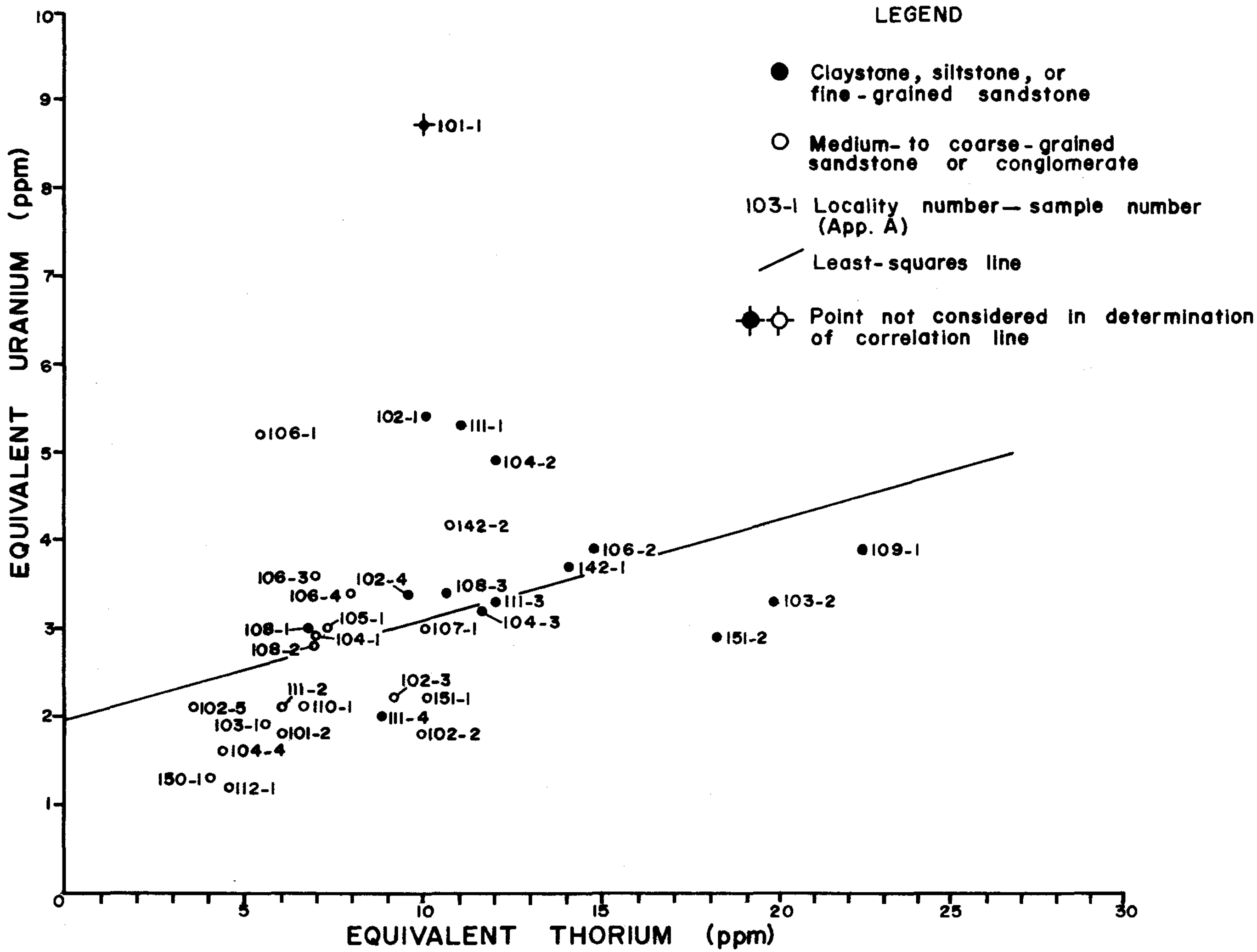

Figure 8. Plot of equivalent uranium versus equivalent thorium for samples from the Deer Lodge, Flint Creek, and Gold Creek basins.

Tertiary sedimentary strata dip gently except in the western part of the basin where they are deformed by folding and faulting (Konizeski and others, 1968, p. 15-25).

The basin is adjacent to the uraniferous Boulder batholith. The batholith may have been a source of both sediment and uranium for Tertiary rocks in the Deer Lodge basin.

Conclusions

A rating of moderate favorability for uranium deposits is assigned to the Tertiary sedimentary sequence in the Deer Lodge basin. The sequence contains several beds of possible host rocks that are greater than 20 ft thick. Favorable chemical indicators are present, and potential host rocks and adjacent fine-grained beds contain carbonaceous material. The rating is based on data collected from exposures of a small part of the total section. Most exposures are on the west side of the basin and consist of Miocene and Pliocene rocks.

Sedimentary rocks of early Oligocene age have favorable lithologic and chemical characteristics but are poorly exposed; they may underlie a large part of this basin, however. These rocks are favorable in many other southwestern Montana basins where they are better exposed; therefore, this basin may be more favorable than the surface data indicate. The favorability of the basin is further enhanced by its proximity to the Boulder batholith.

FLINT CREEK AND GOLD CREEK BASINS

Data were obtained from surface studies of 11 localities (Pl. 2), analyses of 9 rock samples from these localities (App. A), logs of 3 water wells (Pl. 2), 6 measured sections described in the literature (App. B), and the cited references.

Tertiary sedimentary rocks that underlie the Flint Creek and Gold Creek basins range from Oligocene to Pliocene in age. Basal Tertiary rocks constitute a pre-Miocene (probably Oligocene) paleoregolith which unconformably overlies older rocks and which ranges in thickness from 0 to 150 ft (Gwinn, 1960, Table 1). These basal strata are overlain by the Cabbage Patch Formation of late Oligocene to early Miocene age (Gwinn, 1960, p. 105), which has a maximum thickness of 2,200 ft (Rasmussen, 1969, p. 29). The Flint Creek Formation (Gwinn, 1960, p. 105) of late Miocene age (Rasmussen, 1969, p. 84) rests unconformably upon Cabbage Patch rocks and ranges from 0 to 600 ft in thickness (Gwinn, 1960, Table 1). Rocks of Pliocene age lie disconformably on all older rocks and include the 0- to 250-ft-thick Barnes Creek Gravel (Rasmussen, 1960, Table 1) and the Bert Creek Formation. The Bert Creek Formation is mostly gravel, has a maximum known thickness of 46 ft, and is of early Pliocene age (Rasmussen, 1969, p. 86-91). Because the Cabbage Patch Formation represents most of the total Tertiary section exposed in these basins, the discussion of favorability mostly pertains to this formation.

Favorability Characteristics

The maximum stratigraphic thickness of the Tertiary section is more than 3,000 ft, but the thickness of the rocks at any single place in these basins is not known. Sandstone makes up from 4 to 8 percent of the Cabbage Patch Formation (Rasmussen, 1969, p. 28) but is less in the overlying Flint Creek Formation (Gwinn, 1961). Sandstone percent, calculated from lithologic logs of three water wells, ranges from 0 to 27 percent and averages about 7 percent.

Possible host rocks range from medium-grained sandstone to conglomerate. They are arkosic to feldspathic, poorly to moderately sorted, and iron stained in some places. The sandstones generally are impermeable and form beds that average less than 10 ft in thickness, although several sandstone beds greater than 25 ft in thickness have been reported (Rasmussen, 1969, p. 39).

Mudstones, claystones, and siltstones, which separate the potential host rocks, are predominantly composed of volcanic ash. In places these strata contain minor amounts of carbonaceous woody material and several very thin coal beds (Rasmussen, 1969, p. 54).

Detritus for the Cabbage Patch Formation came from the Boulder batholith (Rasmussen, 1969, p. 75-77), which also may have been a source of sediments and possibly uranium for older Tertiary sedimentary rocks that underlie parts of the basins.

The Bert Creek and Barnes Creek gravels (locs. 157, 110) are poorly sorted and the Bert Creek gravel is feldspathic. The gravels are unconsolidated and have few characteristics favorable for uranium deposits. The oldest Tertiary sediments in this area are treated as undifferentiated Eocene and Oligocene sedimentary rocks in this report (Pl. 1). They are composed of red pebbly clay and rhyolitic welded tuff that lie between the Cabbage Patch Formation and Cretaceous strata (Gwinn, 1961).

The Tertiary sedimentary sequence in the Flint Creek and Gold Creek basins is bounded and divided by unconformities (Rasmussen, 1969, p. 20, 21, 23). In addition, the sequence is cut by several faults, along which uraniferous fluids may have had access to the Tertiary strata.

The mean equivalent uranium content (3.1 ppm) of samples from the Flint Creek and Gold Creek basins is slightly below that of the western basins sample group (Fig. 3). None of the samples have anomalous equivalent uranium contents (Fig. 8).

Conclusions

Tertiary sedimentary rocks of the Flint Creek and Gold Creek basins have poor favorability for uranium deposits. The sandstone percent of these rocks is low; potential host strata generally are thin; none of the samples contain anomalous equivalent uranium values; no uranium occurrences or radioactivity anomalies are known; and potential host rocks contain no known carbonaceous material. Although the Boulder batholith was the source of detritus for lower Miocene sediments, they are not enriched in uranium. Older Tertiary sedimentary rocks, which are favorable in other basins, are poorly exposed in these basins but may be widespread in the subsurface.

Sandstones and conglomerates of the Cabbage Patch Formation were the only potentially favorable units exposed, and represent the majority of the units sampled.

BIG HOLE RIVER AND BULL CREEK BASINS

Data were obtained from surface studies of 11 localities (Pl. 2), analyses of 24 rock samples from these localities (App. A), logs of 3 water wells and 1 uranium exploration drill hole (Pl. 2), and the cited references. Sedimentary rocks in these basins are of undifferentiated Tertiary age.

Favorability Characteristics

Tertiary sedimentary rocks are at least 1,290 ft thick in the east-central part of the Big Hole River basin (uranium exploration drill hole 14, App. I). The basin is large and probably contains a much thicker sequence of Tertiary sedimentary rocks. Detritus in these rocks probably was derived in part from granitic rocks in the Idaho batholith and Pioneer Mountains.

It was not possible to estimate the proportion of sandstone and conglomerate for Tertiary sedimentary rocks in the Big Hole River and Bull Creek basins because too little of the Tertiary section is exposed. Sand percentages of the limited surface exposures appear to be high, but percentages indicated in two of the three water wells conflict with outcrop data. The sandstone and conglomerate content of the rocks penetrated by the wells is 2 percent in well 36, 4 percent in well 32, and 99 percent in well 31.

Potential host rocks range from medium-grained sandstone to comglomerate. They are poorly sorted, feldspathic or arkosic, and iron stained. Some of the beds penetrated by water well 36 are composed of granitic sand. Beds range from 2 ft to 50 ft in thickness, but most are less than 20 ft thick. Outcrops of potential host rocks are well cemented and impermeable. Some of the conglomerate in water well 31 is cemented with lime and presumed to be impermeable. Trace amounts of carbonaceous material are in fine-grained beds adjacent to potential host rocks at localities 118 and 119 and are in potential host rocks at locality 119. Volcanic ash is interbedded with sandstones throughout much of the basin (Perry, 1934, p. 9).

No uranium occurrences or radioactivity anomalies were identified in this investigation; but the periodical Nuclear Canada reported in March 1971 that encouraging "roll front" uranium mineralization had been found on "both Montana prospects" of Denison Mines (Law, 1971, p. 8). This firm conducted drilling in the Big Hole basin in June 1970; and although no anomalies were noted on a gamma-ray log released by Denison (drill hole 14, Table I-1), the relatively close time relationship between the news release and the completion date of this drill hole may indicate that the Big Hole basin is more favorable for uranium than can be demonstrated by surface geology.

The mean equivalent uranium content (4.5 ppm) for rock samples from the Big Hole and Bull Creek basins is slightly higher than the mean content for samples in the western basins group (Fig. 3). Equivalent uranium content for samples from locality 119 is anomalously high when compared with the mean concentrations in either (1) samples from the Big Hole and Bull Creek basins or (2) all samples from the western basins (Fig. 3). Samples 119-5 and 119-8 have anomalous uranium, and samples 119-3 and 119-6 contain higher-than-average amounts of uranium (Fig. 9).

Dips in the Tertiary strata are mostly low. The Tertiary section is cut by normal and strike-slip faults on the east side of the Big Hole basin (Ruppel, 1964, p. C14, C15).

Conclusions

Tertiary sedimentary rocks of the Big Hole River and Bull Creek basins have moderate favorability for uranium deposits because (1) the thick sedimentary sequence contains several beds of potential host rocks that are greater than 20 ft thick; (2) samples from one locality in the Bull Creek basin contain anomalously high equivalent uranium relative to equivalent thorium; (3) the potential host rocks and the adjacent fine-grained strata contain carbonaceous material; and (4) the Big Hole basin may be the location of roll-front uranium mineralization reported in the literature.

Because of the paucity of outcrops and subsurface information, only a small part of the total Tertiary section was studied. More subsurface information is needed for an accurate and complete determination of favorability for uranium in these rocks.

DEEP CREEK BASIN

Data were obtained from surface studies of five localities (Pl. 2), analyses of six rock samples from these localities (App. A), and the cited references. Sedimentary rocks studied in the Deep Creek basin are of undifferentiated Tertiary age.

Potential host rocks range from medium-grained sandstone to conglomerate and are arkosic, poorly sorted, moderately permeable, and iron stained. They contain minor amounts of carbonaceous material and are separated by tuffaceous fine-grained rocks that also are partly carbonaceous. The sandstone and conglomerate beds are less than 10 ft thick, except for a 16-ft bed described at locality 149. The equivalent uranium contents of samples 148-2 and 149-1 (Fig. 9) are above average, but are not anomalously high.

The presumed sources of detrital material for the basin are nearby plutonic rocks and tuffs of Tertiary age. No uranium occurrences are known to be associated with these rocks.

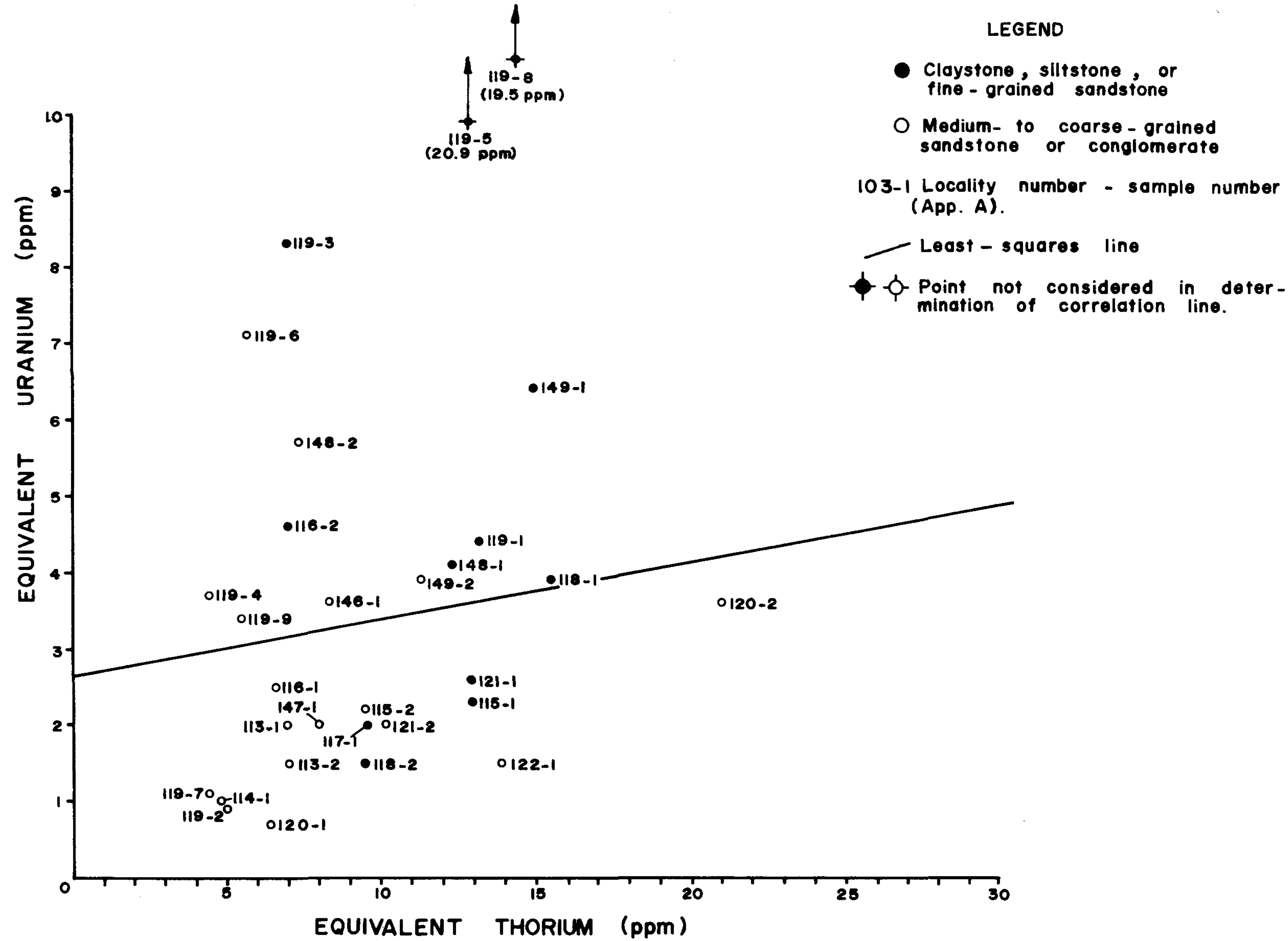

Figure 9. Plot of equivalent uranium versus equivalent thorium for samples from the Big Hole, Bull Creek, and Deep Creek basins.

Stratigraphic and chemical characteristics of Tertiary rocks in the Deep Creek basin are unfavorable, and lithologic characteristics are only moderately favorable. Data were derived from exposures of only a small part of the Tertiary section and are insufficient to provide a meaningful favorability rating.

WISE RIVER, BLACKFOOT, DOUGLAS CREEK, AVON, ROCK CREEK, AND PHILIPSBURG BASINS

Data for evaluation of the Wise River, Blackfoot, Douglas Creek, Avon, Rock Creek, and Philipsburg basins were obtained from surface studies of 20 localities (Pl. 2), analyses of 15 rock samples from these localities (App. A), logs of 4 water wells (Pl. 2), and the cited references. The sedimentary rocks studied in these basins range from Eocene to Pliocene in age, but they are not subdivided by age for the following discussion.

Favorability Characteristics

The Tertiary section in the basins is poorly exposed. Its maximum thickness is unknown, and its sandstone content appears to be low. Potential host rocks are few and range from medium-grained sandstone to conglomerate that generally are poorly sorted. Sandstones and conglomerates are feldspathic in the Wise River basin, arkosic in the Blackfoot basin, and iron stained in the Blackfoot and Rock Creek basins. Both the potential host rocks and the fine-grained strata in the Blackfoot and Avon basins contain carbonaceous material. In the Douglas Creek basin only claystones and siltstones are carbonaceous. Tuffaceous material was observed in two basins; and faults, which may cut Tertiary rocks, have been reported for three basins (Pardee, 1950, p. 388-389, 396-397, Pl. 1; Bierwagen, 1964, Pl. 1). The Avon basin is the only basin from this group that is sufficiently close to uraniferous rocks of the Boulder batholith to have received drainage and, possibly, detritus from them. However, no uranium occurrences have been reported in these basins, and favorable chemical indicators are lacking in the rocks that were sampled (Fig. 10).

Conclusions

Lack of data precludes assigning a meaningful favorability rating to the Tertiary rocks of this basin group. The Avon basin may be the most favorable of these basins because it is the closest to the Boulder batholith. Much additional subsurface information is needed to adequately evaluate the Tertiary rocks of these basins.

BITTERROOT BASIN

Data for the Bitterroot basin were obtained from surface studies of 13 localities (Pl. 2), analyses of 16 rock samples from these localities (App. A), logs of 2 water wells (Pl. 2), 2 measured sections described in

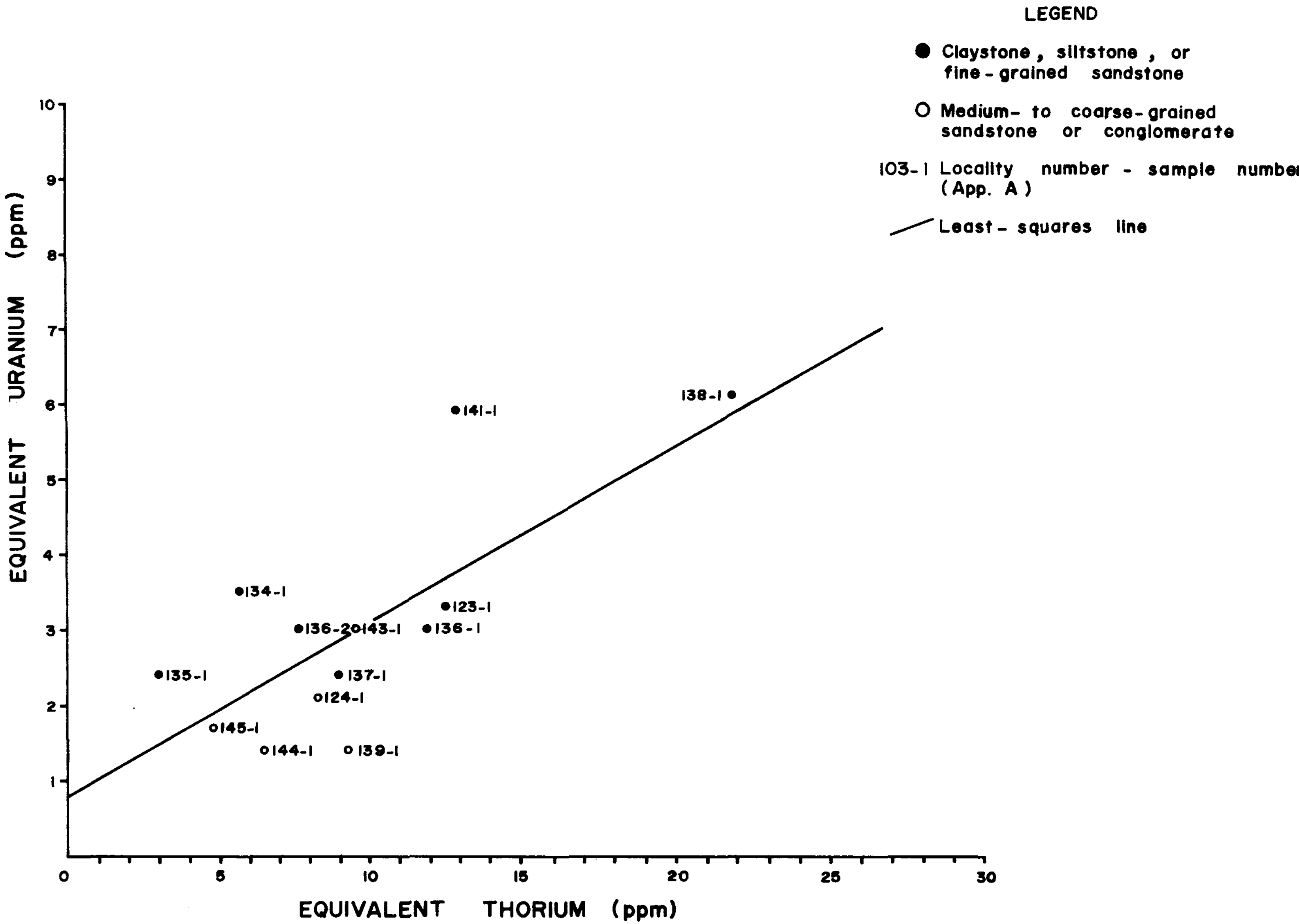

Figure 10. Plot of equivalent uranium versus equivalent thorium for samples from the Wise River, Blackfoot, Douglas Creek, Avon, and Rock Creek basins.

the literature (App. B), and the cited references. The sedimentary rocks range from Miocene (or late Oligocene) to early Pliocene in age (McMurtrey and others, 1972, p. 20, 21).

Favorability Characteristics

The Bitterroot basin is large and contains a relatively thick sequence of Tertiary sedimentary rocks. Although unexposed, sedimentary rocks of the favorable lower Tertiary sequence may be present at depth in the basin. The Idaho batholith was probably an important source of sediment and may have been a source of uranium for the basin.

Cenozoic sedimentary rocks along the axis of the basin have an average thickness of about 3,000 ft, and have a maximum thickness of 4,000 ft just north of Hamilton (Lankston, 1975, Pls. 1, 3a-3f). Less than 500 ft of Quaternary alluvium overlies Tertiary sedimentary rocks (Lankston, 1975, p. 3). A petroleum test well in the southern part of the basin penetrated at least 1,410 ft of Tertiary sedimentary rocks (McMurtrey and others, 1972, p. 15). Gravity data indicate that the basin-fill rocks thin rapidly toward the margins of the basin. At the northwest margin of the basin, water well 28 (Pl. 2) penetrated only 175 ft of Cenozoic sediments before entering granitic basement.

Sandstone and conglomerate make up about 74 percent of the 405 ft of Tertiary rocks penetrated by water well 17. Sandstone percent of surface localities also is high. The Tertiary sequence contains abundant tuffaceous material, which might be a source of uranium.

Potential host rocks range from medium-grained sandstone to conglomerate and are arkosic or feldspathic, poorly sorted, permeable, and iron stained. Outcrops indicate that most potential host rock beds are less than 10 ft thick, although a few are as much as 30 ft thick. A sandstone interval 210 ft thick was penetrated by water well 17.

Minor amounts of carbonaceous material are in fine-grained tuffaceous rocks both above and below potential host rocks. McMurtrey and others (1972, p. 21) reported semi-indurated plant beds of Miocene or late Oligocene age on the southwest side of the valley.

The mean equivalent uranium content for samples from the Bitterroot basin (Table 3) is close to the mean for samples of the western basins (Fig. 3). Sample 125-2, of carbonaceous claystone, contains an anomalously high amount of equivalent uranium (Fig. 11) and anomalous concentrations of Cr and Li (App. E).

Structural development of the Bitterroot basin may be interpreted as a result of either down-faulting (McMurtrey and others, 1972, p. 27-31) or gravity-sliding (Lankston, 1975, p. 3, 47; Hyndman and others, 1975, Fig. 2). High-angle faulting would improve the favorability of the rocks in this basin.

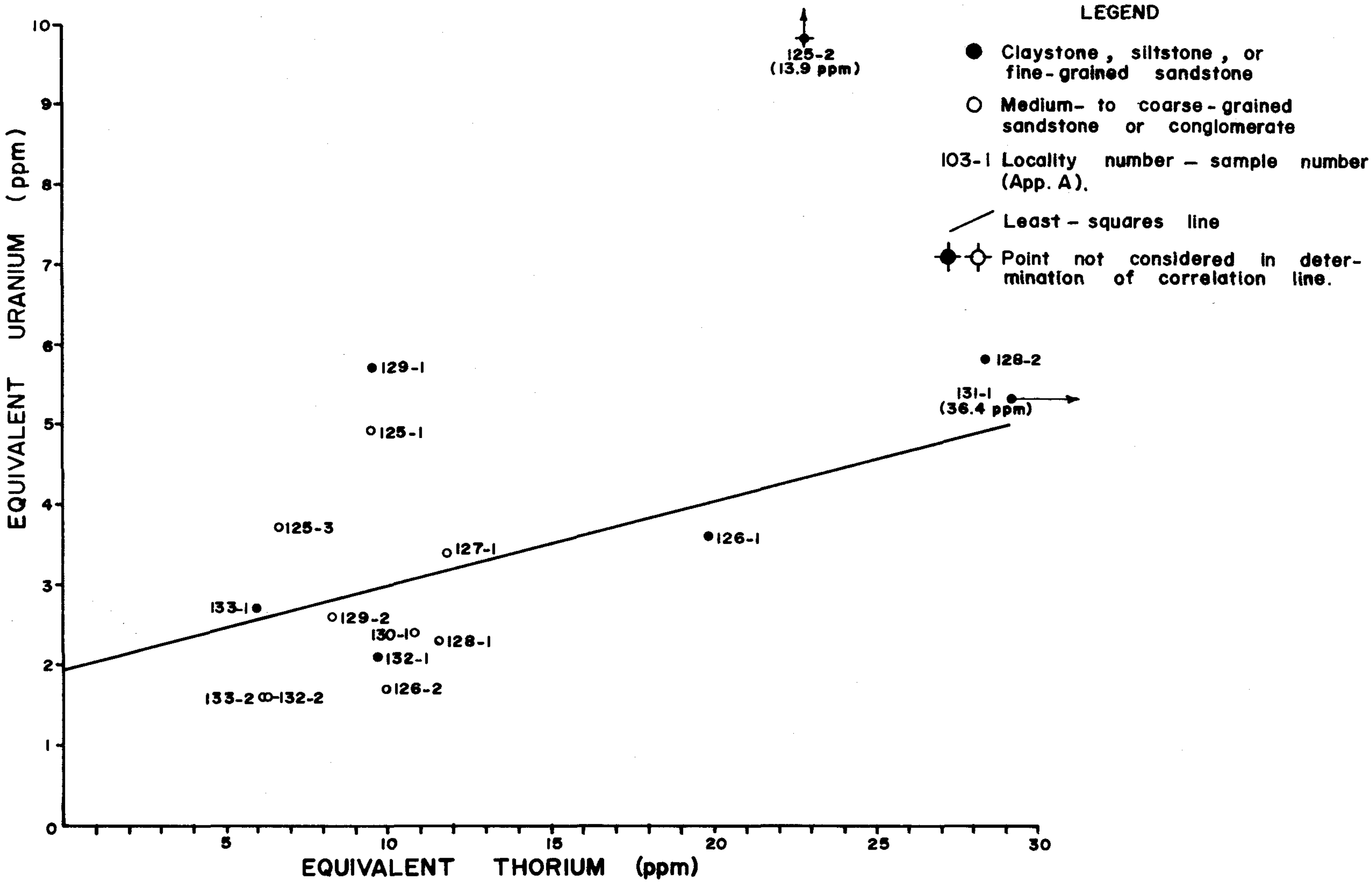

Figure 11. Plot of equivalent uranium versus equivalent thorium for samples from the Bitterroot basin.

Conclusions

On the basis of limited stratigraphic, lithologic, chemical, structural, and geophysical data and other pertinent characteristics, the Tertiary sedimentary rocks in the Bitterroot basin have poor favorability for uranium deposits. Although a favorable sedimentary rock sequence is present, the strata lack uranium occurrences and radioactivity anomalies; and potential host rocks contain no known reductants or permeability barriers.

These conclusions are based on surface and subsurface data gathered mostly from the eastern side of the basin (Pl. 2). However, these data may not be representative of the total Tertiary section because all the strata exposed on the eastern side are of early Pliocene age, whereas rocks as old as Miocene age (perhaps late Oligocene) have been reported from another part of the basin (McMurtrey and others, 1972, p. 21).

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APPENDIX A

DESCRIPTIONS OF SELECTED ROCK UNITS

LOCALITY 101. MODESTY CREEK

NW¼SW¼SE¼ sec. 19, T. 6 N., R. 10 W.; Deer Lodge County; in roadcut on the south side of road. Mapped as Eocene to Oligocene Heterogenous deposits by Konizeski and others (1968, Pl. 1).

Unit		Estimated thick. (ft)
2.	Conglomerate; light yellowish gray (weathers to light gray); with subrounded pebbles of quartzite (60%), quartz (20%), and other rock fragments (20%), in a matrix of poorly sorted, medium grained, feldspathic, micaceous, sandstone; soft, friable (weathers to medium hard, compact); slope former; iron-stained; tabular uneven; internally massive. Lower contact sharp and irregular. Minor carbonaceous material. Contains a few lenticular beds of clay. Sample 101-2	2
1.	Claystone, sandy, micaceous; medium grayish black with brown iron streaks (weathers to mottled medium brown); soft, plastic; slope former; tabular uneven; with internal disturbed irregular, very thin bedding. Lower contact sharp and regular. Minor carbonaceous material. Sample 101-1	1
	Total estimated thickness	3

LOCALITY 102. BIELENBERG CANYON

SW¼NE¼SE¼ sec. 7, T. 6 N., R. 10 W.; Powell County; in gully on the north side of road. Mapped as Eocene to Oligocene Heterogeneous deposits by Konizeski and others (1968, Pl. 1).

Unit		Measured thick. (ft)
12.	Sandstone, feldspathic; dark yellowish orange; medium to fine grained, moderately sorted, with subangular grains; soft, loose; slope former; iron-stained; with internal parallel uneven medium bedding. Lower contact sharp and irregular. Sample 102-5 taken at the base	39.7
11.	Claystone, sandy, micaceous; medium yellowish brown; soft, plastic; slope former; internally massive. Sample 102-4 taken at the top	5.6
10.	Sandstone; streaked light orange gray; medium grained; medium hard, friable; slope former; with internal very thin lenticular bedding	21.4
9.	Covered	67.5
8.	Sandstone (60%); light yellowish gray; fine grained; soft Claystone (40%); medium purple brown; soft	8.8
7.	Conglomerate; soft, friable; subrounded cobble and pebble clasts	7.5

LOCALITY 102. (continued)

Unit		Measured thick. (ft)
6.	Covered	23.1
5.	Conglomerate (60%), micaceous; dark yellowish orange; with subrounded pebbles of quartzite (80%) and granite (20%), in a matrix of poorly sorted, coarse grained, feldspathic sandstone; medium hard, friable; slope former; lenticular; internal medium bedded. Lower contact sharp. Minor amount of heavy minerals (magnetite, sphene). Sample 102-2 Sandstone (35%), feldspathic, micaceous; streaked dark yellowish orange; medium to fine grained, poorly sorted; medium hard, friable; slope former; iron-stained; lenticular bedding. Minor amount of heavy minerals (biotite). Sample 102-3 Claystone (5%); medium grayish brown; soft, plastic; slope former; internal very thin bedding. Trace of carbonaceous material(?)	12.9
4.	Claystone, silty, micaceous; dark yellowish brown; soft, plastic; slope former; internally massive. Sample 102-1	5.4
3.	Sandstone, feldspathic; medium yellowish gray; medium grained, poorly sorted; soft, loose. Trace of carbonaceous material.	2.0
2.	Claystone; dark gray; soft, plastic; subordinate amount of carbonaceous material	1.4
1.	Conglomerate; soft, friable; with pebble clasts	3.4
	Total measured thickness	198.7

LOCALITY 103. WILLIAMS RANCH ROAD

NW¼SE¼SE¼ sec. 8, T. 8 N., R. 9 W.; Powell County; in gravel pit, approximately 1/2 mile south of Williams Ranch. Mapped as Miocene lacustrine and fluvial deposits by Konizeski and others (1968, Pl. 1).

Unit		Estimated thick. (ft)
2.	Claystone; micaceous; yellowish gray; medium hard, compact; lenticular bed. Lower contact sharp and regular. Lens within unit 1. Sample 103-2	1
1.	Sandstone, conglomeratic, feldspathic; banded gray; coarse to very coarse grained, poorly sorted, with subrounded pebbles of quartz, quartzite, and sandstone; medium hard, friable; slope former; manganese stained; lenticular channel; internally thin bedded, with trough cross-bedding. Sample 103-1 taken just above claystone lens (unit 2)	20
	Total estimated thickness	21

LOCALITY 104. WEST SIDE CANAL PIT

SE¼NE¼SW¼ sec. 20, T. 7 N., R. 9 W.; Powell County; in gravel pit on the north side of road, 0.1 mile west of canal. Mapped and described by Konizeski and others (1968, p. 17, Pl. 1), as Pliocene channel deposits. The section includes a sequence of intertonging conglomerate and sand fluvial channels with tan silty clay lenses. The beds vary in dip from (6.5° N.W. and 6.5° N.E.) to approximately horizontal and the strike varies from N. 15° E. to N. 40° W.

Unit		Measured thick. (ft)
5.	Conglomerate; streaked light gray; with rounded pebbles in a matrix of poorly sorted, subangular, coarse grained, feldspathic, micaceous, sandstone; soft, friable; slope former; iron stained; lenticular channel; internally very thin bedded with planar and trough cross-bedding. Lower contact sharp and irregular. Minor amount of heavy minerals. Sample 104-4 taken at the base	6
4.	Claystone, sandy; dark yellowish gray; soft, loose; slope former; lenticular beds; with internal parallel uneven thin bedding. Sample 104-3 taken at the top	4.6
3.	Sandstone; light brownish gray; coarse grained, poorly sorted; soft, friable; slope former; lenticular channel; with internal parallel even thin bedding. Lower contact sharp and irregular	1.4
	Comment: The width of the channel approximately 50 feet.	
2.	Claystone, sandy; yellowish gray; soft, loose; slope former; manganese stained; lenticular bed; internally massive. Sand is very fine to coarse grained and poorly sorted. Sample 104-2 taken at upper contact	4.6
1.	Conglomerate, sandy; dark yellowish orange; with rounded pebbles of quartzite (50%), granite (40%) and quartz; in a matrix of poorly sorted, subangular, coarse grained; feldspathic, micaceous, sandstone; soft, friable; slope former; iron-stained; lenticular channel; internally very thin bedded with planar cross-bedding. Trace of heavy minerals. Sample 104-1	5.0
	Total measured thickness	21.6

LOCALITY 105. BAILEY GRAVEL PIT

NE¼NW¼SE¼ sec. 20, T. 7 N., R. 9 W.; Powell County; north of road, 0.2 miles east of the West Side Canal. Mapped as Alluvium by Konizeski and others (1968, Pl. 1), but is probably Pliocene.

LOCALITY 105. (continued)

Unit		Estimated thick. (ft)
1.	Sandstone, feldspathic, micaceous; light olive brown; medium to coarse grained, moderately sorted; soft, friable; slope former; tabular even; internally massive. Minor amount of heavy minerals. Pebbly in places, and contains petrified wood and bones. Sample 105-1	20

LOCALITY 106. GI SPRING

NW¼SW¼NW¼ sec. 21, T. 8 N., R. 9 W.; Powell County; in gully west of old ranch road, approximately 2½ miles northwest of Deer Lodge. Mapped as Pliocene fluvial deposits by Konizeski and others (1968, Pl. 1).

Unit		Measured thick. (ft)
5.	Siltstone, sandy, micaceous; reddish gray; medium hard; slope former; iron-stained tabular even; internal parallel even medium bedding. Lower contact gradational. Contains several medium thick clay beds and a few very thin carbonaceous streaks	22
4.	Sandstone, feldspathic, conglomeratic; streaked dusky yellow (weathers to green); coarse grained, moderately sorted, with subangular grains; with subangular pebbles of predominantly quartzite; soft, friable; slope former; iron-stained tabular even; internally medium bedded with planar cross-bedding. Lower contact sharp and regular. Conglomeratic near base and contains silt rip-up clasts one to two inches in diameter, and several bands of green mineral staining; also contains several thin reddish sandy silt interbeds. Sample 106-4 taken from near the top	81.1
3.	Conglomerate (90%) banded yellowish gray (weathers to brown); with pebbles of predominantly quartzite in a matrix of very poorly sorted, coarse grained, arkosic sandstone; medium hard, friable; slope former; manganese-stained; lenticular channel; internally thin bedded with planar and trough cross-bedding. Lower contact covered. Minor amount of replaced carbonaceous material; minor amount of heavy minerals. Contains many greenish yellow silt rip-up clasts. Sample 106-3	
	Siltstone (5%), sandy, micaceous; light yellowish gray; medium hard, compact; slope former; lenticular channel; internally thin bedded with planar cross-bedding. Lower contact sharp and irregular. Stained a yellow green stain and contains a few dark mineral bands. Sample 106-2	
	Sandstone (5%), clayey, conglomeratic; banded light gray; coarse to very coarse grained, poorly sorted; soft; thinly bedded; manganese stained	59.4
2.	Covered	16.1

LOCALITY 106. (continued)

Unit		Measured thick. (ft)
1.	Conglomerate; dark blackish gray (weathers to black); with subrounded to rounded pebbles of quartzite (50%), granite (25%), and volcanics (25%); in a matrix of poorly sorted, very coarse grained, feldspathic sandstone; hard; compact; slope former; manganese-stained and cemented (Hollandite, 30% of the rock); lenticular channel; internally very thin bedded with planar cross-bedding. Sample 106-1	4.9
	Total measured thickness	183.5

LOCALITY 107. ROBINSON CREEK

SE¼NW¼NE¼ sec. 5, T. 7 N., R. 10 W.; Powell County; approximately 50 feet from top of the southern slope of Robinson Ridge, 1 mile northwest of Tin Cup Lake. Mapped as Eocene to Oligocene Heterogeneous deposits by Konizeski and others (1968, Pl. 1).

Unit		Estimated thick. (ft)
1.	Conglomerate, light brown; with rounded cobbles of sandstone and siltstone (60%), shale (30%), and granitic conglomerate (10%); in a matrix of red sandy silt; hard, compact; ledge former; calcareous cemented; iron-stained and oxidized; tabular even; internally massive. Minor carbonaceous material. Sample 107-1	12

LOCALITY 108. ANACONDA

SE¼SW¼SE¼ sec. 35, T. 5 N., R. 11 W.; Deer Lodge County; section is exposed along the west flank of a gentle syncline, about 3/4 mile northeast of the Anaconda Electric power substation. The beds strike northeast and dip approximately 10^{o} to the east. Mapped as Miocene (?) conglomerate by Wanek and Barclay (1966, Pl. 1, p. 15-16), and as Miocene Anaconda beds by Csejtey (1963, Pl. 1, p. 41, 47).

Unit		Measured thick. (ft)
4.	Conglomerate (85%). Same as unit 2 .... Sandstone (15%); silty; tan; very fine grained; moderately sorted; medium hard. Lower contact sharp and regular.......	21
3.	Siltstone, clayey; streaked light olive gray; medium hard, loose; cliff former; iron-stained; tabular even; with internal parallel even, thin bedding. Lower contact sharp and regular. Minor carbonaceous material. Contains three inch carbonaceous interbeds with abundant wood fibers and plant impressions. Sample 108-3 taken at the top of the unit	7.7

LOCALITY 108. (continued)

Unit		Measured thick. (ft)
2.	Conglomerate; grayish orange; with rounded cobbles of quartzite (50%), shale (30%), and other rock fragments (20%) in a matrix of poorly sorted subangular to subrounded, medium grained, micaceous, sandstone; medium hard, compact; cliff former; calcareous cemented; iron-stained; lenticular channel; with internal disturbed-irregular, thick bedding. Lower contact sharp and irregular. Thin silt interbeds. Sample 108-2 taken at the base	23.9
1.	Sandstone, silty, micaceous; banded yellowish gray; fine to very fine grained, moderately sorted, with subangular grains; medium hard; compact; cliff former; calcareous cemented; iron-stained; tabular even, with internal parallel even thin bedding. Contains thin silty carbonaceous interbeds. Sample 108-1 from the top of the unit	20.7
	Total measured thickness	73.3

LOCALITY 109. MORSE RANCH CREEK

SE¼NW¼SW¼ sec. 3, T. 10 N., R. 12 W.; Granite County; on southeast side of stream drainage, approximately 1 mile east of Morris Creek and about 1 mile north of I-90. Mapped as early Miocene Cabbage Patch Formation by Gwinn (1961).

Unit		Estimated thick. (ft)
1.	Claystone, silty; streaked grayish yellow; (weathers to knobby nodular surface); hard, compact; slope former; tabular even; internally massive. Lower contact covered. Minor carbonaceous material. Includes thin siltstone beds. Sample 109-1	20

LOCALITY 110. BERT CREEK GRAVEL PIT

SW¼SE¼SW¼ sec. 11, T. 10 N., R. 12 W.; Granite County; on top of hill, approximately 1/4 mile west of Bert Creek and approximately 1/4 mile north of I-90. Measured section B of MV6549, locality 5 of Rasmussen (1969, p. 159). Type section of Bert Creek Formation (Pliocene) and also representative of the coarse grained part of the Pliocene in the Drummond area.

Unit		Estimated thick. (ft)*
1.	Conglomerate, sandy, light olive gray; with subrounded pebbles of quartzite (50%), volcanics (30%) and granite (20%); in a matrix of poorly sorted, very coarse grained, feldspathic sandstone; soft, friable; slope former; manganese stained; tabular even; internally massive. Sample 110-1	46

*Thickness from Rassmussen (1969, p. 159)

LOCALITY 111. BERT CREEK

SE¼SW¼SW¼ sec. 11, T. 10 N., R. 12 W.; Granite County; in small gulch, approximately 1/4 mile northwest of the mouth of Bert Creek. Type section of Cabbage Patch Formation (Rassmussen, 1969, section MV6554, locality 8, p. 152-155).

Unit		Measured thick. (ft)*
6.	Not described. Unit 32 of Rassmussen, 1969, pp. 152-155......	4
5.	Sandstone, arkosic, clayey; light olive brown; fine grained, moderately sorted, with subangular grains; soft, friable; slope former; iron-stained; tabular even; internally massive. Lower contact gradational. Minor amount of heavy minerals. Grade to pebble conglomerate at top. Unit 31 of Rassmussen (1969, p. 152). Sample 111-4 taken at the base..	9.5
4.	Siltstone, micaceous, sandy; yellowish gray; medium hard, compact; slope former; iron-stained; tabular even; internally thin-bedded. Lower contact gradational. Minor amount of heavy minerals. Unit 30 of Rassmussen (1969, p. 152). Sample 111-3	2.2
3.	Sandstone, arkosic, micaceous; medium dusky yellow; coarse grained, moderately sorted; hard, compact; ledge former; iron-stained; tabular even; with internal parallel even, medium bedding. Lower contact sharp and regular. Contains a few subrounded pebble clasts. Unit 29 of Rassmussen (1969, p. 152). Minor amount of opalized wood. Sample 111-2 taken at the base	10.3
2.	Siltstone, clayey, micaceous, tuffaceous; mottled medium yellowish gray; medium hard, compact; slope former; tabular even; internally massive. Unit 28 of Rassmussen (1969, p. 152). Lower contact sharp and regular. Sample 111-1 taken at the top	0.75
1.	Not described; units 1-27 of Rassmussen, 1969, pp. 152-155....	79.25
	Total estimated thickness	102.0

LOCALITY 112. GRIFFIN CREEK

SW¼NE¼NE¼ sec. 16, T. 9 N., R. 11 W.; Powell County; unit described is the resistant caprock on many of the low hills in the area. Lithologically similar and time equivalent to units in the Cabbage Patch type section (see discussion of locality 111). Mapped as Miocene sandstone and conglomerate by Mutch (1961).

*Thickness from Rassmussen (1969, pp. 152-155).

LOCALITY 112. (continued)

Unit		Estimated thick. (ft)
1.	Sandstone, arkosic, micaceous; spotted yellowish brown; very coarse grained, poorly sorted, with subrounded grains; hard, compact; ledge former; siliceous cement; tabular even; with internal parallel even, medium bedding. Contains minor subrounded pebble clasts and heavy minerals. Sample 112-1	5

LOCALITY 113. NORTH FORK BIG HOLE RIVER

NE¼SE¼SW¼ sec. 4, T. 2 S., R. 16 W.; Beaverhead County; in gully 200 feet SW of road on the south side of river. Mapped as Tertiary sediments by Ross and others (1955). This unit is similar in hardness and lithology to rock units mapped as Pliocene-Pleistocene in other areas of southwest Montana.

Unit		Estimated thick. (ft)
1.	Conglomerate (95%), sandy; dark yellowish orange; with rounded pebbles of quartzite (70%), granite (30%), in a matrix of moderately sorted, subrounded, medium to coarse grained arkosic sandstone; medium hard, compact; slope former; iron-stained and cemented; tabular even, internally thick bedded. Sample 113-2 taken at the base of 10-foot bed at the contact with silty sandstone (sample 113-1). Sandstone (5%), silty, arkosic; uniform dark yellowish orange; medium grained; moderately to well sorted; with subangular grains; medium hard, compact; slope former; iron-stained; medium thick lenticular bed; internally massive. Lower contact with conglomerate is sharp irregular. Iron-stained. Sample 113-1	50

LOCALITY 114. PLIMPTON CREEK

SE¼NE¼NW¼ sec. 16, T. 1 S., R. 15 W.; Beaverhead County; resistant caprock on low hill, 0.3 mile north of Plimpton Creek, in the central part of the Big Hole River valley. Dips within this unit are chaotic. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955).

Unit		Estimated thick. (ft)
1.	Sandstone, arkosic, micaceous; spotted pale yellowish brown; medium to very coarse grained, poorly to moderately sorted; with angular to subrounded grains; hard, compact; ledge former; tabular even; internally thin bedded with planar cross bedding. Abundant silicified wood. Conglomeratic in places. Sample 114-1	15

LOCALITY 115. RUBY RANCH ROAD

NW¼SW¼NW¼ sec. 25, T. 2 S., R. 17 W.; Beaverhead County; on the east side of road, 0.2 mile south from Montana Highway 43. Mapped as Tertiary lake beds by Alden (1953, Pl. 1).

Unit		Measured thick. (ft)
1.	Conglomerate (95%); yellowish gray; with subrounded pebbles of quartzite (90%), and granite (10%); in a matrix of poorly sorted, fine to very fine grained sandstone; hard, compact; ledge former; siliceous cement; tabular even; internally thick bedding. Sample 115-2 taken from middle of unit above silty sandstone lens (sample 115-1). Sandstone (5%), silty, micaceous; yellowish gray; fine to very fine grained, moderately sorted; hard, compact; slope former; thin, lenticular beds. Sample 115-1	47.0

LOCALITY 116. SWAMP CREEK ROAD

NE¼NE¼NE¼ sec. 13, T. 3 S., R. 17 W.; Beaverhead County; roadcut. Mapped as Tertiary lake beds by Alden (1953, Pl. 1).

Unit		Estimated thick. (ft)
2.	Claystone, micaceous, conglomeratic; medium yellowish gray; medium hard, compact; slope former; manganese-stained; lenticular bed; with internal parallel even, thin bedding. Lower contact sharp and regular. Trace of heavy minerals. Minor glass shards and fine to coarse grained sand. Sample 116-2 taken of the most carbonaceous part	3
1.	Sandstone, clayey, feldspathic, micaceous; streaked light yellowish gray; coarse grained, poorly sorted, with subangular grains; medium hard, friable; slope former; iron-stained; tabular even; internal medium bedding. Sample 116-1	2
	Total estimated thickness	5

LOCALITY 117. CHALK BLUFF

SE¼SW¼SE¼ sec. 14, T. 1 N., R. 14 W.; Deer Lodge County; in bluff. Mapped as Tertiary lake beds by Alden (1953, Pl. 1).

Unit		Estimated thick. (ft)
1.	Claystone (95%), light tan to light gray; medium hard, compact slope former; tabular even, internal very thick or massive(?) bedding. Iron and manganese-stained in manner which does not seem to conform to bedding or channeling. Siltstone (5%), clayey; medium grayish yellow; medium hard; compact; slope former; iron-stained; thin lenticular beds; internally massive. Subordinate carbonaceous material; minor amount of heavy minerals (?) or manganese oxide (?). Sample 117-1 from near base	200

LOCALITY 118. WISDOM CEMETERY

SW¼SE¼NW¼ sec. 15, T. 2 S., R. 15 W.; Beaverhead County; below cemetery. Mapped as Tertiary lake beds by Alden (1953, Pl. 1).

Unit		Estimated thick. (ft)
4.	Claystone and siltstone, micaceous, sandy; medium hard, compact; slope and ledge former; tabular even; internally thick bedded. Lower contact sharp and regular	23
3.	Sandstone, feldspathic, micaceous, conglomeratic; pale greenish yellow; fine grained, moderately sorted; with angular grains; soft, friable; slope former; tabular even; with internal parallel even, thin bedding. Lower contact sharp and regular. Contains angular to subangular pebbles and minor amount of glass shards. Sample 118-2 taken at the base	20
2.	Claystone, silty; very light gray; medium hard, compact; slope former; tabular even; internally massive. Lower contact gradational. Trace of carbonaceous material. Sample 118-1 taken at the top	4
1.	Claystone (same as unit 4)	23
	Total estimated thickness	70

LOCALITY 119. MONTANA HIGHWAY 278 No. 1

NE¼SE¼NE¼ sec. 16, T. 6 S., R. 14 W.; Beaverhead County; in roadcut. Mapped as Tertiary Lake beds by Alden (1953, Pl. 1).

Unit		Measured thick. (ft)
14.	Sandstone, micaceous; streaked orange gray; very coarse grained, poorly sorted; very hard; ledge former; iron-stained; tabular even; internally thin-bedded; with cross-bedding. Minor amount of petrified wood	7.0
13.	Claystone; medium brownish gray; soft, plastic; slope former; thin to medium thick lenticular bed; with internal parallel even, very thin bedding. Lower contact sharp and regular. Forty feet long	.25
12.	Sandstone, feldspathic; streaked light yellowish gray; medium to coarse grained, moderately sorted, with subangular grains; hard, compact; ledge former; iron-stained; tabular even; internally medium bedded, with planar cross-bedding. Lower contact sharp and regular. Trace of heavy minerals. Sample 119-9 taken at the base	21.2
11.	Claystone, bentonitic; streaked dark brown; soft, plastic; slope former; iron-stained; tabular even; with internal parallel even, very thin bedding. Lower contact sharp and regular.	

LOCALITY 119. (continued)

Unit — Measured thick. (ft)

11. (cont.) Subordinate carbonaceous material. Sample 119-8 taken at the top 14.4

10. Sandstone (50%), arkosic, micaceous; streaked yellowish orange; coarse to very coarse grained, moderately to poorly sorted, with subangular grains; hard, compact; slope former; tabular even; internally thin bedded, with planar cross-bedding. Contains interbeds of brown carbonaceous clay. Sample 119-7 near top........

Sandstone (50%), arkosic, micaceous; streaked medium orange brown; very coarse grained; poorly sorted, with subangular grains; soft, friable; slope former; tabular even; with internal parallel uneven, medium bedding. Lower contact sharp and regular. Sample 119-6 taken at the base, in the oxidized zone 14

9. Claystone, bentonitic; grayish brown; soft, plastic; slope former; manganese-stained; tabular even; with internal parallel even, thin bedding. Lower contact sharp and regular. Trace of carbonaceous material. Sample 119-5 taken at the top.... 10.1

8. Sandstone, feldspathic, micaceous; dusky yellow; coarse grained, moderately sorted, with subangular grains; soft, friable; slope former; iron and manganese-stained; tabular even; internally massive. Lower contact sharp and regular. Trace of heavy minerals. Sample 119-4 taken from strongly iron-stained zone at the base 7.1

7. Claystone, bentonitic; dark yellowish brown; medium hard, compact; slope former; iron and manganese-stained; tabular even; with internal parallel even, thin bedding. Lower contact sharp and regular. Sample 119-3 taken at the top... 5.8

6. Sandstone, micaceous; streaked medium greenish brown; coarse grained, poorly sorted; soft, friable; slope former; iron and manganese-stained; tabular even; with internal parallel even, thin bedding. Lower contact sharp and regular. Strongly iron-stained at base........ 2.7

5. Claystone; streaked medium greenish brown; medium hard, compact; slope former; iron and manganese-stained; tabular even; with internal parallel even, thin bedding. Lower contact sharp and regular. Trace of carbonaceous material........ 9.0

4. Sandstone; streaked medium greenish brown; coarse grained, poorly sorted; soft, friable; slope former; iron-stained; tabular even; internally massive. Lower contact sharp and regular. Trace of carbonaceous material. Strongly iron-stained at base........ 2.0

LOCALITY 119. (continued)

Unit — Measured thick. (ft)

3. Claystone; streaked medium greenish brown; medium hard; slope former; iron-stained; tabular even; with internal parallel even, very thin bedding. Lower contact sharp and regular. Contains very thin, greenish gray, medium hard siltstone and soft, coarse grained, poorly sorted, sandstone interbeds.... 22.7

2. Sandstone, feldspathic, micaceous; orange brown; coarse to very coarse grained, poorly sorted, with subangular grains; soft, friable; slope former; deeply iron and manganese-stained; tabular even; with internal parallel even, medium bedding. Lower contact sharp and regular. Sample 119-2 taken from strongly iron-stained, clayey, and carbonaceous bed at base. 7.0

1. Claystone, micaceous, bentonitic; streaked moderate olive brown; medium hard, plastic; slope former; manganese-stained; tabular even; with internal parallel even, thin bedding. Sample 119-1 .... 1.0

Total measured thickness 124.25

LOCALITY 120. SOUTHEAST JACKSON

NE¼NE¼NE¼ sec. 6, T. 6 S., R. 14 W.; Beaverhead County; on hilltop directly east of locality 121, on the north side of Highway 278. Outcrops form hard cap on second level terrace. Mapped as Tertiary lake beds by Alden (1953, Pl. 1).

Unit — Estimated thick. (ft)

1. Sandstone (50%), micaceous; pale yellowish brown; coarse to very coarse grained, poorly sorted, with angular grains; very hard, compact; ledge former; quartz cement; tabular even; internally thin bedded, with planar cross-bedding. Conglomeratic in places. Minor amount of heavy minerals. Sample 120-2 ....

Conglomerate (50%), micaceous; yellowish gray; with subangular cobbles of quartzite (70%), quartz (30%); in a matrix of moderately sorted, medium grained, feldspathic sandstone; hard, compact; ledge former; tabular even; internally thin bedded with planar cross-bedding. Trace of heavy minerals. Sample 120-1 10

LOCALITY 121. MONTANA HIGHWAY 278 No. 2

NW¼SE¼NE¼ sec. 6, T. 6 S., R. 14 W.; Beaverhead County; in roadcut. Mapped as Tertiary lake beds by Alden (1953, Pl. 1).

LOCALITY 121. (continued)

Unit		Estimated thick. (ft)
2.	Sandstone, conglomeratic, arkosic; very micaceous; yellowish gray; coarse to very coarse grained, poorly sorted, with subangular grains; and pebbles of predominantly quartzite and argillite; hard, compact; ledge former; iron-stained; tabular even; internally medium bedded, with planar cross-bedding. Lower contact gradational. Contains many thin pebble conglomerate beds. Sample 121-2 taken at base	20
1.	Claystone, silty, micaceous; yellowish gray; medium hard, compact; slope former; iron-stained; tabular even; with internal parallel even, thin bedding. Contains several lenses of medium hard, coarse grained sand. Sample 121-1 taken at the top	120
	Total estimated thickness	140

LOCALITY 122. BULL CREEK

SE¼SW¼SE¼ sec. 36, T. 5 S., R. 15 W.; Beaverhead County; south side of highway 278. Mapped as Tertiary lake beds by Alden (1953, Pl. 1).

Unit		Estimated thick. (ft)
5.	Sandstone; similar to unit 1, but is more conglomeratic and contains larger clasts	15
4.	Covered	15
3.	Sandstone; similar to unit 1, but more conglomeratic and contains larger clasts	5
2.	Covered	20
1.	Sandstone, feldspathic, conglomeratic, micaceous; yellowish gray; coarse to very coarse grained, poorly sorted, with angular to subangular grains, and subangular pebbles of sandstone and quartzite and minor quartz, hard, compact; ledge former; siliceous cemented; tabular even; internally parallel even thin bedded with trough and planar cross-bedding. Trace of heavy minerals. Sample 122-1	15
	Total estimated thickness	70

LOCALITY 123. MEADOW CREEK

SE¼SW¼SE¼ sec. 32, T. 1 N., R. 11 W.; Beaverhead County; in gulch. Mapped as Tertiary sediments by Fraser and Waldrop (1972).

LOCALITY 123. (continued)

Unit		Estimated thick. (ft)
1.	Siltstone, clayey; light brownish gray; hard, compact; slope former; manganese stained; tabular even; internally massive. Sample 123-1	30

LOCALITY 124. HIGHWAY 43

SE¼SE¼NE¼ sec. 32, T. 1 N., R. 11 W.; Beaverhead County; roadcut 0.8 miles west of Wise River. Mapped as Tertiary sediments by Fraser and Waldrop (1972).

Unit		Estimated thick. (ft)
3.	Siltstone, clayey; light brown; soft; internal very thin bedding	3
2.	Conglomerate, very micaceous; medium dusky yellow; with rounded pebble and cobbles of quartzite (70%), volcanic rocks (20%) and granite (10%); in a course matrix of poorly sorted, subangular, feldspathic sandstone; soft, friable; slope former; lenticular channel; internally massive. Lower contact sharp and regular. Trace of magnetic minerals. Sample 124-1	3
1.	Claystone, sandy; greenish brown; soft, friable; slope former; internally massive	6
	Total estimated thickness	12

LOCALITY 125. BITTERROOT RIVER BLUFFS

NE¼SE¼NW¼ sec. 6, T. 10 N., R. 19 W.; Ravalli County; west-facing bluffs between Woodchuck and Eight Mile Creeks. Two of the thickest sandstone beds and one claystone bed were sampled. Tertiary sedimentary rocks measured and described by McMurtrey (McMurtrey and others, 1972, p. 19-20). (The units of McMurtrey's measured section are numbered, for purposes of this presentation, from the base to the top.)

Unit		Measured thick. (ft)*
5.	Not described; units 11-17 of McMurtrey (McMurtrey and others, 1972, p. 19-20)	24.1
4.	Sandstone (50%); light gray; medium grained, poorly sorted; medium hard; slope former; internally thin bedded, with planar cross-bedding. Contains many thin pebbly channels... Sandstone (50%), micaceous; streaked orange olive brown; coarse grained, poorly sorted, with subangular grains; soft, friable; slope former; iron-stained; tabular even; internally thin bedded with planar cross-bedding. Lower contact sharp and irregular. Trace of heavy minerals. Contains many thin pebbly channels. Units 7, 8, 9, and 10 of McMurtrey (McMurtrey and others, 1972, p. 19-20). Sample 125-3 taken at base	21.75

LOCALITY 125. (continued)

Unit		Measured thick. (ft)*
3.	Claystone; pale olive; medium hard, compact; slope former; tabular even; internally very thin bedded. Lower contact gradational. Carbonaceous. Unit 6 of McMurtrey (McMurtrey and others, 1972, p. 19-20). Sample 125-2	8
2.	Not described. Units 2-5 of McMurtrey (McMurtrey and others, 1972, p. 19-20)	70.5
1.	Sandstone, feldspathic, slightly micaceous; streaked dark yellowish orange; coarse grained, poorly sorted, with subrounded grains; medium hard, friable; cliff former; iron-stained; tabular even; internally thin bedded, with planar cross-bedding. Lower contact covered. Contains several thin pebbly channels. Unit 1 of McMurtrey (McMurtrey and others, 1972, p. 19-20). Sample 125-1 taken at the base in beds with the deepest iron-staining	30
	Total measured thickness	154.25

LOCALITY 126. SCHROEDER RANCH

NW¼NE¼NW¼ sec. 30, T. 11 N., R. 19 W.; Missoula County; west-facing river cut west of road. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955). Mapped by Jerome (1968, Pl. 1) as Quaternary sediments.

Unit		Estimated thick. (ft)
4.	Siltstone, clayey; tan; soft to medium hard, friable, slope former	25
3.	Conglomerate, granitic; streaked yellowish gray; with rounded pebbles to boulders of granite (80%), metamorphic (10%) and quartzite (10%); in a matrix of moderately sorted, subangular, medium grained, arkosic sandstone; medium hard, compact; cliff former; iron-stained; lenticular channel; internally thin bedded with planar cross-bedding. Lower contact sharp and irregular. Minor magnetite. Sample 126-2 taken at base	15
2.	Sandstone, clayey, feldspathic, micaceous; medium yellowish gray; fine grained, poorly sorted; medium hard, compact; ledge former; iron-stained; tabular even; internal parallel even, thin bedding. Lower contact covered. Trace heavy minerals. Sample 126-1 taken at top	5
1.	Claystone; dark grayish green; medium hard, compact; ledge former	1
	Total estimated thickness	46

*Thicknesses from McMurtrey (McMurtrey and others, 1972, p. 19-20).

LOCALITY 127. SPRING GULCH RAILROAD GRADE

SE¼SW¼SE¼ sec. 30, T. 10 N., R. 18 W.; Ravalli County; roadcut on the north side of road. Mapped as Tertiary sedimentary rocks by McMurtrey and others (1972, Pl. 1).

Unit		Estimated thick. (ft)
1.	Sandstone, feldspathic, micaceous, clayey; medium yellowish brown; medium grained, poorly sorted, with angular grains; soft, friable; slope former; tabular even; internally massive. Trace of heavy minerals. Sample 127-1	5

LOCALITY 128. SPRING GULCH

SW¼NE¼SE¼ sec. 25, T. 10 N., R. 19 W.; Ravalli County; sou*heast facing bluff, 0.2 miles north of road. Mapped as Tertiary sedimentary rocks, and measured by McMurtrey and others (1972, Pl. 1, p. 15). The following units are the uppermost two units in McMurtrey's measured section which is a total of 227 feet thick.

Unit		Measured thick. (ft)*
2.	Siltstone, conglomeratic, sandy, micaceous; yellowish gray; with angular pebbles of granite, quartzite, and argillite; hard, compact; ledge former; silicious cemented; manganese-stained; tabular even; internally massive. Lower contact gradational. Trace of heavy minerals. Sample 128-2 taken at the base	17
1.	Sandstone, silty, feldspathic; yellowish gray; coarse to very coarse grained; poorly sorted; with subangular grains; hard, compact; ledge former; tabular even shape. Internally massive. Lover contact covered. Trace of heavy minerals. Pebbly in places. Sample 128-1 taken at the top	10
	Total estimated thickness	27

LOCALITY 129. BITTERROOT CANAL

NE¼SW¼NE¼ sec. 35, T. 10 N., R. 19 W.; Ravalli County; in west-facing ditch cut, 0.5 mile east of Three Mile Creek and 0.4 mile south of Brown's ranch. Mapped as Tertiary sedimentary rocks by McMurtrey and others (1972, Pl. 1).

Unit		Estimated thick. (ft)
1.	Siltstone, feldspathic, sandy (60%); dark grayish orange; medium hard, compact; slope former; tabular even; internally massive. Minor carbonaceous material and heavy minerals. Sample 129-1	
	Sandstone (40%), arkosic; medium brown; coarse to very coarse grained, poorly sorted, with subangular grains; medium hard, friable; slope former; iron-stained; tabular even; internally massive. Trace heavy minerals. Sample 129-2	15

*Thicknesses from McMurtrey and others (1972, p. 15).

LOCALITY 130. AMBROSE CREEK

SW¼NE¼NW¼ sec. 16, T. 9 N., R. 19 W.; Ravalli County; in gravel pit near the intersection of two small creeks. Mapped as Tertiary sedimentary rocks by McMurtrey and others (1972, Pl. 1).

Unit		Estimated thick. (ft)
1.	Sandstone, clayey, micaceous; light olive brown; medium grained, moderately sorted, with subangular grains; soft, friable; slope former; lenticular bed; internally very thin bedded, with planar cross-bedding. Minor replaced carbonaceous material. Contains many thin to medium conglomeratic channels with abundant yellow mineralized woody material and pebbles of granite (50%), feldspar (25%), quartz and volcanic rocks. Sample 130-1	6

LOCALITY 131. SOUTH FORK WILLOUGHBY CREEK No. 1

SW¼SW¼SW¼ sec. 16, T. 8 N., R. 19 W.; Ravalli County; hill slope on northeast side of road. Mapped as Tertiary sedimentary rocks by McMurtrey and others (1972, Pl. 1).

Unit		Estimated thick. (ft)
1.	Siltstone, tuffaceous; yellowish gray; hard, compact; cliff former; tabular even; internally massive. Minor carbonaceous material. Contains calcareous nodules, glass shards, some quartzite pebbles, and some pebbles of calcareous siltstone. Also contains several medium thick conglomerate channels. Sample 131-1	60

LOCALITY 132. DRY GULCH

SW¼SE¼SW¼ sec. 36, T. 8 N., R. 20 W.; Ravalli County; south-facing stream cut, about 30 feet north of road. Mapped as Tertiary sedimentary rocks by McMurtrey and others (1972, Pl. I).

Unit		Estimated thick. (ft)
1.	Conglomerate (70%) clayey; very pale orange; with subrounded pebbles of quartzite and argillite in a matrix of clay; hard, compact; ledge former; calcareous cement; lenticular channel; internally massive in medium to thick beds. Lower contact sharp and irregular. Minor heavy minerals. Irregular knobby weathering surface; chaotic bedding attitudes. Sample 132-2	
	Sandstone (30%), silty; yellowish gray; very fine grained, poorly sorted, with angular grains; soft, loose; slope former; calcareous cement; tabular even; internally massive in medium beds. Minor heavy minerals. Sample 132-1	20

LOCALITY 133. BLODGETT CREEK

SW¼NW¼SE¼ sec. 11, T. 6 N., R. 21 W.; Ravalli County; on north side of creek, 0.3 mile east of Blodgett Cemetery. Exposure 100 feet to the east of this location. Consists of 23 feet of tuffaceous, soft to medium hard, carbonaceous siltstone overlain by 15 feet of soft, poorly consolidated gravel. Mapped as Tertiary sedimentary rocks by McMurtrey and others (1972, Pl. 1).

Unit		Estimated thick. (ft)
2.	Conglomerate, granitic; dusky yellow; rounded pebbles of granite in a matrix of medium grained, subangular, poorly sorted, feldspathic, micaceous sand; medium hard, friable; slope former; iron-stained; tabular even; internally massive. Lower contact sharp and regular. Sample 133-2	3
1.	Siltstone, sandy, micaceous; light gray; medium hard, compact; slope former; tabular even; internally massive. Sample 133-1 taken at the top	3
	Total estimated thickness	6

LOCALITY 134. ELK CREEK

SW¼SW¼NW¼ sec. 5, T. 13 N., R. 14 W.; Missoula County; roadcut on southwest side of road. Mapped as Tertiary basin deposits by Brenner (1964, Pl. 1, p. 26–27).

Unit		Estimated thick. (ft)
1.	Sandstone, clayey, arkosic; dark yellowish orange; fine to coarse grained, poorly sorted, with subangular grains, in a clay matrix; hard, compact; slope former; iron-stained; tabular even; with internal parallel even, very thin bedding. Minor carbonaceous material. Sample 134-1 was taken from the upper iron-stained part of the unit	6

LOCALITY 135. HIGHWAY 20 No. 1

NW¼NW¼SW¼ sec. 17, T. 13 N., R. 15 W.; Missoula County; in roadcut. Mapped as Tertiary basin deposits by Brenner (1964, Pl. 1, p. 26–27).

Unit		Estimated thick. (ft)
1.	Siltstone, clayey; streaked very pale orange to massive gray and brown; hard, compact; slope former; iron and manganese-stained; tabular even; internally massive. Minor carbonaceous material. Sample 135-1 taken from the most carbonaceous part of the unit	20

LOCALITY 136. NUMBER FIVE DITCH

SW¼NW¼NW¼ sec. 32, T. 13 N., R. 11 W.; Powell County; on southeast side of bluff, by an intermittent tributary to ditch. Mapped as Tertiary sediments by Ross and others (1955).

Unit		Estimated thick. (ft)
1.	Siltstone (50%), clayey, micaceous; streaked light olive gray; medium hard, compact; slope former; iron-stained; tabular even; internally massive. Minor carbonaceous material. Sample 136-1	
	Claystone (40%), bentonitic; tannish gray; medium hard; internally massive. Trace of carbonaceous material. Weathers to a soft, friable surface.	
	Sandstone (10%); medium orange brown; fine grained; poorly sorted; with subangular grains; soft, friable; slope former; iron-stained; tabular even; internally massive. Trace of heavy minerals. Sample 136-2	40

LOCALITY 137. STATE HIGHWAY 271

SE¼SW¼SW¼ sec. 26, T. 12 N., R. 12 W.; Powell County; in roadcut on east side of highway. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955). Konzeski (1961, p. 1633-1641) reports an Early Oligocene age for the sediments, from vertebrate fauna collected in the valley.

Unit		Estimated thick. (ft)
1.	Claystone, silty; medium brownish gray; medium hard, compact; slope former; manganese stained; tabular even; internally massive. Sample 137-1	5

LOCALITY 138. TROUT CREEK

SW¼SW¼SE¼ sec. 1, T. 9 N., R. 8 W.; Powell County; on south-facing hillside, 500 feet north of road. Mapped as Tertiary sediments by Ross and others (1955). Miocene-Pliocene according to paleontological work by Douglass (1902, p. 239) south of Avon.

Unit		Estimated thick. (ft)
1.	Claystone, silty; medium reddish brown; medium hard, compact; slope former; tabular even; internally massive. Trace carbonaceous material. Contains minor volcanic sand grains. Sample 138-1	50

LOCALITY 139. ILLINOIS GULCH

SE¼NW¼SW¼ sec. 25, T. 11 N., R. 8 W.; Powell County; in canal cut on north side of road, 0.8 mile southwest of Blackfoot City. Mapped as Tertiary sediments by Ross and others (1955).

LOCALITY 139. (continued)

Unit		Estimated thick. (ft)
1.	Sandstone, clayey, micaceous; light olive gray; medium grained, poorly sorted with subangular grains, in a clay matrix; soft, friable; slope former; tabular even; internally massive. Minor carbonaceous material and heavy minerals. Contains some granite pebbles. Sample 139-1	2

LOCALITY 140. AVON GRAVEL PIT

NW¼NW¼NW¼ sec. 15, T. 10 N., R. 8 W.; Powell County; at the contact of Tertiary sedimentary rock undifferentiated and Tertiary volcanics according to Ross and others (1955). Samples were taken from the most radioactive part of the altered volcanics (unit 1) and from volcanic breccia (unit 2).

Unit		Estimated thick. (ft)
2.	Breccia volcanic; light brownish red; with angular cobbles of volcanic rock in a matrix of poorly sorted angular sandstone; medium hard, compact; slope former; irregular shape; internally massive. Lower erosional contact sharp and irregular. Sample 140-2	3
1.	Volcanic rock, hydrothermally altered; streaked yellowish red; soft to medium hard; friable to compact. Sample 140-1 taken from fault zone	12
	Total estimated thickness	15

LOCALITY 141. SIX MILE CREEK

NW¼NW¼SW¼ sec. 32, T. 11 N., R. 8 W.; Powell County; in lower terrace on th east side of the Avon Valley. Mapped as Tertiary sediments by Ross and others (1955). Oligocene according to paleontological work by Douglass (19 p. 239) in an area a few miles north of Avon.

Unit		Estimated thick. (ft)
1.	Claystone; light olive brown (weathers to light brown); soft, plastic; slope former; manganese stained; tabular even; internally massive. Minor carbonaceous material. Sample 141-1	25

LOCALITY 142. NEW CHICAGO

SE¼NE¼NE¼ sec. 17, T. 10 N., R. 12 W.; Granite County; west side of road. Mapped as Flint Creek beds (Miocene to Pliocene) by Gwinn (1960). Strike N. 55° W., 18° to the south.

LOCALITY 142. (continued)

Unit	Estimated thick. (ft)
1. Siltstone (90%), tuffaceous; dusky yellow; medium hard, compact; slope former; iron and manganese stained; tabular even; with internal parallel even thin bedding. Minor carbonaceous material and trace of heavy minerals. Contains load casts at contact with sandstone and manganese dendrites associated with carbonaceous material. Sample 142-1	
Sandstone (10%), tuffacous; light olive gray; very fine grained, moderately well sorted; soft, friable; slope former; iron-stained; tabular even; with internal parallel even, thin bedding. Minor carbonaceous material and subordinate heavy minerals. Sample 142-2 taken from contact with siltstone...	40

LOCALITY 143. WILLOW CREEK

NE¼SE¼NW¼ sec. 30, T. 7 N., R. 15 W.; Granite County; roadcut. Mapped as Tertiary sediments by Ross and others (1955).

Unit	Estimated thick. (ft)
1. Conglomerate, micaceous; yellowish orange; with subrounded cobbles of quartzite and argillite (90%); siltstone, conglomerate and volcanics (10%); in a silt matrix; medium hard, compact; ledge former; iron-stained; tabular even; internally massive. Sample 143-1	30

LOCALITY 144. ANTELOPE CREEK

SW¼NE¼SE¼ sec. 17, T. 6 N., R. 15 W.; Granite County; south-facing slope on the north side of creek. Mapped as Tertiary lakebeds by Alden (1953, Pl. 1).

Unit	Estimated thick. (ft)
1. Conglomerate; pale yellow; with rounded pebbles of quartzite and argillite in a matrix of moderately sorted, subrounded, coarse to very coarse grained sandstone; hard, compact; cliff former; strongly iron-stained; lenticular channel; internally medium bedded, with planar cross-bedding. Contains many medium thick lenticular conglomeratic sandstone beds. Sample 144-1	40

LOCALITY 145. WEST FORK ROCK CREEK

SE¼SW¼NW¼ sec. 36, T. 6 N., R. 16 W.; Granite County; south-facing cliff on the north side of road. Mapped as Quaternary gravel by Ross and others (1955); this unit is considered by us to be Tertiary because of its hard well-cemented nature and lithologic similarity to sediments mapped as Tertiary to the south near the McDonald Mine.

LOCALITY 145. (continued)

Unit	Estimated thick. (ft)
1. Conglomerate; streaked grayish red; with rounded cobbles of quartzite and argillite in a matrix of poorly sorted arkosic sandy claystone; very hard, compact; cliff former; silica and chert cement; iron and manganese-stained; tabular even; internally massive. Sample 145-1	200

LOCALITY 146. BACON DITCH

NE¼NW¼NW¼ sec. 26, T. 2 N., R. 13 W.; Deer Lodge County; south-facing ditch cut, about 100 feet west of forest service road. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955).

Unit	Estimated thick. (ft)
1. Conglomerate; pale olive; with subrounded pebbles of predominantly quartzite and minor volcanics in a matrix of poorly sorted, subangular, medium grained sandy clay; medium hard, compact, slope former; tabular even; internally massive. Minor carbonaceous material. Sample 146-1	6

LOCALITY 147. LA MARCHE CREEK

NW¼SW¼NW¼ sec. 26, T. 2 N., R. 13 W.; Deer Lodge County; next to the forest service road. Mapped as Tertiary sediments by Ross and others (1955).

Unit	Estimated thick. (ft)
1. Interbedded silts and clays (60%); soft; slope former, with thin to very thin bedding	
Sandstone (40%), micaceous; streaked medium orange gray; medium to coarse grained, poorly sorted; with subangular grains; soft, friable; slope former; iron-stained; tabular even; internally massive. Sample 147-1	8

LOCALITY 148. FRENCH CREEK

SW¼SE¼SE¼ sec. 3, T. 2 N., R. 12 W.; Deer Lodge County; steep stream cut west of French Creek. Mapped as Tertiary sediments by Ross and others (1955).

Unit	Estimated thick. (ft)
1. Tuffaceous siltstone/vitric tuff (95%); light to medium gray and brown; medium hard to hard, compact; cliff former; iron-stained; tabular even; with internal parallel even, very thin to medium bedding. Lower contact sharp and regular. Minor heavy minerals. Large variation in amount of carbonaceous material. Contains claystone interbeds which are light gray, medium hard, medium to thick bedded, iron and manganese-stained. Also contains two medium thick tuff beds. Sample 148-1	

LOCALITY 148. (continued)

Unit	Estimated thick. (ft)
1. (cont.) Sandstone (5%), arkosic, micaceous; light olive brown; medium to coarse grained, poorly sorted; with subangular grains; soft, friable; slope former; iron-stained; lenticular bed; with internal parallel even, medium bedding. Trace of heavy minerals. Sample 148-2	100

LOCALITY 149. HOME RANCH

NW¼NW¼NE¼ sec. 10, T. 2 N., R. 12 W.; Deer Lodge County; stream cut 0.7 mile east of ranch and 0.2 mile southwest of locality 148. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955).

Unit	Measured thick. (ft)
5. Siltstone, micaceous; streaked medium greenish brown; medium hard, compact; slope former; iron-stained; tabular even; with internal parallel even thick bedding. Lower contact sharp and regular	15.6
4. Sandstone, volcanic, silty; light brownish gray; very coarse grained, poorly sorted; with subrounded grains; medium hard, friable; ledge former; tabular even; internally thin bedded, with planar cross-bedding. Lower contact sharp and regular	4.0
3. Claystone, sandy; medium brownish gray; soft, plastic; slope former; tabular even; with internal parallel even, medium bedding. Lower contact gradational	9.3
2. Sandstone, micaceous, conglomeratic; banded moderate olive brown (weathers to uniform medium gray); medium to coarse grained, poorly sorted, with subangular grains and subrounded pebbles of quartzite; soft, friable; slope former; iron-stained; tabular uneven; with internal parallel even, thin bedding. Lower contact gradational. Trace of heavy minerals. Sample 149-2 taken at the base	16.2
1. Siltstone, clayey; medium yellowish brown (weathers to medium brownish gray); medium hard, compact; ledge former; tabular even, with internal parallel even, medium bedding. Minor to trace carbonaceous material. Contains several medium thick beds of gray volcanic ash. Sample 149-1 taken at the top	35.3
Total measured thickness	80.4

LOCALITY 150. PRAIRIE GULCH

NE¼NE¼NW¼ sec. 35, T. 6 N., R. 11 W.; Deer Lodge County; south-facing road(Strike N. 340° W. and dip 21° to the west. Mapped as Modesty Creek beds (Miocene-Pliocene) by Csejtey (1963, Pl. 1, p. 48 thru 51).

Unit	Estimated thick. (ft)
1. Conglomerate, metamorphic; grayish orange; with subrounded cobbles of quartzite and argillite (95%) and volcanics (5%); in a sandy silt matrix; hard, compact; ledge and pinnacle former; calcareous cemented; iron-stained; tabular even; with internal parallel uneven medium bedding. Contains several hard, iron-stained, siltstone interbeds. Sample 150-1	200

LOCALITY 151. SAND HOLLOW

SE¼NW¼SE¼ sec. 21, T. 6 N., R. 9 W.; Deer Lodge County; west-facing bluff, on east side of Clark Fork River. Mapped as Pliocene fluvial deposits by Konizeski and others (1962, Pl. 1).

Unit	Estimated thick. (ft)
1. Siltstone (80%), sandy, tuffaceous, micaceous, conglomeratic; light grayish brown; with subangular pebbles of granite (70%), and volcanic rocks (30%); soft to medium hard, compact; slope former; tabular even; with internal parallel even, thin bedding. Lower contact sharp and irregular. Minor amount of heavy minerals. Contains glass shards. Sample 151-2 from thin conglomeratic lens	
Sandstone (20%), arkosic, micaceous; dark grayish orange; coarse grained, poorly sorted; with subangular grains; soft, friable; slope former; tabular even; medium thick; with internal parallel even, thin bedding. Lower contact with siltstone sharp and regular. Minor amount of heavy minerals (magnetite). Sample 151-1	60

LOCALITY 152. ROCK CREEK DITCH

NW¼SW¼SE¼ sec. 10, T. 8 N., R. 10 W.; Powell County; roadcut. Mapped as Miocene lacustrine and fluvial deposits by Konizeski and others (1962, Pl. 1, pp. 13-16).

Unit	Estimated thick. (ft)
1. Claystone (90%), brown, pink and green; soft to medium hard, plastic to frangible; slope former; with internal parallel even medium bedding.	
Sandstone (10%), medium brownish gray; fine to very fine grained, moderately sorted; hard; ledge former; internally very thin bedded with planar cross-bedding. Lower contact with claystone is sharp, regular	20

LOCALITY 153. COTTONWOOD CREEK

NE¼NE¼NE¼ sec. 8, T. 7 N., R. 8 W.; Powell County; roadcut. Mapped as Miocene lacustrine and fluvial deposits by Konizeski and others (1962, Pl. 1, pp. 13-16).

Unit		Estimated thick. (ft)
4.	Claystone, silty, micaceous; greenish gray; with green and yellow streaks; soft; slope former; tabular even. Lower contact sharp and regular. Minor biotite	30
3.	Sandstone, micaceous; greenish gray with yellowish green streaks; fine grained, moderately sorted; hard; slope former; tabular even; with internal, parallel even, thin bedding. Lower contact sharp, regular. Subordinate biotite. Contains several very thin interbeds, of hard siltstone (fissile)	3
2.	Claystone (same as unit 4)	10
1.	Conglomerate, volcanic, greenish brown; with subrounded cobbles of basalt and rhyolite in a matrix of silicic medium grained sandstone; hard; slope former; tabular even	4
	Total estimated thickness	47

LOCALITY 154. GOLD CREEK

SW¼NE¼NW¼ sec. 35, T. 10 N., R. 11 W.; Powell County; in erosion cut of bluffs, one mile west of Gold Creek, Montana. Mapped as volcanic rich silts and clays by Mutch (1961).

Unit		Estimated thick. (ft)
1.	Claystone and siltstone, conglomeratic; tan-light gray; with rounded to subrounded pebbles of volcanic rocks (50%), limestone (40%), and quartzite (10%); hard; slope former; tabular even; internally massive	20

LOCALITY 156. SHERRY TOP SWITCHING STATION

NE¼NE¼SE¼ sec. 19, T. 10 N., R. 12 W.; Granite County; in erosion cut under power lines in northwest-facing bluffs. Mapped as Flint Creek formation by Gwinn (1961).

Unit		Estimated thick. (ft)
1.	Siltstone, and claystone; tan to light gray; soft to medium hard; slope former; internally massive. Siltstone contains 10-20% nodular silty limestone	50

LOCALITY 157. BARNES CREEK GRAVEL PIT

WN¼NE¼NE¼ sec. 31, T. 10 N., R. 12 W.; Granite County; Mapped as Barnes Creek gravel by Gwinn (1961).

LOCALITY 157. (continued)

Unit		Estimated thick. (ft)
1.	Sandstone (50%), conglomeratic; tan; coarse grained, poorly sorted, with pebbles; soft, unconsolidated; slope former; internally thin bedded, with planar cross-bedding. Gravel (50%); tan; with pebbles in a matrix of poorly sorted, coarse grained, sandstone; soft; slope former; internally thin bedded, with planar cross-bedding	8

LOCALITY 158. ALLENDALE DITCH

SW¼NE¼SW¼ sec. 2, T. 10 N., R. 13 W.; Granite County; in stream cut, one mile west of the Drummond Radio Range Station. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955).

Unit		Estimated thick. (ft)
4.	Shale; greenish gray to dark brown; soft to medium hard; slope former; internally very thin bedded, very fissile. Lower contact sharp, regular. Trace of carbonaceous material (plant stems and fragments)	1.5
3.	Claystone; brownish yellow, with dark gray and black speckles of manganese stain; medium hard; slope former; internally thin bedded. Lower contact sharp, regular	1
2.	Shale, (same as unit 4)	5
1.	Siltstone, sandy, conglomeratic, calcareous; tan; with angular pebbles of limestone; medium hard; internally massive. Contains a few thin planar cross-beds	25
	Total estimated thickness	32.5

LOCALITY 159. MORSE RANCH

NW¼SE¼SE¼ sec. 3, T. 10 N., R. 12 W.; Granite County; in gully. Mapped as Cabbage Patch formation by Gwinn (1961), and Rasmussen (1969, Pl. 1, pp. 21-79).

Unit		Estimated thick. (ft)
1.	Claystone; tan to light gray; medium hard; slope former; internally massive	20

LOCALITY 160. MORRIS CREEK

NW¼SW¼NE¼ sec. 3, T. 10 N., R. 12 W.; Granite County; Mapped as Cabbage Patch formation by Gwinn (1961), and Rasmussen (1969, Pl. 1, pp. 21-79).

LOCALITY 160. (continued)

Unit		Estimated thick. (ft)
1.	Claystone; tan to light gray; medium hard; slope former; internally massive	15

LOCALITY 165. PINTLAR CREEK

SE¼SW¼SW¼ sec. 24, T. 1 N., R. 15 W.; Deer Lodge County; on hillside east of road to Pintlar Lake at the National Forest boundary line. Mapped as Tertiary sedimentary rock undifferentiated by Ross and others (1955).

Unit		Estimated thick. (ft)
1.	Siltstone, reddish tan; hard; ledge former; manganese stained; internally massive	3.5

LOCALITY 166. NORTH BENCH No. 1

SW¼NW¼NE¼ sec. 20, T. 9 N., R. 19 W.; Ravalli County; in small gravel pit. Mapped as Tertiary sedimentary rocks by McMurtrey and others (1972, Pl. 1).

Unit		Estimated thick. (ft)
1.	Sandstone, arkosic, conglomeratic; tan to gray; coarse-grained, moderately to poorly sorted, with subangular grains and pebble and cobble clasts of granite and sandstone; soft, internally medium bedded	10

LOCALITY 167. NORTH BENCH No. 2

NW¼SW¼NW¼ sec. 21, T. 9 N., R. 19 W.; Ravalli County; in garbage pit. Mapped as Tertiary sedimentary rocks by McMurtrey and others (1972, Pl. 1).

Unit		Estimated thick. (ft)
1.	Vitric tuff (?), (tuffaceous sandstone); light gray; very fine grained, well sorted; soft; very thin to thin bedding	3

LOCALITY 171. JOHNSON'S GULCH GRAVEL PIT

NE¼SW¼SE¼ sec. 16, T. 6 N., R. 20 W; Ravalli County. Mapped as Tertiary sedimentary rocks by McMurtrey and others (1972, Pl. 1).

Unit		Estimated thick. (ft)
1.	Sandstone (60%), arkosic; light gray; coarse grained, poorly sorted, with angular to subangular grains; soft, with internal medium planar, cross-bedding. Lower contact sharp, regular	
	Conglomerate (40%), sandy, granitic; light gray; with pebbles of granite (50%), quartzite and argillite (50%), in a matrix of poorly sorted, coarse grained, arkosic sandstone; soft; forms medium thick lenticular channels. Lower contact sharp, regular	20

LOCALITY 172. BITTERROOT IRRIGATION CANAL No. 2

NE¼NE¼SE¼ sec. 14, T. 6 N., R. 20 W.; Ravalli County. Mapped as Tertiary sedimentary rocks by McMurtrey and others (1972, Pl. 1).

Unit		Estimated thick. (ft)
1.	Siltstone (90%) brown, medium hard; internally massive. Minor carbonaceous material.	
	Sandstone (10%), conglomeratic, arkosic; light gray; coarse grained, poorly sorted, with pebbles; soft; lenticular channel. Lower contact with siltstone sharp, regular	15

LOCALITY 177. DOUGLAS CREEK

NE¼SW¼NE¼ sec. 20, T. 12 N., R. 12 W.; Powell County; roadcut near a small lake. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955).

Unit		Estimated thick. (ft)
1.	Siltstone, tuffaceous, bentonitic; tan to gray with gray streaks; medium hard; slope former; tabular even with internally massive beds. Minor carbonaceous material in vugs and fractures associated with manganese staining. Weathers to nodules and knobby surface features	5

LOCALITY 179. HIGHWAY 271

NW¼NW¼NW¼ sec. 26, T. 12 N., R. 12 W.; Powell County; roadcut on the east side of highway. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955) and Tertiary lake beds by Shea (1947, Pl. 1). Konizeski (1961, p. 1633-1641) gives an Early Oligocene age from vertebrate fauna.

Unit		Estimated thick. (ft)
1.	Claystone; light gray to tan; medium hard; slope former; tabular even, and internally massive. Trace of carbonaceous material associated with manganese staining	25

LOCALITY 180. SPOTTED DOG CREEK

NW¼SE¼SE¼ sec. 27, T. 10 N., R. 8 W.; Powell County; stream cut, 1 mile southeast of Avon, Montana. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955).

Unit		Estimated thick. (ft)
1.	Siltstone, sandy; brownish gray; soft, friable; slope former; internally massive. Sand grains are subrounded and volcanic (tuff, andesite, basalt)	6

LOCALITY 181. AVON

NE¼NE¼SE¼ sec. 21, T. 10 N., R. 8 W.; Powell County; roadcut on state highway 271, 0.4 mile north of Avon, Montana. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955).

Unit		Estimated thick. (ft)
1.	Claystone (95%), sandy, bentonitic; red, gray, and tan; soft to medium hard, plastic; slope former; tabular even with internal parallel even, thin beds. Minor carbonaceous material. Contains volcanic clasts which have weathered to soft clay.. Sandstone (5%); tan to gray; medium grained, poorly sorted, soft; with clayey matrix; slope former; lenticular..........	15

LOCALITY 183. HALFWAY CREEK

NW¼SE¼SE¼ sec. 35, T. 12 N., R. 9 W.; Powell County; on bluff on the east side and adjacent to highway 271. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955).

Unit		Estimated thick. (ft)
2.	Siltstone (95%); tan; soft; sticky; medium to thick bedding. Lower contact sharp, regular .... Sandstone (5%); tan; coarse grained, moderately sorted; soft, lenticular; with internal very thin bedding	10
1.	Claystone (same lithologic description as locality 182, and locality 141)	30
	Total estimated thickness	40

LOCALITY 188. DEEP CREEK

SW¼SE¼NE¼ sec. 9, T. 2 N., R. 12 W.; Deer Lodge County; in small gravel pit. Mapped as Tertiary sedimentary rocks undifferentiated by Ross and others (1955).

Unit		Estimated thick. (ft)
2.	Sandstone, conglomeratic; orange to brown with rusty to orange iron streaks and bands; very coarse grained; poorly sorted; with subrounded pebbles; medium hard; slope former; tabular even; with internal parallel even, thin to medium bedding. Lower contact sharp, regular	4
1.	Claystone; gray to brown; soft; slope former; tabular even; with internal parallel even, thin bedding	2
	Total estimated thickness	6

LOCALITY 189. TRAIL CREEK

SW¼SE¼NW¼ sec. 14, T. 5 N., R. 15 W.; Granite County; in stream cut on the south side of highway 28. Mapped as Tertiary clays - chiefly montmorillonite by Poulter (1956).

Unit		Estimated thick. (ft)
1.	Claystone, montmorillonitic; buff to reddish brown; soft, sticky, plastic, slope former; tabular even; internally massive. Contains a few very thin pebbly interbeds.........	10

LOCALITY 190. PORTERS CORNER

NW¼SE¼SE¼ sec. 22, T. 6 N., R. 14 W.; Granite County; poorly exposed section in roadcut on the east side of U.S. highway 10-A, 0.2 mile north of Porters Corner, Montana. Mapped as Quaternary alluvium by Ross and others (1955) but similar in lithology to Tertiary clays - chiefly montmorillonite of Poulter (1956).

Unit		Estimated thick. (ft)
1.	Claystone (70%), montmorillonitic; cream to reddish brown; soft to medium hard, sticky, plastic; slope former. Sandstone (30%), micaceous; tan to gray; coarse grained, poorly sorted; soft; slope former; tabular even. Lower contact with claystone is sharp, regular...........................	7

LOCALITY 201. SUNLIGHT MINE

NW¼NE¼SE¼ sec. 31, T. 2 N., R. 3 W.; Jefferson County; at south end of Bull Mountain, south of Sunlight Mine. Units 1 and 2 described below correspond to units 2 and 3, respectively, of measured section number 6 of Kuenzi (1966, p. 269). Climbing Arrow Member of Renova Formation.

Unit		Estimated thick. (ft)
2.	Conglomerate, granite; yellowish gray; with rounded pebbles, in a matrix of moderately sorted, very coarse grained, arkosic sandstone; very hard, compact; ledge former; low permeability; tabular even; internal parallel even, thin bedding. Lower contact sharp, regular. Minor biotite and some smokey quartz. Sample 201-2	4
1.	Claystone; light olive gray (weathers to light gray); soft, plastic; slope former; internal parallel even, medium thick bedding. Trace carbonaceous material. Sample 201-1..	6
	Total estimated thickness	10

LOCALITY 202. MAYFLOWER GULCH

NW¼NW¼SW¼ sec. 17, T. 1 N., R. 3 W.; Madison County; NE rim of Parrot Bench on west side of gulch. Unit described below appears to correspond to unit 266 of measured section number 2 of Kuenzi (1966, p. 221). Upper portion of Sixmile Creek Formation.

Unit		Estimated thick. (ft)
1.	Sandstone, tuffaceous, feldspathic; light gray; medium grained, moderately sorted, with rounded grains; medium hard, compact (weathers soft and friable); ledge former; tabular uneven; internally very thin bedded, with graded trough cross-bedding. Contains up to 70% glass fragments. Sample 202-1	22

LOCALITY 203. JEFFERSON RIVER

SE¼SW¼NW¼ sec. 28, T. 1 N., R. 4 W.; Madison County; cliff overlooking river at the west end of Parrot Bench. Unit 2 described below appears to correspond to unit 169 of measured section number 1 of Kuenzi (1966, p. 200). Bone Basin Member of the Renova Formation.

Unit		Estimated thick. (ft)
2.	Sandstone, feldspathic; pale olive; coarse grained, well sorted; very hard, compact; cliff former; calcareous cemented; tabular even; internal massive bedding. Lower contact sharp, regular. Minor heavy minerals. Sample 203-2	3
1.	Siltstone, sandy; yellowish gray (weathers to light greenish gray); medium hard, compact (weathers to soft, loose); slope former; calcareous cemented; tabular even; internal parallel even, thin bedding. Trace carbonaceous material. Sample 203-1	1
	Total estimated thickness	4

LOCALITY 204. PALISADE CLIFFS

NE¼NE¼SW¼ sec. 15, T. 2 N., R. 5 W.; Jefferson County; prominent west-facing cliffs. Units 1 and 2 described below correspond to units 57 and 58, respectively, of measured section number 9 of Kuenzi (1966, p. 277-278). Sixmile Creek Formation.

Unit		Estimated thick. (ft)
2.	Conglomerate, sandy; pale yellowish brown; with subrounded cobbles of volcanic rocks (70%), and granite (30%), in a matrix of poorly sorted, coarse grained, arkosic sandstone; medium hard, friable (weathers to soft, loose); slope former; tabular even; internal massive bedding. Lower contact sharp, regular. Minor biotite. Sample 204-2	1

LOCALITY 204. (continued)

Unit		Estimated thick. (ft)
1.	Claystone; grayish orange pink (weathers to medium brown); medium hard, compact (weathers to soft, loose); slope former; tabular even; internal massive bedding. Trace of organic material. Sample 204-1	4
	Total estimated thickness	5

LOCALITY 205. PALISADE CLIFFS SOUTH

NW¼SE¼NW¼ sec. 22, T. 2 N., R. 5 W.; Jefferson County; Mapped as Dunbar Creek Member of Renova Formation by Kuenzi and Fields (1971, Fig. 3). Strike 1°; dip 17° to east.

Unit		Estimated thick. (ft)
3.	Siltstone (see description unit 1)	20
2.	Conglomerate, granite; yellowish gray (weathers to yellowish gray with grayish orange streaks); with rounded pebble clasts, in a matrix of poorly sorted, very coarse grained, arkosic sandstone; hard, compact (weathers to medium hard, compact); ledge former; strongly iron-stained; lenticular bed; internally medium bedded with graded planar cross-bedding. Lower contact sharp, irregular. Minor biotite and some smokey quartz. Lateral extent approximately 150 feet. Sample 205-2	10
1.	Siltstone, sandy; light olive gray; hard compact (weathers to soft, loose); slope former; iron-stained (primarily along contact); internal thick parallel even bedding. Minor biotite. Sample 205-1	30
	Total estimated thickness	60

LOCALITY 206. LITTLE PIPESTONE

SW¼NE¼SW¼ sec. 9 T. 1 N., R. 5 W.; Jefferson County; stream cut on south side of creek along old highway 10. Units described below are within measured section number 5 of Kuenzi (1966, p. 267-268). Climbing Arrow Member of the Renova Formation.

Unit		Estimated thick. (ft)
3.	Conglomerate, sandy; yellowish gray; with rounded cobbles of metamorphic rocks (80%) and granite (20%), in a matrix of poorly sorted, very coarse grained, feldspathic sandstone; hard, compact (weathers to medium hard, compact); ledge former; calcareous cemented; iron-stained; tabular uneven; internally thin bedded with graded planar cross-bedding. Lower contact sharp, irregular. Subordinate heavy minerals concentrated in bands parallel to bedding (biotite, magnetite, garnet). Sample 206-2	5

LOCALITY 206. (continued)

Unit		Estimated thick. (ft)
2.	Siltstone, sandy; light olive; medium hard, compact; slope former; impermeable; tabular uneven; thin, parallel even bedding. Lower contact sharp, irregular. Sample 206-1	5
1.	Conglomerate (see description unit 3)	3
	Total estimated thickness	13

LOCALITY 207. LITTLE PIPESTONE EAST

SW¼NW¼NW¼ sec. 10, T. 1 N., R. 5 W.; Jefferson County; in roadcut on edge of bench south of Little Pipestone Creek. Mapped as Quaternary undifferentiated (includes some late Tertiary) by Kuenzi and Fields (1971, Fig. 3). Beds approximately horizontal.

Unit		Estimated thick. (ft)
1.	Conglomerate, metamorphic; medium orange gray; with rounded cobbles of metamorphic rocks (90%), and granite (10%), in a matrix of poorly sorted, very coarse grained, feldspathic sand; soft, friable; slope former; permeable; iron-stained; lenticular bed; internally medium bedded with graded parallel uneven bedding. Trace of carbonaceous material; minor heavy minerals (primarily). Channel deposit with interbedded irregular medium thick beds of conglomerate and sandstone. Sample 207-1	10

LOCALITY 208. SAND CREEK

SE¼NE¼NW¼ sec. 1, T. 2 N., R. 9 W.; Silver Bow County; next to railroad tracks west of highway 91. Mapped as Pliocene-Miocene intermontane basin deposits by Smedes (1967).

Unit		Estimated thick. (ft)
1.	Conglomerate, granite; yellowish gray (weathers to yellowish gray with grayish orange streaks); with rounded pebbles in a matrix pf poorly sorted, very coarse grained, feldspathic sand; soft, friable (weathers to soft, loose); slope former; iron-stained; lenticular bed; internally medium bedded with graded trough cross-bedding. Minor biotite. Sample 208-1..	15

LOCALITY 209. DIVIDE

SW¼SW¼NE¼ sec. 17, T. 1 S., R. 9 W.; Silver Bow County; in gravel pit east side of highway 91. Mapped as Pliocene-Miocene intermontane basin deposits by Smedes (1967).

LOCALITY 209. (continued)

Unit		Estimated thick. (ft)
1.	Conglomerate, well sorted, quartzite; light olive gray; with rounded cobbles, in a matrix of poorly sorted, very coarse grained, feldspathic sand; soft, friable (weathers to soft, loose); slope former; permeable; iron-stained; lenticular bed; internally medium bedded with graded trough cross-bedding. Sample 209-1	20

LOCALITY 210. LIME GULCH

SE¼NE¼SE¼ sec. 33, T. 1 N., R. 9 W.; Silver Bow County; along east side of highway 91. Mapped as Pliocene-Miocene intermontane basin deposits by Smedes (1967). Average strike 45°; dip 9° to east.

Unit		Estimated thick. (ft)
4.	Covered. Probably same as unit 3	73
3.	Conglomerate (30%), limestone; very pale orange (weathers to yellowish gray); with subrounded cobbles of limestone (50%), quartzite (40%), and granite (10%), in a matrix of poorly sorted, very coarse grained sandstone; hard, compact (weathers to medium hard, compact); cliff former; calcareous cemented; lenticular bed; internal massive bedding. Lower contact sharp irregular. Trace heavy minerals. Sample 210-2	
	Siltstone (70%), sandy; pinkish gray; poorly sorted, with subrounded grains; medium hard, compact (weathers to soft, friable); slope former; calcareous cemented; lenticular bed; internally thick bedded. Lower contact sharp irregular. Trace heavy minerals. Sample 210-1	132
2.	Covered	33
1.	Conglomerate (20%); (see description sample 210-2)...........	
	Siltstone (80%), sandy; (see description sample 210-1)	21
	Total measured thickness	259

LOCALITY 211. TWIN BRIDGES

SE¼NW¼SW¼ sec. 26, T. 3 S., R. 6 W.; Madison County; in gravel pit. Mapped as Tertiary-Quaternary gravels and silts by Petkewich (1972, Pl. 1).

Unit		Estimated thick. (ft)
1.	Conglomerate, well sorted, metamorphic; light gray with grayish orange streaks; with rounded cobbles of quartzite (80%), and gneissic rocks (20%), in a matrix of poorly sorted, coarse grained, feldspathic sand; soft, compact; slope former; permeable; iron-stained and black staining on clasts; lenticular bed; internal massive beds. Subordinate heavy minerals (garnet, magnetite and hastingsite). Contains minor sand lenses. Sample 211-1	25

LOCALITY 212. WATERLOO

NW¼NE¼NW¼ sec. 8, T. 2 S., R. 5 W.; Madison County; in roadcut along Riverside Drive. Unit described below is within 50 foot thick permeable fanglomerate bench deposits. Mapped as Tertiary-Quaternary gravels and silts by Petkewich (1972, Pl. 1). Beds approximately horizontal.

Unit	Estimated thick. (ft)
1. Sandstone, feldspathic; light brownish gray (weathers to grayish orange); medium grained, well sorted, with subangular grains; loft, loose; slope former; permeable; iron-stained; lenticular bed; internally thin trough cross-bedding. Minor heavy minerals (biotite, magnetite). Sample 212-1	3

LOCALITY 213. CURRANT CREEK

NE¼NW¼NE¼ sec. 2, T. 3 S., R. 6 W.; Madison County; in pit on east of road. Unit described below overlain by 25 feet of fanglomerate bench deposits, and mapped as Tertiary-Quaternary gravels and silts by Petkewich (1972, Pl. 1).

Unit	Estimated thick. (ft)
1. Siltstone, sandy; yellowish gray; soft, friable (weathers to soft, loose); slope former; permeable; tabular even; internal massive bedding. Trace of heavy minerals (magnetite). Sample 213-1	25

LOCALITY 214. CALIFORNIA CREEK

SW¼NE¼SW¼ sec. 35, T. 5 S., R. 4 W.; Madison County; south side of Quaking Aspen Creek valley. Mapped as late Tertiary-Quaternary conglomerate by Petkewich (1972, Pl. 1). Strike 15°; dip 12° to east.

Unit	Estimated thick. (ft)
1. Conglomerate, metamorphic; light gray; with subrounded cobbles of gniessic rocks, in a matrix of poorly sorted, subrounded, very coarse grained, feldspathic calcareous sandstone; hard, compact; ledge former; abundant calcareous cement; tabular even; internal thick, parallel even bedding. Sample 214-1.	30
Water sample taken from spring flowing from this unit. Sample 214-2.	

LOCALITY 215. TAYLOR CEMETARY

NW¼SW¼NE¼ sec. 22, T. 6 S., R. 4 W.; Madison County; along county road. Mapped as basalt pebble conglomerate member of the Sixmile Creek Formation by Petkewich (1972, Pl. 1).

LOCALITY 215. (continued)

Unit	Estimated thick. (ft)
1. Conglomerate, volcanic; light gray with medium gray streaks; with subrounded cobbles of volcanic rocks (80%) and gneissic rocks (20%) in a matrix of poorly sorted, very coarse grained, sand; soft, loose; ledge former; tabular even; internally very thick, parallel uneven bedded. Minor heavy minerals. Contains minor discontinuous silt beds. Sample 215-1	65

LOCALITY 216. ROCHESTER CREEK

SE¼SW¼NE¼ sec. 15, T. 3 S., R. 7 W.; Madison County; on prominent cliff up creek. Unit has limited extent (about 1/2 mile) and caps ridge underlain by Precambrian rocks. Mapped as Sixmile Creek Formation by Hoffman (1972, Pl. 1).

Unit	Estimated thick. (ft)
1. Conglomerate, metamorphic; yellowish gray (weathers to light olive gray); with subrounded cobbles of gneissic rocks, in a matrix of poorly sorted, very coarse grained feldspathic sandstone; hard, compact (weathers to medium hard, compact); cliff former; calcareous cemented; tabular even; internally thick parallel even bedded. Lower contact sharp irregular. Minor heavy minerals. Contains a few thin fine grained beds. Sample 216-1	50

LOCALITY 217. RATTLESNAKE BLUFF

NE¼SW¼SW¼ sec. 7, T. 5 S., R. 5 W.; Madison County; on west side of canyon. Units described below are within measured section number 8 of Petkewich (1972, p. 334-336). Units 6, 7, 8 below correspond to Petkewich's units 24, 25, 26, respectively, of the quartzite pebble conglomerate member of the Sixmile Creek Formation; units 1 thru 5 below correspond to Petkewich's units 1 thru 23 of the undifferentiated Sixmile Creek Formation. Strike 20°; dip 15° to west.

Unit	Measured thick. (ft)
8. Conglomerate (see description unit 6)	14.2
7. Sandstone, calcareous (see description unit 1)	24.4
6. Conglomerate, metamorphic; yellowish gray; with rounded cobbles of quartzite (80%) and gneissic rocks (20%), in a matrix of poorly sorted, very coarse grained, feldspathic calcareous sandstone; hard, compact; cliff former; abundant calcareous cement; tabular even; internal massive bedding. Lower contact sharp, regular. Minor heavy minerals in matrix. Sample 217-2	30.3
5. Sandstone, calcareous (see description unit 1)	113.0

LOCALITY 217. (continued)

Unit		Measured thick. (ft)
4.	Conglomerate (see description unit 6)	6.0
3.	Sandstone, calcareous (see description unit 1)	53.3
2.	Siltstone, tuffaceous	2.9
1.	Sandstone, calcareous; light gray; very fine grained, poorly sorted, with rounded grains; hard, compact; slope former; abundant calcareous cement; tabular even; internal parallel even, thick bedding. Less calcareous; with minor glassy sandstone lenses. Sample 217-1	110.8
	Total measured thickness	354.9

LOCALITY 218. BENCH ROAD

SE¼SW¼SW¼ sec. 6, T. 5 S., R. 6 W.; Madison County; in gravel pit east of road. Mapped as Sixmile Creek Formation by Petkewich (1972, Pl. 1). Beds approximately horizontal.

Unit		Estimated thick. (ft)
4.	Siltstone, clayey (see description unit 2)	5
3.	Sandstone, arkosic; light olive gray; medium grained, poorly sorted; soft, friable; slope former; iron-stained; lenticular channel; internal massive bedding. Lower contact sharp, regular. Subordinate biotite, with black coating on some grains. Contains scattered rounded pebbles of quartzite and volcanic rocks. Lateral extent about 20 feet. Sample 218-2.	5
2.	Siltstone, clayey; yellowish gray; moderately sorted; hard, compact; slope former; iron-stained; tabular even; internal parallel even, thin bedding. Lower contact sharp, irregular. Trace of heavy minerals. Sample 218-1	5
1.	Sandstone	7
	Total estimated thickness	22

LOCALITY 219. BEAVERHEAD ROCK

NW¼NW¼NE¼ sec. 27, T. 5 S., R. 7 W.; Madison County; in gravel pit east of highway 41. Mapped as Climbing Arrow member of Renova Formation by Petkewich (1972, Pl. 1), but due to proximity of younger sediments the placement of this unit within the formation is uncertain. Beds approximately horizontal.

LOCALITY 219. (continued)

Unit		Estimated thick. (ft)
1.	Sandstone, arkosic; grayish orange; medium grained, well sorted, with rounded grains; soft, friable; slope former; strongly iron-stained; lenticular bed; internally thick bedded with trough cross-bedding. Lateral extent about 10 feet. Sample 219-1	10

LOCALITY 220. McKINNEY DITCH

SW¼SW¼SE¼ sec. 26, T. 4 S., R. 7 W.; Madison County; in gravel pit. Mapped as Sixmile Creek Formation by Hoffman (1972, Pl. 1).

Unit		Estimated thick. (ft)
2.	Siltstone	4
1.	Conglomerate, metamorphic; yellowish gray; with rounded, cobbles of quartzite (80%) and gneissic rocks (20%), in a matrix of moderately sorted, medium grained, arkosic sand; soft, friable; slope former; tabular even; internal massive bedding. Minor petrified wood fragments (yellow staining); grains have black oily coating; minor heavy minerals. Sample 220-1.	6
	Total estimated thickness	10

LOCALITY 221. BARTON CREEK

SE¼SW¼SE¼ sec. 16, T. 7 S., R. 4 W.; Madison County; on north side of creek. Unit described below appears to correspond to unit 13 of measured section number 4 of Dorr and Wheeler (1964, p. 317-319). This unit is in the upper portion of the Madison Valley equivalent (Dorr and Wheeler, 1964, p. 317-318).

Unit		Estimated thick. (ft)
1.	Conglomerate, metamorphic; light gray (weathers to light olive gray); with subrounded pebbles of quartzite (50%) and gneissic rocks (50%), in a matrix of poorly sorted, medium grained, tuffaceous sandstone; hard, compact; cliff former; tabular even; internal parallel even, medium bedding. Trace of silica replaced bone fragments. Sample 221-1	15

LOCALITY 222. SPRING BROOK

SE¼SE¼NW¼ sec. 17, T. 9 S., R. 5 W.; Madison County; on hill SW side of brook. Unit described below is within the Madison Valley equivalent based on lithologic descriptions and geologic mapping done immediately to the north by Dorr and Wheeler (1964).

LOCALITY 222. (continued)

Unit		Estimated thick. (ft)
1.	Sandstone, conglomeratic; grayish yellow; coarse grained; poorly sorted; with subrounded pebbles of metamorphic rocks (60%), and tuff/siltstone (40%); hard, compact; cliff former; iron stained; tabular even; internal massive bedding. Unit is altered due to close proximity to Tertiary volcanics. Sample 222-1	7

LOCALITY 223. LEDFORD CREEK

SE¼SW¼NW¼ sec. 20, T. 9 S., R. 4 W.; Madison County; on road between Robb Creek and Ledford Creek. Units described below are within the Madison Valley equivalent based on lithologic descriptions and geologic mapping nearby by Dorr and Wheeler (1964).

Unit		Estimated thick. (ft)
2.	Sandstone; medium grained; calcareous cemented	2
1.	Conglomerate, metamorphic; light gray; with rounded cobbles of quartzite (50%) and gneissic rocks (50%), in a matrix of moderately sorted, medium grained, sand; soft, loose; slope former; calcareous cemented; permeable; lenticular channel; internal massive bedding. Lateral extent about 100 feet. Sample 223-1	8
	Total estimated thickness	10

LOCALITY 224. FRYING PAN BASIN

SW¼SE¼NE¼ sec. 20, T. 6 S., R. 9 W.; Beaverhead County; on cliff in the northeast corner of basin. Mapped as Tertiary sediments undifferentiated by Ross and others (1955).

Unit		Estimated thick. (ft)
1.	Siltstone, tuffaceous; light gray; medium grained, well sorted; medium hard, compact; cliff former; tabular uneven; internal massive bedding. Minor carbonaceous material (wood fragments composed of fusinite); trace of pyrite and calcite; (sample 224-2 taken of yellowish mineral (montmorillonite). Sample 224-1	60

LOCALITY 225. SAGE CREEK

NE¼SW¼NE¼ sec. 33, T. 12 S., R. 6 W.; Beaverhead County; in draw. Mapped as Sage Creek Formation by Scholten and others (1955, Pl. 1). Conglomerate is within a 100-foot section of fine silty material.

Unit		Estimated thick. (ft)
3.	Claystone, sandy (see unit 1)	10

LOCALITY 225. SAGE CREEK

Unit		Estimated thick. (ft)
2.	Conglomerate, sandy; yellowish gray; with rounded cobbles of volcanic rocks (40%), metamorphic rocks (30%), and sedimentary rocks (20%), in a matrix of moderately sorted, medium grained sandstone; hard, compact (weathers to medium hard, compact); cliff former; calcareous cemented; tabular even; internal parallel uneven, medium bedding. Lower contact gradational. Trace of biotite. Sample 225-2.	8
1.	Claystone, sandy; yellowish gray; fine grained, poorly sorted; hard, compact (weathers to medium hard, compact); slope former; tabular even; internal massive bedding. Sample 225-1	3
	Total estimated thickness	21

LOCALITY 226. BIG SPRING GULCH

NE¼NW¼SW¼ sec. 9, T. 12 S., R. 8 W.; Beaverhead County; water sample taken from spring on topographic map. Sample 226-1.

LOCALITY 227. LITTLE SAGE CREEK

SE¼NW¼SW¼ sec. 28, T. 11 S., R. 7 W.; Beaverhead County; on northwest side of road. Mapped as Blacktail Deer Creek Formation by Scholten and others (1955, Pl. 1). 315°; dip 7° to west.

Unit		Measured thick. (ft)
3.	Conglomerate, volcanic; light brownish gray; with subrounded cobbles of volcanic rocks (70%) and quartzite (30%), in a matrix of moderately sorted, medium grained sandstone; hard, compact; cliff former; calcareous cemented; tabular even; internal parallel uneven; medium bedded. Lower contact sharp, regular. Trace carbonaceous material. Possible channel....	20
2.	Sandstone, tuffaceous; yellowish gray; medium grained, moderately sorted, with rounded grains; hard, compact (weather to medium hard, compact); cliff former; slightly calcareous cemented; iron-stained; tabular even; internally medium bedded with planar cross-bedding. Lower contact sharp, regular. Trace carbonaceous material. Sample 227-4	67.5
1.	Sandstone (10%), conglomeratic, tuffaceous; very pale orange; medium grained, poorly sorted; with subrounded pebbles of volcanic rocks (80%) and quartzite (20%); hard, compact (weathers to medium hard, compact); cliff former; calcareous cemented; tabular even; internal irregularly thick bedding. Lower contact irregular. Sample taken near upper contact. Sample 227-3	

LOCALITY 227. (continued)

Unit		Measured thick. (ft)
1.	Conglomerate (30%), well sorted, volcanic; light gray; with rounded cobbles of volcanic rocks (60%) and quartzite (40%), in a matrix of poorly sorted, very coarse grained sandstone; hard, compact; cliff former; calcareous cemented; lenticular channel; internally medium bedded with trough cross-bedding. Lower contact sharp, irregular. Sample 227-2 .... Sandstone (60%), silty, tuffaceous; pale yellowish brown; very fine grained, well sorted; hard, compact. Bedding characteristics same as in sample 227-3. Sample 227-1	153.5
	Total measured thickness	241.0

LOCALITY 228. BOX SPRINGS

SE¼NE¼NE¼ sec. 21, T. 11 S., R. 7 W.; Beaverhead County; water sample. Sample 228-1.

LOCALITY 229. BLACKTAIL DEER CREEK

SW¼NE¼SW¼ sec. 8, T. 11 S., R. 6 W.; Beaverhead County; west of road. Units described below are within the type section of the Blacktail Deer Creek Formation as measured by Hibbard and Keenmon (1950, p. 195-198), and mapped by Scholten and others (1955, Pl. 1). Samples are representative of the sand, clay interbeds with the section Strike 170°; dip 5° to west.

Unit		Estimated thick. (ft)
2.	Sandstone, conglomeratic, feldspathic; yellowish gray; coarse grained, poorly sorted, with subrounded grains; with subrounded pebbles of quartzite (60%) and volcanics (40%); hard, compact; ledge former; slightly calcareous cemented; iron-stained; tabular even; internally parallel even medium bedded. Lower contact sharp, regular. Sample 229-2	2
1.	Siltstone, clayey; pale greenish yellow; moderately sorted; hard, compact; slope former; iron-stained; tabular even; internally parallel even thick bedded. Sample 229-1	8
	Total estimated thickness	10

LOCALITY 230. BURNS MOUNTAIN

SE¼SE¼NW¼ sec. 3, T. 8 S., R. 10 W.; Beaverhead County; along creek. Mapped as later tuffs (Oligocene) by Lowell (1952).

Unit		Estimated thick. (ft)
1.	Sandstone, tuffaceous; light greenish gray; medium grained, well sorted, with subangular grains; hard, compact; cliff former; iron-stained; tabular uneven; internal massive bedding. Abrasion of grains and some cross-bedding indicates some reworking. Sample 230-1	30

LOCALITY 231. FRYING PAN GULCH

NE¼SE¼SW¼ sec. 31, T. 6 S., R. 9 W.; Beaverhead County; along dirt road to Christensen Ranch. Mapped as Oligocene rhyolite tuff by Myers (1952, Pl. 1).

Unit		Estimated thick. (ft)
1.	Tuff; light gray; medium grained, moderately sorted; hard, compact (weathers to medium hard, compact); slope former; iron-stained; tabular even; internal massive bedding. Minor heavy minerals in some beds (primarily). Contains 80% glassy volcanic rock fragments. Sample 231-1	5

LOCALITY 232. CROOKED CREEK

NW¼NW¼NE¼ sec. 8, T. 11 S., R. 8 W.; Beaverhead County; on the north side of road. Mapped within the Cook Ranch Volcanics of Scholten and others (1955, Pl. 1), but the lithology indicates that they are probably in the Cook Ranch Formation, which is mapped just to the south across Sage Creek. Strike 265°; dip 18° to south.

Unit		Estimated thick. (ft)
3.	Sandstone, conglomeratic, feldspathic; light yellowish gray; very coarse grained, poorly sorted; with subrounded pebbles of volcanic rocks (45%), metamorphic rocks (45%), and reworked claystone (10%); hard, compact; ledge former; iron-stained; tabular even; internal massive bedding. Lower contact sharp, regular. Sample 232-3	2
2.	Claystone, sandy; yellowish gray; medium hard, compact; slope former; iron-stained; tabular even; internal massive bedding. Lower contact gradational. Sample 232-2	4
1.	Sandstone; yellowish gray; coarse grained, moderately sorted; medium hard, loose (weathers to soft, loose); slope former; iron-stained; tabular even; internally parallel even, medium bedded. Sample 232-1	15
	Total estimated thickness	21

LOCALITY 233. HORSE PRAIRIE CREEK

SE¼NW¼SW¼ sec. 5, T. 10 S., R. 13 W.; Beaverhead County; along old railroad grade. Mapped as Tertiary sediments undifferentiated by Ross and others (1955). Minor faulting in section. Strike 10°; dip 30° to east. Thickness of sub-units within unit 2 below become thinner in basal portions.

Unit		Measured thick. (ft)
5.	Siltstone, clayey (see unit 2 description)	104.7
4.	Sandstone, conglomeratic, granitic (see unit 2 description) ..	141.1

LOCALITY 233. (continued)

Unit		Measured thick. (ft)
3.	Siltstone, clayey (see unit 2 description)	176.6
2.	Sandstone (60%), conglomeratic, granitic; moderate yellowish brown; with subrounded pebbles of granitic rocks, in a matrix of poorly sorted, coarse grained, arkosic sandstone; medium hard, friable; slope former; iron stained; tabular even, internal massive bedding. Lower contact sharp, regular. Sample 233-2 ... Siltstone (40%), clayey; light olive gray; poorly sorted; medium hard, compact; slope former; tabular even; internal parallel uneven, medium bedding. Lower contact sharp, regular. Trace carbonaceous material. Scattered subangular pebbles of granitic rock (80%) and volcanic rock (20%) in some beds. Sample 233-1	431.2
1.	Siltstone, clayey (see unit 2 description)	58.6
	Total measured thickness	912.2

LOCALITY 234. KATE CREEK

NE¼SE¼NW¼ sec. 12, T. 12 S., R. 12 W.; Beaverhead County; in roadcut on west side of road at Junction of Kate Creek and Medicine Lodge Creek. Mapped within shale unit of Medicine Lodge units by M'Gonigle (1965, Pl. 1).

Unit		Estimated thick. (ft)
1.	Conglomerate, well sorted, metamorphic; grayish orange; with rounded cobbles of metamorphic rocks (60%), volcanic rocks (30%), and granitic rocks (10%), in a matrix of poorly sorted coarse grained sandstone; hard, compact; cliff former; calcareous cemented; iron-stained; tabular even; internal parallel even, thick bedding. Sample 234-1	12

LOCALITY 235. BACHELOR MOUNTAIN

SE¼SW¼NE¼ sec. 14, T. 9 S., R. 13 W.; Beaverhead County; south end of mountain. Mapped as Tertiary sediments undifferentiated by Ross and others (1955). Strike 85°; dip 22° to south.

Unit		Estimated thick. (ft)
1.	Sandstone, feldspathic; yellowish gray; medium grained, well sorted; hard, compact; ledge former; iron-stained; tabular even; internal massive bedding. Sample 235-1	20

LOCALITY 236. COYOTE CREEK

NE¼SE¼SE¼ sec. 33, T. 9 S., R. 14 W.; Beaverhead County; up Horse Prairie Guard station road from Bloody Dick Creek turn off. Mapped as Tertiary sediments undifferentiated by Ross and others (1955).

LOCALITY 236. (continued)

Unit		Estimated thick. (ft)
1.	Sandstone, conglomeratic, arkosic; yellowish gray, very coarse grained, poorly sorted; with subrounded pebbles of granitic rock (60%), quartzite (30%), and siltstone (10%); hard, compact; cliff former; iron-stained; tabular even; internal parallel even, medium bedding. Sample 236-1	5

LOCALITY 237. TIPPET PLACE

SE¼SE¼NE¼ sec. 23, T. 2 N., R. 5 W.; Jefferson County; in stream cut along road about 20 feet from contact with Cretaceous volcanics. Mapped as Sixmile Creek Formation by Kuenzi and Fields (1971, Fig. 3). Beds approximately horizontal.

Unit		Estimated thick. (ft)
1.	Conglomerate, volcanic; dusky yellow; with subrounded pebbles of volcanic rocks (95%) and granite (5%), in a matrix of moderately sorted, coarse grained, granitic, arkosic sand; medium hard, friable (weathers to soft, loose); slope former; iron-stained (yellowish green to orange staining); lenticular channel; internally medium bedded with trough cross-bedding. Smokey quartz present. Sample 237-1	15

LOCALITY 238. ANDERSON LEASE

NE¼SW¼NW¼ sec. 17, T. 9 S., R. 5 W.; Madison County; prospect pit on lease. Unit described below is within the Madison Valley equivalent based on lithologic descriptions and geologic mapping done immediately to the north by Dorr and Wheeler (1964). Strike 100°; dip 4° to south.

Unit		Estimated thick. (ft)
1.	Sandstone, clayey, feldspathic; light gray (weathers to yellow); coarse grained, poorly sorted; medium hard, compact; slope former; strongly iron-stained; tabular even; internal parallel uneven, medium bedding. Minor heavy minerals (primarily). Sample has abundant smokey quartz, and is highly altered. Sample 238-1	5

LOCALITY 239. SWEETWATER ROAD

SW¼SE¼SW¼ sec. 34, T. 8 S., R. 5 W.; Madison County; on the north side of draw. Mapped as the Madison Valley equivalent by Dorr and Wheeler (1964, Fig. 1).

Unit		Estimated thick. (ft)
1.	Sandstone, clayey; pale greenish yellow; coarse grained, poorly sorted; soft, friable; slope former; iron-stained; tabular uneven; internally parallel uneven, medium bedded. Trace of silica replaced wood. Contains gypsum. Sample 239-1	20

LOCALITY 240. BELMONT RANCH

SE¼SW¼NE¼ sec. 12, T. 8 S., R. 5 W.; Madison County; in cliffs along west side of Sweetwater Road west of Upper Ruby Cemetary. Units 1 and 2 described below correspond to units 2 and 3, respectively, of measured section number 2 of Dorr and Wheeler (1964, p. 312-314). The units are in the lower portion of the Madison Valley equivalent (Dorr and Wheeler, 1964, p. 313).

Unit		Estimated thick. (ft)
2.	Conglomerate, metamorphic; light gray (weathers to yellowish gray); with subrounded pebbles of quartzite (95%) and granite (5%), in a matrix of poorly sorted, coarse grained, sandstone; hard, compact; ledge former; calcareous cemented; tabular even; internall parallel even, thin bedding, Lower contact sharp regular; trace of heavy minerals. Sample 240-2	4
1.	Siltstone; yellowish gray; medium hard, friable; cliff former; tabular even; internal massive bedding. Sample 240-1	42
	Total estimated thickness	46

LOCALITY 241. RUBY RIVER RESERVOIR

SE¼SW¼SW¼ sec. 19, T. 7 S., R. 4 W.; Madison County; on hill along west side of reservoir. Mapped as "Red Conglomerate" by Dorr and Wheeler (1964, Figs. 1 and 2).

Unit		Estimated thick. (ft)
1.	Conglomerate, limestone; well sorted; grayish orange (weathers to moderate reddish orange); with subrounded cobbles of limestone (80%), and quartzite (20%), in a matrix of poorly sorted, very coarse grained sandstone; very hard, compact (weathers to hard, compact); cliff former; calcareous cemented; impermeable; iron-stained; tabular uneven; internally massive. Sample 241-1	20

LOCALITY 242. COTTONWOOD CREEK

SE¼SW¼SE¼ sec. 34, T. 7 S., R. 5 W.; Madison County; in roadcut along Cottonwood Creek road. Mapped as Passamari Formation by Dorr and Wheeler (1964, Fig. 1). Sandstones described below constitute a very minor portion of Passamari Formation.

Unit		Estimated thick. (ft)
3.	Claystone (see description unit 1)	3
2.	Sandstone; yellowish gray; medium grained, moderately sorted, with subrounded grains; medium hard, friable (weathers to soft, friable); slope former; iron-stained; lenticular bed; internally parallel even, thin bedding. Lower contact sharp, irregular. Minor carbonaceous material. Sample 242-2	2

LOCALITY 242. (continued)

Unit		Estimated thick. (ft)
1.	Claystone; pale olive; hard, compact; slope former; calcareous cemented; tabular even; internal massive bedding. Minor carbonaceous material. Sample 242-1	5
	Total estimated thickness	10

LOCALITY 243. COOK RANCH

SE¼NE¼NW¼ sec. 34, T. 12 S., R. 8 W.; Beaverhead County; on the west side of Sage Creek Road. Cook Ranch and Sage Creek Formations of Scholten and others (1955, Pl. 1), and proposed Sage Creek Formation of Hough (1955). Strike 165°; dip 13° to west.

Unit		Measured thick. (ft)
4.	Conglomerate, well sorted, quartzite; light gray; with rounded cobbles of quartzite (60%) and volcanic rocks (40%), in a matrix of poorly sorted, very coarse grained sandstone; hard, compact; cliff former; iron-stained; tabular uneven; internal massive bedding. Lower contact sharp, irregular. Sample 243-2	84.0
3.	Siltstone; light greenish gray; moderately sorted; hard, compact (weathers to medium hard, loose); slope former; calcareous cemented; tabular even; internal parallel even, thick bedding. Lower contact sharp, regular. Differential cementation within unit forms resistant beds. Sample 243-1	133.0
2.	Sandstone; light gray; medium grained; hard, compact; ledge former; calcareous cemented; tabular even; internal parallel even, medium thick bedding	2.0
1.	Siltstone; light greenish gray; moderately sorted; hard, compact (weathers to medium hard, loose); slope former; calcareous cemented; tabular even; internal parallel even, thick bedding. Differential cementation within unit forms resistant beds	147.3
	Total measured thickness	366.4

LOCALITY 244. SAGE CREEK WEST

SE¼SW¼SW¼ sec. 33, T. 12 S., R. 8 W.; Beaverhead County; on north side of Sage Creek Road. Mapped as Sage Creek Formation by Scholten and others (1955, Pl. 1).

Unit		Estimated thick. (ft)
1.	Sandstone, tuffaceous; yellowish gray; medium grained, moderately sorted; hard, compact (weathers medium hard, compact); cliff former; calcareous cemented; tabular even; internal parallel even, medium bedding. Minor biotite. Contains pumice fragments. Sample 244-1	40

LOCALITY 245. ROCK CREEK

NW¼NE¼NW¼ sec. 5, T. 14 S., R. 10 W.; Beaverhead County; in Rock Creek Canyon west of Muddy Creek. Mapped as "Muddy Creek" beds by Scholten and others (1955, Pl. 1).

Unit		Estimated thick. (ft)
1.	Tuff; light greenish gray; very hard, compact; cliff former; slightly iron-stained; irregular shape; internal massive bedding. Sample 245-1	15

LOCALITY 246. TRAIL HOLLOW

NW¼NW¼NW¼ sec. 33, T. 13 S., R. 10 W.; Beaverhead County; on north side of Muddy Creek road across from Trail Hollow. Mapped as "Muddy Creek" beds by Scholten and others (1955, Pl. 1). Strike 141°; dip 16° to NE. Approximately 100 feet of claystone and shale exposed; sample taken from basal portion.

Unit		Estimated thick. (ft)
3.	Claystone	4
2.	Shale, carbonaceous; moderate brown; medium hard, brittle (weathers to soft, brittle); slope former; tabular even; internal parallel even, laminar bedding. Abundant gypsum along some bedding planes. Sample 246-1	1
1.	Claystone	5
	Total estimated thickness	10

LOCALITY 247. BIG SHEEP CREEK

NW¼SE¼SW¼ sec. 20, T. 13 S., R. 9 W.; Beaverhead County; along west side of road at mouth of canyon. Mapped as Beaverhead Formation by Scholten and others (1955, Pl. 1).

Unit		Estimated thick. (ft)
1.	Conglomerate; well sorted; limestone; moderate orange pink with subrounded cobbles of limestone (60%) and quartzite (40%), in a matrix of poorly sorted, very coarse grained sandstone; very hard, compact; cliff former; calcareous cemented; impermeable; iron-stained; tabular even; internal massive bedding. Sample 247-1	15

LOCALITY 248. MEDICINE LODGE PEAK

NE¼SE¼NE¼ sec. 14, T. 12 S., R. 12 W.; Beaverhead County; along west side of road. Lithologically similar to Medicine Lodge shales mapped by McGonigle (1965, Pl. 1) to the north. Sample taken from tailings pile; unit not exposed at surface. Sample 248-1 is lignite, grayish black; medium hard, brittle; slope former, with minor gypsum.

LOCALITY 249. KEYSTONE RESERVOIR

NW¼NE¼SE¼ sec. 35, T. 11 S., R. 12 W.; Beaverhead County; in Keystone Gulch Mapped as Medicine Lodge Shales by M'Gonigle (1965, Pl. 1). Strike 150°; dip 26° to east.

Unit		Estimated thick. (ft)
2.	Siltstone; light yellow (weathers to pale brown); coarse grained, hard, compact; cliff former; iron-stained; tabular even; internal parallel even, very thin bedding. Lower contact sharp, regular. Minor carbonaceous material. Sample 249-2.	12
1.	Lignite; black (weathers to dark brown); medium hard, brittle; slope former; tabular even; internal parallel even; laminar bedding. Gypsum present along bedding plane. Sample 249-1.	4
	Total estimated thickness	16

LOCALITY 250. SHENON CREEK

NW¼NW¼SW¼ sec. 18, T. 10 S., R. 13 W.; Beaverhead County; sample taken from tailings of mine on east side of highway. Mapped as Tertiary sediments undifferentiated by Ross and others (1955) but close association with Tertiary volcanic rocks and lithology indicate volcanic origin.

Unit		Estimated thick. (ft)
1.	Tuff (?); light brown; fine grained; hard, compact; iron-stained; irregular shape; internal massive bedding. Extremely altered. Sample 250-1	15

LOCALITY 251. MUDDY CREEK

NW¼SW¼SE¼ sec. 3, T. 14 S., R. 10 W.; Beaverhead County; north side of creek. Mapped as Quaternary terrace gravels and alluvial fans by Scholten and others (1955, Pl. 1) but lithologic similarities to the "Muddy Creek" beds indicate that they should be considered "Muddy Creek" beds.

Unit		Measured thick. (ft)
8.	Sandstone; grayish yellow; medium grained, well sorted; medium hard, compact (weathers to soft, friable); slope former; iron-stained; tabular even; internal parallel even, medium bedding. Lower contact sharp, regular. Contains a few minor gravel lenses. Sample 251-3	192.2
7.	Thin bedded sequence of light gray, iron-stained sandstones; light brown; carbonaceous siltstones; and purplish gray claystones and shales. Sandstones comprise bottom layers, claystones and shales form majority of upper portion	221.2
6.	Sandstone; light gray; medium grained, well sorted; very hard, compact; ledge former; silica cemented; iron-stained; tabular even; internal parallel, thin bedding. Lower contact sharp, regular	3.5

LOCALITY 251. (continued)

Unit		Measured thick. (ft)
5.	Sandstone; strongly iron-stained in upper portion (see description unit 2)	106.4
4.	Conglomerate; (see description unit 2)	3
3.	Sandstone; light gray; fine grained, well sorted; medium hard, compact; slope former; slightly iron-stained; tabular even; internal parallel even, medium bedding. Lower contact sharp, regular	39.4
2.	Conglomerate, sedimentary; pale yellowish orange (weathers to grayish orange); with subrounded cobbles of sandstones and siltstones (80%), limestone (10%), and quartzite (10%), in a matrix of well sorted, medium grained sandstone; hard, compact; ledge former; calcareous cemented; iron-stained; tabular uneven; internal massive bedding. Lower contact sharp, irregular. Sample 251-2	4
1.	Siltstone, sandy; light gray; moderately sorted; medium hard, compact; slope former; calcareous cemented; iron-stained; tabular even; internal massive bedding. Sample 251-1	42.1
	Total measured thickness	611.8

LOCALITY 252. LIMA RESERVOIR

SW¼SW¼NW¼ sec. 32, T. 13 S., R. 6 W.; Beaverhead County; in cliff on the north side of Lima Dam. Mapped as Beaverhead Formation by Scholten and others (1955, Pl. 1).

Unit		Estimated thick. (ft)
1.	Conglomerate; well sorted; pale red; with subrounded cobbles of limestone and quartzite in a matrix of poorly sorted, very coarse grained sandstone; very hard, compact; cliff former; calcareous cemented; impermeable; iron-stained; tabular even; internal parallel even, very thick bedding. Sample 252-1	360

LOCALITY 253. CEDAR CREEK

SE¼NW¼SW¼ sec. 2, T. 6 S., R. 1 W.; Madison County; on the northern tip of the bench located on the SW side of creek. Mapped as Quaternary and Tertiary sediments undifferentiated by Egbert (1967, Pl. 1), but lithologic similarities to units mapped by Hadley (1969b) to the south indicate that the unit is lower Pleistocene in age.

Unit		Estimated thick. (ft)
1.	Sandstone, feldspathic; light gray; medium grained, well sorted; hard, compact; cliff former; calcareous cemented; tabular even; internally thin bedded with planar cross-bedding. Sample 253-1	5

LOCALITY 254. SQUAW CREEK

NW¼SE¼NE¼ sec. 33, T. 10 S., R. 1 E.; Madison County; in roadcut. Mapped as Quaternary alluvium, pyroclastic rocks, landslides, glacial material and later Tertiary lake beds undifferentiated by Egbert (1967, Pl. 1). Unit is closely associated with Tertiary volcanics.

Unit		Estimated thick. (ft)
1.	Sandstone, tuffaceous; light gray; fine grained, moderately sorted; soft, loose, slope former; tabular even; internal parallel uneven, medium bedding. Contains 90% glassy fragments. Beds folded. Sample 254-1	30

LOCALITY 255. VARNEY

NW¼NW¼SW¼ sec. 29, T. 7 S., R. 1 W.; Madison County; in stream bed. Mapped as lower Pliestocene cobble gravels by Hadley (1969b).

Unit		Estimated thick. (ft)
2.	Conglomerate, well sorted; limestone; pale yellowish brown; with subrounded cobbles of limestone (75%) and quartzite (25%), in a matrix of poorly sorted, very coarse grained sandstone; hard, compact; ledge former; calcareous cemented; tabular even; internal massive bedding. Lower contact sharp, regular. Trace carbonaceous material. Sample 255-2	3
1.	Siltstone, sandy; pale yellow; poorly sorted; medium hard, compact (weathers to soft, loose); slope former; calcareous cemented; tabular even; internal massive bedding. Trace carbonaceous material. Scattered pebbles of quartzite. Sample 255-1	4
	Total estimated thickness	7

LOCALITY 256. SPRING CREEK DITCH

NW¼NE¼NW¼ sec. 20, T. 6 S., R. 1 W.; Madison County; in roadcut along county road on the west side of Madison River. Mapped as Quaternary and Tertiary sediments undifferentiated by Egbert (1967, Pl. 1).

Unit		Estimated thick. (ft)
1.	Sandstone, conglomeratic; yellowish gray; coarse grained, moderately sorted; with subrounded pebbles of volcanic rocks (80%), quartzite (10%), and claystone (10%); very hard, compact; cliff former; calcareous cemented; tabular even; internal parallel even, thick bedding. Sample 256-1	5

LOCALITY 257. BEAR CREEK

NE¼SW¼NW¼ sec. 11, T. 6 S., R. 1 W.; Madison County; in gravel pit. Mapped as Quaternary and Tertiary sediments undifferentiated by Egbert (1967, Pl. 1), but lithologic similarities to units mapped by Hadley (1969a, 1969b) to the south indicate that unit is lower Pleistocene in age.

LOCALITY 257. (continued)

Unit		Estimated thick. (ft)
1.	Conglomerate, well sorted, granite gneiss; medium gray; with rounded cobbles of granite gneiss (95%), and sandstone (5%), in a matrix of well sorted, medium grained sandstone; soft, loose; slope former; iron-stained; tabular even; internal parallel even, thick bedding. Some clasts have black coating of manganese oxide. Sample 257-1	50

LOCALITY 258. NORTH MEADOW CREEK

NE¼NW¼SE¼ sec. 19, T. 4 S., R. 1 W.; Madison County; in gravel pit located on the east side of creek. Mapped as Quaternary and Tertiary sediments undifferentiated by Egbert (1967, Pl. 1).

Unit		Estimated thick. (ft)
1.	Conglomerate, well sorted, granite gneiss; moderate brown (weathers to grayish orange); with rounded cobbles of granite gneiss, in a matrix of moderately sorted, medium grained sandstone; soft, loose; slope former; strongly iron-stained; tabular uneven; internal parallel even, thick bedding. Sample 258-1	40

LOCALITY 259. RIVERSIDE DRIVE

SE¼NE¼NW¼ sec. 18, T. 2 S., R. 5 W.; Madison County; water sample taken at base of bench along Riverside Drive, from spring flowing out of unit mapped as Sixmile Creek Formation by Petkewich (1972, Pl. 1). Sample 259-1.

LOCALITY 260. DRY BOULDER CREEK

SE¼NE¼NW¼ sec. 18, T. 2 S., R. 5 W.; Madison County; NE of creek along Riverside Drive. Mapped as Sixmile Creek Formation by Petkewich (1972, Pl. 1). Strike 115°; dip 5° to south.

Unit		Estimated thick. (ft)
1.	Sandstone, tuffaceous; yellowish gray; medium grained, moderately sorted; medium hard, compact; slope former; tabular even; internally massive. Unit grades from 80% glass, 20% clay (decomposed glass) near bottom to 50% glass, 50% clay in upper portion. Sample 260-1	8

LOCALITY 261. STONE CREEK

NW¼NW¼NE¼ sec. 13, T. 6 S., R. 8 W.; Beaverhead County; in roadcut along highway 41. Mapped as Tertiary sediments undifferentiated by Ross and others (1955). Strike 175°; dip 1° to west.

Unit		Estimated thick. (ft)
3.	Sandstone, silty; thick bedded. Interbedded with thin conglomeratic sandstone layers	15

LOCALITY 261. (continued)

Unit		Estimated thick. (ft)
2.	Sandstone, conglomeratic; yellowish gray; medium grained, poorly sorted; with subrounded pebbles of metamorphic rocks (80%) and volcanic rock (20%), very hard, compact; ledge former; calcareous cemented; tabular even; internal massive bedding. Lower contact sharp, regular. Sample 261-2	1
1.	Sandstone, silty; pale yellowish brown; fine grained, poorly sorted; medium hard, compact; cliff former; calcareous cemented; tabular even; internal massive bedding. Sample 261-1	5
	Total estimated thickness	21

LOCALITY 262. EAST FORK

SW¼SW¼NW¼ sec. 6, T. 11 S., R. 5 W.; Beaverhead County; along the north side of the east fork of Blacktail Deer Creek. Mapped as Blacktail Deer Creek Formation by Scholten and others (1955, Pl. 1). Strike 30°; dip 5° to NW.

Unit		Measured thick. (ft)
4.	Covered. Probably same as unit 3	112.0
3.	Conglomerate (40%), well sorted, metamorphic; yellowish gray; with subrounded cobbles of metamorphic rocks (80%) and limestone (20%), in a matrix of poorly sorted, very coarse grained, sandstone; very hard, compact; cliff former; calcareous cemented; tabular even; thick bedded; internal massive bedding. Lower contact sharp, irregular. Sample 262-4	
	Siltstone (60%), sandy; grayish orange; poorly sorted; soft, compact; slope former; calcareous cemented; tabular even; thick bedded; internal massive bedding. Lower contact sharp, regular. Trace of heavy minerals (primarily). Sample 262-3	268.8
2.	Sandstone, tuffaceous; light gray; medium grained, well sorted; medium hard, compact; cliff former; slightly iron-stained; tabular even; internally medium bedded with trough cross-bedding. Lower contact sharp, regular. Trace of heavy minerals (primarily). Units grades from 90% glass fragments in lower portion to 50% glass fragments in upper portion. Sample 262-2	84
1.	Siltstone, sandy; dull yellow orange; poorly sorted; medium hard, compact; slope former; calcareous cemented; tabular even; internally parallel even thick bedded. Minor carbonaceous material; trace of heavy minerals (magnetite). Unit contains minor conglomeratic layers. Sample 262-1	145.6
	Total measured thickness	610.4

LOCALITY 265. GRANT

NW¼NW¼SE¼ sec. 31, T. 9 S., R. 12 W.; Beaverhead County; in roadcut along Horse Prairie Creek. Mapped as Tertiary sediments undifferentiated by Ross and others (1955), but are lithologically similar to "Medicine Lodge" beds mapped to the southeast by Scholten and others (1955, Pl. 1). Strike 240°; dip 6° to north.

Unit		Estimated thick. (ft)
2.	Siltstone; light brown; hard, compact; internally very thin bedded. Subordinate carbonaceous material (leaf imprints)	15
1.	Sandstone; hard, compact; medium beds	2
	Total estimated thickness	17

LOCALITY 267. EVERSON CREEK

NE¼SE¼SW¼ sec. 33, T. 10 S., R. 14 W.; Beaverhead County; in cliffs west of Horse Prairie Creek. Approximately 350 feet of section exposed. Consisting primarily of lacustrine volcanic siltstone composed of 50% glass, 25% basalt fragments and minor sands.

LOCALITY 301. THREE FORKS AREA 1-A

SE¼NE¼SE¼ sec. 11, T. 1 N., R. 1 E.; Gallatin County; in small westerly-draining gully; in type area of Climbing Arrow Formation (Robinson, 1963, p. 70). This section, which contains a higher proportion of sand than average, is otherwise typical of the formation. Strike N. 35° E., dip 4° NW.

Unit		Measured thick. (ft)
5.	Sandstone, micaceous; pale olive; fine to very fine grained; moderately sorted, with angular grains; soft, friable; slope former; tabular even; internally massive. Lower contact gradational. Subordinate heavy minerals. Sample 301-5 taken at lower contact	3
4.	Sandstone; dusky yellow; fine grained (coarsens downward), moderately sorted, with subangular grains; soft, friable; slope former; tabular uneven; internally massive. Lower contact sharp, regular. Subordinate biotite. Sample 301-4.	8.3
3.	Claystone, bentonitic; light olive; medium hard, brittle; slope former; lentic, bed; internally massive. Lower contact gradational. Sample 301-3 taken at lower contact where the unit is more sandy.	
2.	Sandstone, feldspathic; dark yellowish orange; medium to coarse grained, moderately sorted, with subangular grains; medium hard, friable; slope former; lentic, channel; internally very thin bedded with cross-bedding. Contains clayballs and minor amount of biotite. Lower contact sharp and irregular. Stained with iron oxides in a pattern suggestive of a roll front. Sample 301-2. Sample 301-6 taken from black cemented (pyrolusite) layer about 25 feet south of the measured section near the middle of unit 2	13.6
1.	Sandstone, arkosic; dusky yellow and streaked; medium grained, moderately sorted, with subangular grains; soft, friable; slope former; lentic. Minor biotite. Sample 301-1	0.5
	Total measured thickness	28

LOCALITY 302. THREE FORKS AREA 1-B

SW¼SW¼NW¼ sec. 12, T. 1 N., R. 1 E.; Gallatin County; type area of the Climbing Arrow Formation (Robinson, 1963, p. 70). This section is characteristic of the formation in the Three Forks basin south of the Jefferson River. It contains 31% medium to coarse grained, poorly sorted sandstone in beds that range from 0.5 to 16.4 feet thick and average 5.3 feet thick. The upper third of the section duplicates the section of the Climbing Arrow Formation measured by Robinson (ibid). Strike north 52° east; dip 2.5° east.

LOCALITY 302. (continued)

Unit		Measured thick. (ft)
32.	Sandstone, quartz; light brownish gray; medium grained, moderately sorted, with subangular grains; medium hard, friable; slope former. Lower contact sharp, irregular	2.1
31.	Claystone, silty; medium brownish green; medium hard, brittle; slope former; internally massive. Lower 2 feet micaceous with parallel uneven laminae. Lower contact sharp, irregular	26.5
30.	Sandstone, feldspathic; light greenish brown; medium grained, with subangular grains; soft, friable; slope former. Lower contact sharp, irregular. Minor biotite	3.4
29.	Siltstone, sandy; poorly sorted; soft, friable; slope former. Lower contact sharp, irregular and intensely iron-stained. Minor biotite	11.2
28.	Sandstone, subfeldspathic; light brownish gray; medium grained, poorly sorted; soft, friable. Lower contact sharp, irregular and iron-stained. Minor biotite	4.4
27.	Claystone, silty; light olive; medium hard, compact; slope former; internally massive (laminated near base). Lower contact sharp, irregular. Minor biotite and, near the base, carbonaceous material. Sample 302-9 taken at base where unit is sandy	11.6
26.	Sandstone, arkosic; dusky yellow with yellowish brown mottles; medium grained (locally very coarse grained), moderately sorted with subangular grains; soft to hard, friable; cliff former; locally iron-stained; lentic, channel. Minor biotite and smokey quartz. Contains clay balls. Sample 302-8 cemented with iron oxides; Sample 302-7 without iron oxides.	13.4
25.	Claystone, silty; medium brownish green; soft, brittle. Lower contact gradational	3.8
24.	Sandstone, silty, subfeldspathic; dusky yellow; medium grained, poorly sorted with subrounded to subangular grains; soft, friable; slope former. Lower contact sharp, irregular. Iron-stained at upper contact. Sample 302-6 includes black organic (?) material that locally coats sand grains	7.8
23.	Siltstone, clayey; medium brownish green; medium hard, friable; slope former; internally massive. Lower contact sharp, irregular	16.5
22.	Sandstone, feldspathic; light grayish brown; medium grained, moderately sorted, with subangular grains; soft, friable. Lower contact sharp, irregular. Contains clay balls and minor biotite	5.4

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LOCALITY 302. (continued)

Unit		Measured thick. (ft)
21.	Sandstone, silty; medium brownish green; fine to very fine grained, poorly sorted, with subangular grains; medium hard, compact; slope former; internally massive. Lower contact sharp, irregular. Minor biotite	16.7
20.	Claystone (89%), silty; medium brownish green, medium hard, compact; slope former; internally massive. Lower contact gradational. Minor biotite. Unit coarsens downward to sandstone. Sandstone (11%), subfeldspathic; light yellowish gray, medium to coarse grained, moderately sorted; soft, friable; slope former. Forms thin beds in upper 1/2 of unit. Lower contact sharp, irregular	20.6
19.	Sandstone, quartz; light yellowish brown; medium grained, poorly sorted, with subangular grains; soft, friable; slope former; iron-stained at upper and lower contacts; internally massive. Lower contact sharp, irregular. Minor biotite	2.4
18.	Claystone, silty; medium brownish green; medium hard, compact; slope former; internally massive. Lower contact gradational. Minor biotite. Unit coarsens near base to sandstone	26
17.	Sandstone, quartz; light brownish yellow; banded with iron-staining; medium (near top) to coarse grained (at base), moderately sorted, with subangular grains; medium hard, friable; slope former; lentic, channel. Lower contact sharp, irregular. Trace of biotite	7.3
16.	Sandstone, silty; (fines upward to blocky claystone near top) medium brownish green and mottled with iron-staining; very fine grained, moderately sorted; soft, friable; slope former	7.1
15.	Sandstone, quartz; light yellowish brown and banded with iron-staining; medium to coarse grained, moderately sorted, with subangular grains; soft, friable; slope former; tabular uneven. Lower contact sharp, irregular. Minor biotite	3.7
14.	Claystone, silty; moderate olive brown; soft, plastic; slope former. Lower contact gradational. Sample 302-5; sample 302-4 of clay with purplish coating	11.2
13.	Sandstone (90%), feldspathic; yellowish gray; medium to coarse grained, moderately to poorly sorted, with subangular grains; medium hard, friable; steep slope former; tabular uneven; internally cross-bedded. Lower contact gradational. Contains clay balls and minor biotite. Sample 302-3. Claystone and siltstone (10%); light gray to orangish gray with some reddish brown iron-stained layers. Very thin to thin forms beds and lenses	10.4-15.

Note: Offset about 500 feet across covered interval. Correlation of this unit is based on (1) lateral continuity of sandstone beds in the unit and (2) lithologic characteristics.

LOCALITY 302. (continued)

Unit		Measured thick. (ft)
12.	Claystone; dark brownish green; medium hard, friable; slope former. Contains thin bed of iron-stained, coarse grained sandstone	9.2
11.	Sandstone, silty; medium greenish brown; very fine grained, medium hard, frangible; slope former; iron-stained, in part.	10
10.	Sandstone; medium yellowish gray; medium grained, poorly sorted, with subangular grains; medium hard, friable; slope former; lentic channel; internally massive. Lower contact sharp, irregular. Contains very thin bed of coarse grained sandstone with subordinate clay pebbles	3.1
9.	Sandstone, silty and clayey; dark brownish green with purplish bands; very fine grained; medium hard, compact; slope former; iron-stained near top	10.6
8.	Sandstone, feldspathic; dusky yellow; fine to coarse grained, poorly sorted, with subangular grains (10-15% granite clasts, very coarse-sand-sized, and subrounded); soft, friable; slope former; locally iron-stained; lentic channel. Minor amount of biotite. Lower contact covered. Unit becomes fine grained and interfingers with claystone to the east. Sample 302-1 is of the iron-stained portion; Sample 302-2 is of the non-stained portion	8.4
7.	Sandstone; light yellowish gray, coarse grained, poorly sorted, with subangular grains; soft, friable; slope former; iron-staining at upper and lower contacts	8
6.	Claystone, sandy; medium greenish brown; medium hard, compact; slope former	4.3
5.	Sandstone; light yellowish gray; with coarse, angular grains; medium hard, friable; slope former; iron-stained at upper and lower contacts. Minor biotite	0.5
4.	Claystone, silty; dark greenish brown; medium hard to hard, brittle; slope former; internally massive. Lower contact sharp, regular	3.3
3.	Sandstone, quartz; medium brownish yellow; medium grained moderately to well sorted, with subangular grains; medium hard, friable; slope former; iron-stained at the top; lentic channel; internally cross-bedded. Minor heavy minerals	3.6
2.	Siltstone; medium yellowish brown; hard, friable; slope former; Interfingers with sandstone to the west	11.2
1.	Sandstone; light grayish yellow; medium grained, poorly sorted, with subangular grains; soft, friable; slope former	3.9
	Total measured thickness	287.6-292.7

LOCALITY 303. WEST MILLIGAN CANYON ROAD

SW¼SE¼NW¼ sec. 22, T. 2 N., R. 1 W.; Jefferson County; roadcut. Unit described is near the base of the more than 80 feet of Climbing Arrow Formation mapped by Robinson (1963, pp. 69-77, Pl. 1) at this location.

Unit		Estimated thick. (ft)
1.	Sandstone, feldspathic to arkosic; yellowish gray, with dark yellowish orange streaks; medium to very coarse grained, poorly sorted, with subangular grains; medium hard, friable; cliff former; lower half calcareous and iron-stained; lentic channel; internally thin bedded with trough crossbeds. Contains clay balls and minor biotite and muscovite. Localized pebble lenses are composed of quartzite and volcanic rocks. Sample 303-2 representative of unit; sample 303-1 taken from iron-oxide-cemented walls of a joint	9

LOCALITY 304. G. BALLARD RANCH 1

SE¼NE¼NE¼ sec. 26, T. 2 N., R. 2 W.; Jefferson County; in reentrant in the south side of an ENE trending ridge, 125 yards north of Cottonwood Canyon Road. Mapped as Tertiary Bozeman Group by Richard (1966, Pl. 1). Correlated with the Climbing Arrow Formation of Robinson (1963, pp. 69-77, Pl. 1) on the basis of lithologic characteristics and stratigraphic position. Strike north 15° east, dip 4° east.

Unit		Measured thick. (ft)
13.	Claystone; dark brownish green; medium hard, friable; slope former; tabular even; internally massive. Lower contact sharp, regular	9.2
12.	Ash, vitric; light gray; soft, loose; slope former; tabular even; internally parallel even, very thin bedded. Lower contact sharp, regular. Sample 304-4	0.2
11.	Tuff, vitric; pale greenish yellow; medium hard, brittle; slope former; tabular even; internal parallel even, very thin to laminated bedding. 35% glass shards. Lower contact sharp, regular. Sample 304-3	1.2
10.	Claystone (coarsens upward into siltstone); medium greenish yellow at bottom to dark yellowish brown at top; medium hard, brittle; slope former; internally massive. Lower contact sharp	9.8
9.	Sandstone; light greenish yellow; fine grained, poorly sorted, with subangular grains; soft, friable; slope former. Lower contact sharp, regular. Minor biotite	1.8
8.	Tuff; light whitish green; medium hard, friable; slope former; internal parallel even laminae. Lower contact sharp, regular. Hackley surface on unweathered laminae	4.8

LOCALITY 304. (continued)

Unit		Measured thick. (ft)
7.	Claystone (upper 85%); medium yellowish green; medium hard, brittle; slope former. Grades into underlying sandstone. Sandstone (lower 15%); medium grayish green; medium grained, with subangular grains; slope former. Lower contact sharp, regular	17.9
6.	Claystone, bentonitic, tuffaceous, micaceous; medium grayish green; soft, frangible; slope former; internally massive. Lower contact sharp, irregular. Subordinate biotite	4
5.	Sandstone, subfeldspathic; medium brownish gray; medium grained, poorly sorted, with subangular grains. Lower contact sharp, regular. Minor biotite	0.3
4.	Claystone; medium brownish green with brownish orange (iron-stained) mottles; soft, compact; slope former; internally massive. Lower contact sharp, irregular	9.1
3.	Sandstone, feldspathic; yellowish brown; medium to coarse grained, poorly sorted, with subangular grains; soft, friable; slope former; locally calcareous cemented parallel to bedding; iron-stained. Lower contact sharp, irregular. Trace of biotite; minor magnetite. Sample 304-2	4.4
2.	Claystone, silty, bentonitic; grayish olive; soft, frangible; iron-stained. Lower contact sharp, irregular. Fines upward to plastic brownish green clay. Sample 304-1	7.8
1.	Sandstone; medium orangish brown; fine to medium grained, moderately sorted, with subangular grains; medium hard, friable; slope former, iron-stained	0.2
	Total measured thickness	70.7

LOCALITY 305. MILLIGAN CREEK CONGLOMERATE

SW¼SE¼NW¼ sec. 1, T. 1 N., R. 1 W.; Jefferson County; north side of gulch. Milligan Creek Formation of Robinson (1963, pp. 64-69, Pl. 1).

Unit		Measured thick. (ft)
3.	Covered (limestone and marlstone float) to top of hill	30.8
2.	Conglomerate (55%), sandy; light gray (weathers to grayish brown); with subangular to subrounded pebbles of volcanic rocks (45%), quartzite (40%) and granite (15%), in a silicified matrix of poorly sorted, angular to subangular, medium to very coarse grained micaceous, arkosic sandstone; in medium thick beds; hard, friable; cliff former; locally calcareous; permeable. Trace of magnetite. Anomalously radioactive. Sample 305-1	

LOCALITY 305. (continued)

Unit		Measured thick. (ft)
2. (cont.)	Sandstone (45%), conglomeratic, arkosic; light gray (weathers to pale yellowish brown; medium to very coarse grained, poorly sorted; with subangular pebbles of quartzite (50%), porphyritic mafic rocks (30%), and granite (20%); hard, brittle; ledge former, cemented with a mixture of chalcedony and quartz (locally calcareous); slightly permeable; medium thick lentic channel; internally thin to medium bedded with planar cross-bedding. Lower contact covered. Minor magnetite and biotite. Sample 305-2. More lithified than the conglomerate. Radioactivity appears to correlate with degree of cementing within this unit	11
1.	Covered (limestone and marlstone float)	55.2
	Total measured thickness	97

LOCALITY 306. G. BALLARD RANCH No. 2

SE¼SE¼SW¼ sec. 24, T. 2 N., R. 2 W.; Jefferson County; 265 feet ENE of two prominent tuff beds which crop out just north of the obtuse corner of Cottonwood Canyon Road. Strike north 18° east and dip 6° east. Section seems to stratigraphically overlie section 304. Mapped as the Tertiary Bozeman group by Richard (1966, Pl. 1); correlated with the Climbing Arrow Formation of Robinson (1963, p. 69-77, Pl. 1) on the basis of lithologic characteristics and stratigraphic position.

Unit		Measured thick. (ft)
10.	Claystone; medium purplish brown; soft; slope former, internally massive. Lower contact gradational	1.8
9.	Sandstone (2 inch beds interbedded with clayey siltstone similar to unit 8); medium brownish orange; medium grained, moderately sorted, with subangular grains; soft, loose; slope former; iron-stained	1.1
8.	Siltstone, clayey (grades to silty claystone and back); medium greenish brown; soft, friable; slope former; internally massive. Lower contact gradational. Slight reddish staining near top	11.3
7.	Sandstone, silty and clayey; medium brownish gray, fine to medium grained, very poorly sorted, with subangular grains; soft, friable; slope former; internally massive; lower contact gradational. Minor biotite	0.9
6.	Claystone (85%), silty, bentonitic; medium greenish brown to dark slightly reddish brown; slope former ... Siltstone (15%), grading to fine grained sandstone; medium yellowish brown, slope former. Comments: Lower contact of unit is sharp. Contacts within the unit are gradational.	16.1

LOCALITY 306. (continued)

Unit		Measured thick. (ft)
5.	Sandstone, quartz; medium brownish gray; medium grained, moderately sorted, with angular grains; soft, loose; slope former. Lower contact gradational. Minor biotite	1.1
4.	Sandstone, feldspathic; iron-stained to grayish orange with unstained medium yellowish gray bands; fine to coarse grained, moderately sorted, with subangular to angular grains; hard to medium hard, friable (laterally soft, loose); ledge former; silica cemented (laterally uncemented; slope former); lentic channel; internally very thin bedded with planar cross-bedding. Lower contact sharp, regular. Minor biotite; trace of silicified wood. Iron-staining occurs in the coarser portions of unit and surrounds the silicified wood fragments. Higher radioactivity occurs adjacent to the silicified wood. Sample 306-1	2.0
3.	Sandstone, clayey, subfeldspathic; medium yellowish green; fine grained, moderately sorted, with subangular grains; soft, friable; slope former. Lower contact gradational. Trace to minor biotite	2.3
2.	Claystone, silty; light to medium yellowish green; soft, plastic; slope former. Lower contact gradational	2.9
1.	Claystone, sandy and silty; medium brown; soft, frangible; slope former	2.5
	Total measured thickness	42

LOCALITY 308. SHODDY SPRINGS

SW¼NE¼SW¼ sec. 3, T. 2 N., R. 1 W.; Jefferson County; water sample 308-1 from stream adjacent to the house on the Silver Sage Ranch. Water apparently rises from Climbing Arrow Formation of Robinson (1963, pp. 69-77, Pl. 1).

LOCALITY 309. SILVER SAGE No. 1

S½SE¼SE¼ sec. 2, T. 2 N., R. 1 W.; Jefferson County; 100 feet north of road to Silver Sage Ranch. Climbing Arrow Formation of Robinson (1963, pp. 69-77, Pl. 1). Strike north 60° west; dip 5° northeast.

Unit		Measured thick. (ft)
7.	Sandstone; light yellowish brown; medium grained, poorly sorted, with subangular grains; soft, loose; slope former. Lower contact sharp	1.5
6.	Claystone, silty, micaceous in middle; medium greenish brown to reddish brown; soft, frangible (plastic at base); slope former; tabular even; internally massive. Lower contact sharp, regular	1.5

LOCALITY 309. (continued)

Unit		Measured thick. (ft)
5.	Sandstone, silty; medium brownish gray; medium grained at bottom, fining upwards to very fine grained at top, poorly sorted, with subangular grains; soft, friable; cliff former. Lower contact sharp. Contains clay balls and minor biotite.	1.7
4.	Siltstone, clayey (micaceous at base); dark greenish gray (pinkish brown in middle); tabular uneven; internally massive. Lower contact sharp, regular	1.3
3.	Sandstone, subfeldspathic; light gray; fine to coarse grained, poorly sorted, with subangular grains; medium hard, brittle; cliff former; iron-stained in lower portion; lentic channel; internally very thin bedded. Lower contact sharp, irregular. Contains some balls and laminae of light pink, translucent clay in lower portion. Minor heavy minerals (biotite and magnetite). Sample 309-2 of finer lower portion. The following sample was taken 175 feet ESE of the measured section in a 9-inch thick bed which probably is equivalent to this unit:	4.3
	Sample 309-3. Sandstone; yellowish gray and banded; fine to medium grained, poorly sorted, with subangular grains; medium hard, friable; ledge former; internally thin bedded with planar cross-bedding. Trace of biotite.	
2.	Claystone; pale yellowish brown to pale brown; soft, brittle; slope former. Lower contact sharp. Sample 309-1	1.7
1.	Sandstone (75%), medium yellowish gray; fine grained, moderately sorted, with subangular grains; soft, friable; slope former. Subordinate biotite Claystone (25%), silty; dark brownish gray; soft, frangible; slope former	0.6
	Total measured thickness	12.6

LOCALITY 310. JOHNSTON FARM

SE¼SW¼NW¼ sec. 16, T. 2 N., R. 1 E.; Broadwater County; about 500 feet east of line between sections 16 and 17. Climbing Arrow Formation of Robinson (1963, pp. 69-77, Pl. 1). Strike north 62° west; dip 2° northeast.

Unit		Measured thick. (ft)
11.	Sandstone, clayey, tuffaceous; medium yellowish brown; medium grained, poorly sorted, with subangular grains; soft, loose; slope former. Lower contact sharp	1.8
10.	Claystone (silty near base), bentonitic; medium greenish brown to reddish brown; soft, frangible; slope former; internally massive. Lower contact sharp, regular	5

LOCALITY 310. (continued)

Unit		Measured thick. (ft)
9.	Sandstone, subfeldspathic (tuffaceous and clayey in upper portion); light gray; medium grained, moderately sorted, with subangular grains; soft, friable; steep slope former; lentic channel. Lower contact sharp, regular. Contains clay balls. Sample 310-4	2.6
8.	Claystone, coarsens to clayey siltstone in upper portion; medium greenish brown; soft, plastic; slope former; tabular even; internally massive. Lower contact sharp, regular	1.8
7.	Sandstone, (upper one third finer grained, clayey, tuffaceous and bentonitic); medium orangish gray; medium grained, poorly sorted, with subangular grains; soft, loose; steep slope former; moderately iron-stained; lentic channel. Lower contact sharp. Contains some petrified bone fragments and minor heavy minerals	8
6.	Sandstone, tuffaceous (fines upward to sandy claystone), bentonitic; grayish olive; fine to medium grained, poorly sorted, with subangular grains; soft, friable; steep slope former; locally iron-stained; lentic. Lower contact sharp. Trace of silicified wood and bone fragments. Minor magnetite, and 10-20% pumice granules. Sample 310-3 taken from near the bottom contact	3.5
5.	Claystone, silty; dusky yellow; medium hard, brittle; slope former. Lower contact sharp. Sample 310-2 taken near the top	0.9
4.	Sandstone, tuffaceous/vitric tuff; yellowish gray; fine grained, moderately sorted, with subangular grains; soft, friable; steep slope former. Lower contact covered. Minor biotite and petrified wood. Sample 310-1	0.7
3.	Covered	13.2
2.	Claystone; medium grayish brown and mottled (weathers to light brownish gray); medium hard, brittle; slope former; iron-stained; lentic bed; internal parallel very thin bedding. Interbedded with siltstone in lower part	4.2
1.	Sandstone; light yellowish gray; medium to very fine grained (fines upward), with subangular grains; medium hard, friable; steep slope former; lentic channel. Trace petrified wood; minor heavy minerals. Very thin black layer of manganese oxide or carbonaceous material near top	6.4
	Total measured thickness	48.1

LOCALITY 311. DUNBAR CREEK TYPE AREA

E½ sec. 7, T. 1 S., R. 2 E.; Gallatin County; type area of Dunbar Creek Formation (Robinson, 1963, pp. 77-81, Pl. 1). Unit described is probably unit 1 of Robinson's measured section G (p. 78, Pl. 2).

Unit		Estimated thick. (ft)
1.	Sandstone, feldspathic; yellowish gray; coarse grained, moderately sorted, with angular to subangular grains; very hard, brittle; cliff former; permeable; clay (?) cemented. Minor biotite. Sample 311-1	8-10

LOCALITY 312. SILVER SAGE No. 2

Center SE¼SW¼ sec. 3, T. 2 N., R. 1 W.; Jefferson County; top of northern knob between east-west gravel road and eastern driveway to Silver Sage Ranch. Climbing Arrow Formation of Robinson(1963, pp. 69-77).

Unit

1. Limestone, aphanitic; grayish yellow and speckled (weathers to light gray); hard, brittle; surficially iron-stained. Manganese dendrites. Sample 312-2 characteristic of unit. Sample 312-1 of anomalously radioactive part of unit with minor carbonized wood. Anomaly seems confined to a point source.

LOCALITY 313. CHERRY CREEK FAULT SECTION

Center W½, sec. 26, T. 2 S., R. 1 E.; Madison County; Units 1 and 2 described below probably correspond to units 21 and 22, respectively, of section I of Feichtinger (1970, pp. 65-68, Pl. I and II). Dunbar Creek Formation of Robinson (1963, pp. 77-81).

Unit		Estimated thick. (ft)
2.	Conglomerate, sandy; light orangish gray; with subangular pebbles of volcanic rocks, granite and quartz, in a matrix of medium to very coarse grained, poorly sorted sand; hard, friable; ledge former; calcareous cemented; tabular uneven; channel; internally medium bedded with planar cross-bedding. Lower contact erosional with less than 1 foot of relief. Minor heavy minerals (amphibole, magnetite, and biotite). Sample 313-2	12
1.	Siltstone, sandy; light yellowish orange, with subangular, poorly sorted sand; soft, friable; slope former; tabular uneven; internally massive. Minor amphibole. Contains pebble lenses. Sample 313-1	19
	Total estimated thickness	31

LOCALITY 314. CROWLEY DITCH

NW¼NE¼SE¼ sec. 18, T. 1 S., R. 2 E.; Gallatin County; north side of small east-trending draw adjacent to Madison River. Dunbar Creek Formation of Robinson (1963, pp. 77-81), as mapped by Feichtinger (1970, Pl. 1).

Unit		Estimated thick. (ft)
14.	Sandstone, fine grained	6
13.	Conglomerate, pebble; poorly sorted; ledge former	5
12.	Sandstone, fine grained	2
11.	Sandstone; medium grained to pebbley; channel (?); lightly iron-stained, cross-bedded	6
10.	Sandstone; fine grained; ledge former	4
9.	Sandstone, silty; fine grained; ledge former	6
8.	Sandstone, feldspathic; dull yellowish brown and streaked (weathers to grayish brown); coarse grained, moderately sorted, with angular to subangular grains; hard, compact; ledge former; cemented with iron oxides; lentic channel; internal trough cross-bedding. Lower contact sharp, irregular. Sample 314-2	3
7.	Siltstone; yellowish gray (weathers to light gray); medium hard, friable; slope former; tabular uneven; internally massive. Lower contact sharp, irregular. Minor carbonaceous material. Sample 314-1	1
6.	Siltstone (50%) Sandstone (50%); fine grained; in medium thick beds; some iron-staining near base	25
5.	Sandstone (locally silty or conglomeratic); light gray; fine grained; tabular; internally medium bedded	30
4.	Sandstone, conglomeratic; coarse to medium grained; some iron-staining; internally cross-bedded	2
3.	Sandstone (95%); light gray; both fine grained (74%) and medium grained (26%) beds, poorly sorted; ledge former; tabular; internally medium to thick bedded Siltstone and claystone (5%); thin bedded	10-15
2.	Sandstone, conglomeratic; dull yellow and streaked; medium grained, poorly sorted, with subrounded pebbles; medium hard, compact; iron-stained; tabular uneven; internally trough cross-bedded. Lower contact sharp, irregular. Minor biotite and muscovite; trace of volcanic glass. Probably channel. Sample 314-4 collected at bottom	4

LOCALITY 314. (continued)

Unit		Estimated thick. (ft)
1.	Siltstone, sandy; light yellowish gray (weathers to light gray); with fine grained, poorly sorted sand; medium hard, brittle; tabular even; internally massive. Sample 314-3 collected at top	4
	Total estimated thickness	108-113

LOCALITY 315. NORTH JORGENSON DITCH

NE¼SE¼NW¼ sec. 19, T. 1 S., R. 2 E.; Gallatin County; north side of broad draw trending east to the Madison River. Units 1 and 2 described below probably correspond to units 15 (upper portion) and 16, respectively, of stratigraphic section IV of Feichtinger (1970, pp. 74-78, Pl. 2). Dunbar Creek Formation of Robinson (1963, pp. 77-81) as mapped by Feichtinger (1970, Pl. 1).

Unit		Estimated thick. (ft)
2.	Sandstone, silty; dusky yellow and streaked; medium grained, poorly sorted (ranges from fine grained to conglomeratic with subrounded pebbles of siltstone); medium hard, friable; iron-stained; lentic channel; internal trough cross-bedding. Lower contact sharp, irregular. Minor biotite and muscovite. Sample 315-2. Lower contact is iron cemented and dark reddish brown	2
1.	Siltstone, tuffaceous; light yellowish gray (weathers to light gray); medium hard, compact; lentic channel; internally massive. Contains manganese (?) dendrites and probable root casts. Sample 315-1	0.3
	Total estimated thickness	2.3

LOCALITY 316. REY CREEK

Center NE¼SE¼ sec. 4, T. 1 N., R. 2 E.; Gallatin County; due east of Christiansan Ranch. Units 2, 4, 5, and 7 probably correspond to units 9, 12, 13, and 21, respectively, of stratigraphic section III of Schneider (1970, pp. 54-56). Unit 2 is from Schneider's "Lower Unit", which is of Miocene age. Units 4 and 5 are from the lower portion of Schneider's "Middle Unit" which is also of Miocene age. Unit 7 is from basal portion of Schneider's "Upper Unit" which is of Pliocene age (p. 12).

Unit		Estimated thick. (ft)
8.	Not described	*12
7.	Sandstone; yellowish gray and streaked; fine grained, well sorted; soft, friable; locally calcareous; internal very thin to laminated cross-bedding. Minor muscovite; iron-stained along laminae. Description and sample 316-1 taken from upper part of unit	*68

LOCALITY 316. (continued)

Unit		Estimated thick. (ft)
6.	Not described	*91
5.	Sandstone, silty; yellowish gray; medium grained, very poorly sorted, with subrounded grains; medium hard, friable; locally cemented and streaked with iron oxides (probably related to surface weathering). Contains clay balls and some very thin lenses of pebbly sandstone. Sample 316-4 from near base of unit; sample 316-2 taken of iron-oxide-cemented layers from near base	*35
4.	Sandstone, silty; light gray; very fine grained, poorly sorted. Sample 316-3 taken in upper part	*20
3.	Not described	*10
2.	Conglomerate; dull yellowish brown; in a matrix of very poorly sorted, subangular to subrounded, very fine to very coarse silty sand; tabular uneven; iron-stained. Lower contact erosional. Minor magnetite. Sample 316-5	* 3
1.	Not described	*50
	Total estimated thickness	289

*Thickness from Schneider (1970, p. 54-56).

LOCALITY 317. SOUTHWEST SIDE HIGH FLAT

NW¼SW¼NW¼ sec. 6, T. 3 S., R. 4 E.; Gallatin County; about 100 yards southwest of ranch road along ridge. Outcrop is of "the only lithologic unit constituting a marker horizon in the Miocene section" (Mifflin, 1963, p. 20).

Unit		Estimated thick. (ft)
1.	Sandstone, conglomeratic, subfeldspathic; light gray (weathers to grayish brown); coarse to very coarse grained, moderately sorted with angular grains and with pebbles of quartz (85%), metamorphic rocks (10%), and feldspar (5%); very hard, brittle; ledge former; silica cemented; tabular even; internal parallel even medium beds. Subordinate hornblende. Sample 317-1. Unit apparently deposited unconformably against a hill composed of quartzites and other metamorphic rocks of pre-Cambrian age	10

LOCALITY 318. RED BLUFF GULCH

NW¼NE¼SW¼ sec. 13, T. 3 S., R. 1 W.; Madison County; in north draining gulch. Red Bluff Formation of Andretta and Alsup (1960, p. 186). Strike north 74° west; dip 6° south. Bleaching and alteration may be hydrothermal in origin (Robert Levich, personal communication, 1975).

LOCALITY 318. (continued)

Unit		Measured thick. (ft)
7.	Sandstone, pebbly; dark pinkish brown; coarse grained, hard, brittle; cliff former; iron-stained at base; lentic bed; internally massive. Contains sand sized grains of pumice. Basal portion altered to soft, friable, iron-stained, yellow sandstone. Lower contact sharp, irregular. Sample 318-2 from the oxidized layer at base	15.1
6.	Siltstone, clayey, tuffaceous; light gray; medium hard, brittle, bleached; tabular even; internally parallel even thin beds. Lower contact covered. Trace of organic material. Appears to be highly altered. Sample 318-1	2.8
5.	Covered	16.4
4.	Conglomerate, arkosic; light pinkish brown and mottled (weathers to medium orangish brown); with angular pebbles of feldspar; hard, brittle; ledge former; tabular uneven; internally medium bedded. Lower contact sharp, irregular. Contains some smoky quartz	5.2
3.	Sandstone, pebbly; light reddish gray; (weathers to purplish red); fine grained; hard, brittle; ledge former; siliceous or ferruginous cemented; iron-stained; tabular uneven; internal parallel even very thin to thin beds. Lower contact gradational	2.6
2.	Conglomerate, sandy; light grayish purple (weathers to medium grayish purple); with angular pebbles of feldspar and quartz in a matrix of coarse grained, moderately sorted sandstone; medium hard, brittle; slope former; bleached; lentic channel; internally medium bedded. Lower contact sharp, regular	3
1.	Conglomerate (60%), sandy, arkosic; light whitish purple (weathers to dark grayish purple); with subangular pebbles of feldspar in a matrix of medium grained, moderately sorted sandstone; hard, brittle; cliff former; possibly ferruginous cemented; iron-stained; medium thick lentic bed; internally parallel uneven, medium bedded .... Sandstone (40%), conglomeratic, subfeldspathic; medium grayish purple (weathers to dark purplish red); fine to medium grained, poorly sorted; hard, brittle; cliff former; medium thick lentic channel; internally medium bedded with cross-bedding. Contains sand sized grains of pumice	17.8
	Total measured thickness	61.9

LOCALITY 319. RED BLUFF WARM SPRING

SW¼NW¼NE¼ sec. 18, T. 3 S., R. 1 E.; Madison County; Water sample 319-1 from spring on east side of road. Water is warm (74° F.).

LOCALITY 320. CRANE SCHOOL

NW¼SE¼SE¼ sec. 22, T. 5 N., R. 3 E.; Gallatin County; in bulldozed prospect on low knoll, west side of south draining valley. Sixmile Creek Formation of Robinson (1967).

Unit		
1.	Siltstone; salmon pink; soft to hard; very calcareous where hard. Cut by veins of banded chalcedony which trend north 50° east. Yellow powdery coating on siltsone pieces is identified as jarosite. Sample 320-1 taken of chalcedony and jarosite...	

LOCALITY 321. SIXMILE CREEK No. 1

Center W½NE¼ sec. 17, T. 5 N., R. 3 E.; Broadwater County; at base, east side of low north-south ridge. Climbing Arrow Formation of Robinson (1967). Dip 25° to 30° to the east. The lower member of the formation is comprised of shales, lignites, bentonitic clays and conglomerates (ibid.). The conglomerates, which locally make up 10% to 20% of the member in this locality, are strongly cemented with carbonate or silica, and are not permeable. The lignites (unit 1, below) are anomalously radioactive.

Unit		Estimated thick. (ft)
1.	Lignite; dull reddish brown; medium hard, frangible; slope former; tabular even; internal parallel laminae. Contains jarosite along bedding plains. Sample 321-1	3

LOCALITY 322. DRY HOLLOW No. 1

NE¼NE¼NW¼ sec. 6, T. 5 N., R. 3 E.; Broadwater County; on north side of hollow. Strike due north and dip 19° west. Basal part of the Sixmile Creek Formation of Robinson (1967).

Unit		Estimated thick. (ft)
4.	Similar to unit 2, but without pebbles	4.5
3.	Sandstone, tuffaceous; fine grained. Predominately glass shards	0.5
2.	Sandstone, pebbly, tuffaceous; yellowish gray; fine to medium grained, moderately sorted, with angular grains and angular to subrounded pebbles; medium hard, friable; cliff former; calcareous cemented near base; tabular even; internally medium bedded. More than 50% glass shards; trace of magnetite. Lower contact gradational. Sample 322-1	2
1.	Conglomerate, pebble; calcareous cemented	1
	Total estimated thickness	8

LOCALITY 323. CROW CREEK

NE¼NW¼NE¼ sec. 32, T. 6 N., R. 1 E.; Broadwater County; west side of small gully in bench on north side of creek. Oligocene sedimentary tuff unit of Klepper and others (1971, pp. 12-13, Pl. 1). Strike north 70° west and dip 20° south.

Unit		Estimated thick. (ft)
3.	Siltstone, clayey, tuffaceous/lithic tuff; pinkish gray with white spots; medium hard, brittle; slope former. 2 foot thick layer 2 feet below top of unit contains 10%-15% white pumice granules up to 3 mm in diameter. Sample 323-1	15
2.	Covered	5
1.	Siltstone, sandy; mottled pink and gray; medium hard to hard; ledge former	6
	Total estimated thickness	26

LOCALITY 324. MILLIGAN CANYON ROAD EXIT No. 1

SW¼NE¼NW¼ sec. 16, T. 2 N., R. 1 W.; Jefferson County; east side of reentrant. Climbing Arrow Formation of Robinson (1963, p. 69-77, Pl. 1). Unit 5 is tentatively correlated with the uppermost units in localities 325 and 326.

Unit		Estimated thick. (ft)
5.	Sandstone, pebbly; medium grained, poorly sorted; with subrounded to subangular pebbles of igneous and metamorphic rocks. Locally characterized by anomalous radioactivity. Samples described below are from anomalously radioactive beds exposed in a prospect pit about 25 to 50 feet from the measured section	9

Sample 324-3. Sandstone, feldspathic to arkosic; moderate yellowish brown (weathers to medium brown); coarse grained, poorly sorted, with subangular grains; soft, friable (weathers to soft, loose); slope former; iron-stained; tabular even; internally massive. Lower contact sharp, regular. Trace smokey quartz. Estimated thickness, 2 ft.

Sample 324-2. Iron oxide cemented contact between sandstone (sample 324-3) and claystone (324-1); moderate brown; medium hard, friable; ledge former; tabular even, internally parallel even, very thin to laminar bedding. Lower contact sharp, regular. Contains smokey quartz. Estimated thickness 0.2 ft.

Sample 324-1. Claystone, silty; dusky yellow (weathers to light gray); medium hard, plastic (weathers to soft, loose); slope former; iron-stained along silty laminae; internally mostly massive. Not exposed in measured section. Estimated thickness, 3 ft.

LOCALITY 324. (continued)

Unit		Estimated thick. (ft)
4.	Claystone, sandy, micaceous; dark olive brown (less dark near top). Iron-stained at upper contact. Lower contact covered.	7
3.	Sandstone, silty, pebbly; coarse grained, poorly sorted, with subrounded to angular pebbles. Lower contact covered	27
2.	Covered (gravel and sand)	10
1.	Sandstone, tuffaceous; white	7
	Total estimated thickness	60

LOCALITY 325. MILLIGAN CANYON ROAD EXIT No. 2

W½NW¼SE¼ sec. 16, T. 2 N., R. 1 W.; Jefferson County; near south end of prominent west-southwest-facing escarpment. Climbing Arrow Formation of Robinson (1963, pp. 69-77, Pl. 1). Strike north 6° east and dip 4.5° east. Unit 9 is tentatively correlated with the uppermost units of localities 324 and 326.

Unit		Measured thick. (ft)
9.	Sandstone, locally conglomeratic; dark reddish brown (weathers to light yellowish brown); coarse grained, poorly sorted, with subrounded to subangular grains; contains lenses of subrounded to angular pebbles; soft, loose; slope former; iron-stained, tabular even, channel; internally massive. Lower contact sharp, regular. Locally anomalously radioactive	12
8.	Claystone, sandy, pebbly, bentonitic; medium greenish brown (weathers to light grayish brown); soft, friable, (weathers to soft, loose); slope former; tabular even; internally massive. Lower contact sharp, regular. Anomalously radioactive	8.3
7.	Sandstone, feldspathic; yellowish gray (weathers to light grayish brown); coarse to medium grained (fines upward), poorly sorted, with subrounded to subangular grains; soft, loose (weathers to soft, friable); iron-cemented at base; lentic channel. Lower contact sharp; irregular. Minor carbonaceous material and mica. Anomalously radioactive. Contains meta-autunite and coffinite. <u>Sample 325-4</u> representative of unit; <u>Sample 325-5</u> from pale greenish yellow, bleached zone with petrified wood..........................	4.6
6.	Claystone, sandy; moderate olive brown (weathers to medium reddish brown); soft, frangible (weathers to soft, loose): slope former; iron-stained near the top. Contains about 5% angular, medium to coarse-grained quartz sand; trace biotite. Anomalously radioactive. <u>Sample 325-3</u> from near top	3.7

LOCALITY 325. (continued)

Unit		Measured thick. (ft)
5.	Sandstone, silty, arkosic; dusky yellow (weathers to light orangish gray); medium grained, poorly sorted, with subrounded to subangular grains; soft, friable; (weathers to medium hard, friable); slope former; iron-stained near top; lentic channel. Lower contact sharp, irregular. Minor biotite and smokey quartz. <u>Sample 325-2</u> from near top, above thin clay lens	8.6
4.	Claystone, sandy, bentonitic; moderate olive brown (weathers to medium gray) with 10-15% angular, medium to coarse grained quartz sand; soft, compact (weathers to soft, loose); slope former; lentic; internally massive. Lower contact sharp. <u>Sample 325-1</u> from near top	3.7
3.	Sandstone, quartz; medium brown (weathers to light gray); medium to coarse grained, poorly sorted, with angular grains; soft, loose (weathers to medium hard, friable); slightly iron-stained near the top ; tabular even; internally massive. Lower contact sharp, regular. Minor biotite	5.2
2.	Claystone, sandy; medium greenish brown (weathers to light gray); with less than 10% lenses of medium grained angular quartz sand; medium hard, frangible (weathers to soft, loose); slope former; tabular even; internally massive	13
1.	Sandstone, pebbly and silty; medium brown (weathers to light brownish gray); medium grained, poorly sorted, with angular grains; medium hard, friable; slope former	0.7
	Total measured thickness	59.8

LOCALITY 326. MILLIGAN CANYON ROAD EXIT No. 3

NW¼SW¼SE¼ sec. 16, T. 2 N., R. 1 W.; Jefferson County; 200 to 300 yards south of locality 325. Hand level used to determine thickness. Climbing Arrow Formation of Robinson (1963, pp. 69-77, Pl. 1). Strike north 8.5° east; dip 4.5° east. Unit 6 tentatively correlated with uppermost units of localities 324 and 325. Units 2 thru 6 are anomalously radioactive.

Unit		Estimated thick. (ft)
6.	Sandstone, feldspathic; light gray (weathers to reddish gray); medium to coarse grained, moderately sorted, with subangular grains; hard, brittle; ledge former; silica cemented; tabular even; internal parallel thin beds; lower contact sharp, regular. Minor biotite and smokey quartz. <u>Sample 326-2</u>	2.5

LOCALITY 326. (continued)

Unit		Estimated thick. (ft)
5.	Siltstone, sandy, tuffaceous; very pale orange; with poorly sorted, very fine to very coarse sand grains of quartz, feldspar and pumice; soft, friable; slope former; locally calcareous cemented; internally disturbed and irregular (exhibits penecontemporaneous drag folding induced by east-flowing current). Contains rounded pebbles of pumice near base of exposure. Lower contact covered. Minor petrified wood. Sample 326-1	9
4.	Covered	12
3.	Sandstone, conglomeratic, volcanic (fines upward to tuffaceous siltstone); with pebbles of pumice	4
2.	Covered	2.5
1.	Sandstone, conglomeratic, arkosic; yellowish gray (weathers to light gray); coarse to very coarse grained, moderately sorted, with rounded and subangular grains, with pebbles of volcanic rock (75%+); medium hard, friable; cliff and ledge former; tabular even; internally very thin bedded with planar crossbedding. Sample 326-3	8
	Total estimated thickness	38

LOCALITY 327. DEEP CREEK

N½SW¼SE¼ sec. 30, T. 7 N., R. 3 E.; Broadwater County; on prominent nose, 200-300 yards east of residence on north side of U.S. Highway 12. Hand level used to determine thickness. Tertiary deposits mapped by Nelson (1963, pp. J41-J45, Pl. 1), which, according to Robinson (1967), are equivalent to the Miocene and Pliocene Sixmile Creek Formation. Strike north 37° W.; dip 24.5° E.

Unit		Estimated thick. (ft)
11.	Conglomerate, silty to sandy; very pale orange; calcareous cemented, degree of cementation variable. Most resistant near middle of unit; forms prominent ledges and cliffs. Upper 80-100 feet poorly cemented. Composition and shape of clasts similar to basal conglomerate of unit 2, but contains some clasts up to 6 inches in diameter. Locally contains beds of massive claystone or siltstone up to 8 feet thick. Sample 327-2 taken from base of lowest cemented bed	159.3
10.	Claystone; grayish orange (weathers to light pinkish gray); soft, loose; slope former. Sample 327-1	13.6
9.	Claystone, pebbly; slope former, but calcareous cemented near top to form isolated ledges and knobs. Pebbles similar to those in unit 8	9.1

LOCALITY 327. (continued)

Unit		Estimated thick. (ft)
8.	Conglomerate, flat pebble; ledge former; calcareous cemented. Similar to basal conglomerate of unit 2	3.6
7.	Clay; medium reddish brown (weathers to light pinkish gray); loose	15
6.	Conglomerate, flat pebble; calcareous cemented. Similar to basal conglomerate of unit 2 except pebbles are smaller	5.9
5.	Siltstone, and claystone; light pinkish gray; soft; slope former; calcareous cemented. Contains medium thick ledge of silty limestone in middle	63.7
4.	Gravel, flat pebble; similar to basal conglomerate of unit 2, but loose	10.9
3.	Claystone; fines upward from thin basal conglomerate similar to that of unit 2 thru 2.5 feet of siltstone to 14.3 feet of claystone	17.1
2.	Siltstone and claystone (fines upward from medium thick basal flat pebble conglomerate which is calcareous cemented, clay-bound, and composed of Belt Series rocks thru thin bed of pebbly siltstone, to siltstone and claystone); light pinkish gray; calcareous cemented	47.3
1.	Siltstone and claystone; light pinkish gray; slope former; very calcareous; internally massive	23.7
	Total estimated thickness	369.2

LOCALITY 328. MAGPIE CREEK POINT

NE¼SW¼SE¼ sec. 11, T. 10 N., R. 1 W.; Lewis and Clark County, south side of prominent point which is on the southeast side of Magpie Creek. Section starts at a shear zone or fault at lake level and ends at the base of the older Quaternary gravels (Mertie and others, 1951, pp. 41 and 42, Pl. 1). Hand-level used to estimate thickness. Tertiary unit 3 of Mertie and others (op. cit., pp. 35-37, Pl. 1). Tertiary rocks in the locality are of Lower Miocene age (White, 1954, p. 398, Figs. 42 and 51). Unit thicknesses have been corrected, where appropriate, to compensate for net slip along a west-dipping normal fault that cuts the rocks of this section.

Unit		Estimated thick. (ft)
7.	Sandstone (fines upward to sandy siltstone); light brown; fine grained, with angular grains; porous; unevenly bedded in lower 8 feet (cross-bedded channel scour in basal 1 foot), internally massive above lower 8 feet. Lower contact sharp, irregular	37.4

LOCALITY 328. (continued)

Unit		Estimated thick. (ft)
6.	Sandstone and siltstone; light pinkish brown; very fine grained; medium hard; cliff former; porous; internally massive. Lower contact sharp, irregular. 85-95% glass shards	14.8
5.	Siltstone or claystone, tuffaceous; white; soft, friable; internally massive; composed of glass shards. Lower contact gradational	8.4
4.	Siltstone, sandy (similar to unit 1); light brownish gray; internally massive; contains trace of silicified bones. Composed of reworked glass shards. Contains a 0.5 foot lens of very fine grained water laid ash. In upper 10-20 feet, unit coarsens, becomes lighter in color, and contains some lenses of medium and coarse grained sand	135
3.	Claystone; light brown; soft to medium hard; slope former; (locally, cliff former)	17.7
2.	Sand, pebbly, ardosic; light olive brown (weathers to medium brown); medium to coarse grained, moderately sorted, with subangular to angular grains; with pebbles of argillite (80%+), welded tuffs, shales and quartzites; soft, loose; slope former; iron-stained. Trace heavy minerals (biotite and magnetite). Sample 328-2	10.8
1.	Siltstone, sandy; yellowish gray (weathers to medium reddish brown); with fine grained, poorly sorted, subangular to angular grains of sand; locally calcareous; cliff former; internally massive; contains glass shards. Sample 328-1. Unit coarsens near top to a slope-forming, poorly sorted, fine-grained quartz sandstone, with angular to subangular grains, that contains some glass shards and a minor amount of heavy minerals (some magnetite)	62.8
	Total estimated thickness	286.9

LOCALITY 329. CAVE GULCH SOUTHEAST RIDGE

NE¼NW¼SE¼ sec. 2, T. 10 N., R. 1 W.; Lewis and Clark County; roadcut, Highway 284, just northwest of top of ridge between Cave Gulch and Magpie Creek. Tertiary Unit 4 of Mertie and others (1951, pp. 37 and 38, Pl. 1); Miocene or younger since it overlies Mertie's Unit 3 (see locality 328).

Unit		Estimated thick. (ft)
1.	Conglomerate, silty shale; moderate brown (weathers to dark pinkish brown); with angular flat pebbles of brown shale (70%) and pink shale (25%); medium hard, friable; cliff former; calcareous cemented; lentic channel; internal parallel even beds. Lower contact erosional (greater than 6 feet of relief). Sample 329-1	18-20

LOCALITY 330. WINSTON BADLANDS No. 1

NE¼SW¼NW¼ sec. 20, T. 9 N., R. 1 E.; Broadwater County; Base of section located 400 feet at north 20° east from break in slope at west end of inter fluve. Section ends at covered reentrant about 1/4 mile northeast. Hand level used to estimate thickness. Lower part of Tertiary unit 2 of Oligocene age (Mertie and others, 1951, pp. 33-35, Pl. 1 and 2) as mapped by Becraft (1958, pp. 153-159, Pl. 3). Average attitude: strike north 26° west; dip of 28° east. Although many anomalously radioactive localities in the Winston badlands were mapped and discussed by Becraft (ibid.), the only anomalous unit in this measured section is the lignite of unit 2.

Unit		Estimated thick. (ft)
23.	Clay, bentonitic; dark greenish brown	7.3
22.	Claystone, silicified	1.8
21.	Claystone, silty, bentonitic; dark greenish gray (weathers to light grayish brown)	7.3
20.	Siltstone; medium brown (whitish in top 2 feet); cliff former; internally massive	12.7
19.	Claystone, bentonitic; slope former	10.9
18.	Claystone; dark greenish brown; interbedded with 1 foot beds of silicified claystone. Cliff former. Basal 0.5 foot is medium gray siltstone	8.2
17.	Siltstone, conglomeratic, medium greenish brown (weathers to a yellowish gray). Pebbles of pumice in basal 3 feet	9.1
16.	Sandstone, tuffaceous; light gray; with medium to coarse grains of pumice (95%), quartz, and volcanic rocks	0.9
15.	Siltstone and claystone, tuffaceous; medium brown, very slightly bentonitic	5.5
14.	Covered	9.1
13.	Siltstone, tuffaceous; medium yellowish brown. Capped by 2 inches of silicified siltstone that overlies 3 inches of coarse grained, white, resistant sandstone composed of pumice grains	2.7
12.	Claystone or siltstone, tuffaceous; hard; ridge former. Coarsens upward to sandstone	0.8
11.	Sandstone, tuffaceous; light yellowish gray; fine to medium grained; medium hard. Predominately composed of sand-sized pumice grains	1.7
10.	Siltstone, sandy; light yellowish gray; grades upward into a medium greenish brown silicified claystone	3.0

LOCALITY 330. (continued)

Unit		Estimated thick. (ft)
9.	Sandstone, conglomerate, claystone (all interbedded); light gray; internally very thin bedded; all composed of appropriate sized pumice clasts	8.5
8.	Clay, bentonitic; medium brown (weathers to medium gray)	6.8
7.	Sandstone, conglomeratic; medium gray; medium to coarse grained, with angular grains of quartz (50%), pumice (25%) and lithic clasts (25%), and pebbles of volcanic rocks and pumice; ledge former; permeable; cross bedded; fines upward to medium grained sandstone. Contains some very thin lenses of bentonitic clay	5.9
6.	Sandstone, similar to unit 5	5.1
5.	Sandstone; weathers medium yellowish gray; medium grained; some bentonitic clay lenses; pebbles of volcanic rock scattered throughout. Basal 0.7 feet is white and is composed of sand-sized grains of pumice	5.9
4.	Sandstone, clayey, tuffaceous; medium brown to medium orangish brown; medium grained; composed of sand-sized pumice grains. Varies from clayey sandstone to bentonitic sandy claystone..	5.9
3.	Sandstone, pumiceous; grayish yellow; composed of well sorted, medium to coarse grained, subangular to subrounded grains of pumice (90%), and medium grained, angular quartz, biotite and lithic clasts (10%); medium hard, friable; ledge former; porous; iron-stained. Sample 330-4. Unit overlies a very thin layer of banded chalcedony, which overlies a bentonitic clay	3
2.	Sandstone (65%), clayey (gradational with claystone), slightly bentonitic; medium yellowish green (weathers to light yellowish gray); composed of medium-sand-sized grains of pumice in a clay matrix; grades vertically within beds to claystone without pumice grains; soft; slope former. Lower contacts are sharp, regular. Becomes more bentonitic and contains a larger proportion of clay in beds up-section in the unit. Bed thickness averages 7.5 feet and ranges from 2 to 15 feet. Interbedded with more resistant lithologies	
	Sandstone (30%), pebbly, tuffaceous; white (weathers to very pale orange); medium to coarse grained; composed of subrounded medium sand to pebble-sized clasts of pumice (locally contains grains of quartz and biotite) in a tuffaceous matrix; hard to medium hard; ledge former. Thickness averages 2 feet and ranges from 0.5 to 7 feet (thickest near base of unit). Sample 330-3	
	Claystone (2%), siliceous; white; very hard; ledge former; silica cemented; locally iron-stained; locally carbonaceous. Thickness ranges from 2 to 6 inches	

LOCALITY 330. (continued)

Unit		Estimated thick. (ft)
2.	Sandstone (2%), siliceous; medium sized grains of pumice (90%) and quartz (10%); very hard; ledge former; siliceous cemented, impermeable. Thickness ranges from 2 to 8 inches.	
	Lignite (1%); moderate brown; anomalously radioactive; 1 to 3 inches thick, grades down into a 2 inch thick light tan carbonaceous shale. Persists about 300 feet laterally. One bed only, located 10 to 15 feet above base of unit. Sample 330-2	222.4
1.	Clay, bentonitic; dark greenish brown (in lower 70 feet) to medium reddish brown (appear 130 feet); medium hard, plastic (weathers to soft, loose); internally massive. Trace gypsum crystals, both as plates up to 3 inches in diameter and as needles. Lower 70 feet contains rounded pebbles of pumice. Upper third contains 10% lenses of medium grained, hard, ledge-forming quartz sandstone. The lenses range from 0.5 to 1.5 feet thick, and are separated by 5 to 15 feet of claystone. The frequency and thickness of the sandstone lenses increase up section. Sample 330-1 taken of the acicular gypsum	201.3
	Total estimated thickness	545.8

LOCALITY 331. EAST SIDE GOON HILL

N½NE¼SW¼ sec. 3, T. 10 N., R. 1 W.; Lewis and Clark County; at water level next to Highway 284 at the south end of the inlet. Although Mertie and others (1951, Pl. 1) map these rocks as their Tertiary Unit 3 (pp. 35-37), the outcrops appear lithologically similar to their Tertiary Unit 2 (pp. 33-35). A lower Oligocene age is assigned to this locality by White (1954, p. 396, Fig. 40 and 51).

Unit		Estimated thick. (ft)
4.	Similar to basal 5 feet of unit 3	0.5
3.	Sandstone (fines to sandy and clayey siltstone in upper 3.5 feet), tuffaceous; pale greenish yellow; composed of moderately sorted, medium to coarse grained, subangular to subrounded grains of pumice. Sample 331-1	8.5
2.	Sandstone (fines upward to siltstone), quartz; greenish brown, medium grained, with subangular grains	6
1.	Claystone, slightly bentonitic; medium yellowish brown; with rounded pebbles of siltstone or claystone. Becomes increasingly sandy in upper 2 feet. Lies unconformably on the pre-Tertiary rocks that make up Goon Hill, and contains fragments of these rocks in the lower 2 feet of the unit	8
	Total estimated thickness	23

LOCALITY 332. EAST HELENA SUBSTATION

SW¼NW¼SE¼ sec. 26, T. 10 N., R. 3 W.; Lewis and Clark County; roadcut near power substation on U.S. Highway 12. Oligocene "Lake Beds" of Lorenz and Swenson (1951, pp. 16-18, Pl. 1). Strike north 66.5° west; dip 8° north.

Unit		Measured thick. (ft)
6.	Siltstone; (lower 1 foot is poorly sorted, medium grained, white, tuffaceous sandstone); medium yellowish brown (weathers to light gray); soft, loose; slope former; tabular uneven; Internally massive. Lower contact gradational	3
5.	Sandstone, tuffaceous; light gray (weathers to light brownish gray); medium grained, moderately sorted, with angular grains; soft, friable; ledge former; permeable; tabular uneven; internal parallel uneven thin beds. Lower contact sharp	4.5
4.	Siltstone, sandy, tuffaceous (top 1/2 bentonitic); upper 1/2 banded yellowish gray, lower 1/2 banded light orangish brown; with subangular sand grains; soft, loose (weathers to medium hard, friable); iron-stained in lower one-half; tabular even; internally massive. Lower contact gradational.	9
3.	Conglomerate, sandy, pumiceous; banded yellow and white (weathers to light yellowish gray); with angular pebbles of pumice (90%) and volcanic rocks (10%), in a matrix of poorly sorted, medium to very coarse grained, pumiceous sandstone; soft, friable, very lightly iron-stained; tabular even; internal parallel uneven thin to very thin beds. Lower contact erosional (less than one foot relief). Sample 332-1	5.7
2.	Siltstone, conglomeratic; dark orange; with subangular pebbles of unit 1 in lower 1/3; medium hard, compact; iron-stained; tabular uneven; internally medium bedded. Lower contact gradational	1.2
1.	Sandstone, conglomeratic, tuffaceous; light greenish white (weathers to light gray); very fine to very coarse grained, very poorly sorted; with subangular pebbles of pumice (95%) and dark volcanic rocks (5%); medium hard, friable; upper 2 feet slightly iron-stained; tabular even; internally massive	5.6
	Total measured thickness	29

LOCALITY 333. KETTLE HOLLOW

SW¼SW¼SE¼ sec. 17, T. 11 N., R. 4 E.; Meagher County; just west of road, on barely perceptible, northeast-trending low ridge. Mapped as Miocene tuffs by Birkholtz (1967, pp. 26-28, Pl. 1).

LOCALITY 333. (continued)

Unit		
1.	Tuff, lapilli, bentonitic; medium yellowish gray with pink spots (weathers to light yellowish gray); soft, friable; slope former; porous. Composed of bentonized pumiceous lapilli and ash (95%) and subangular pebbles of a black volcanic rock (5%). Sample 333-1	

LOCALITY 334. NORTH OF BEAVER CREEK

SW¼NW¼NW¼ sec. 25, T. 12 N., R. 4 E.; Meagher County; east of road in adjacent drainageway. Mapped as Tertiary sedimentary rocks by Hruska (1967, pp. 48-51, P.. 1); probably equivalent to the Fort Logan Formation of Koerr (1939, as per Hruska, p. 49). Lithology not characteristic of Tertiary sediments in the Smith River Valley.

Unit		Estimated thick. (ft)
1.	Sandstone, conglomeratic, feldspathic; grayish orange (weathers to pinkish gray); medium grained; moderately sorted, with angular grains; contains subrounded pebbles of siltstone (50%), Belt Series rocks (45%), and felsic igneous rocks (5%); hard, brittle; ledge former; channel; internally thin to very thin bedded with cross-bedding. Sample 334-1	4-5

LOCALITY 335. SOUTH OF SHEEP CREEK No. 1

S½SW¼SW¼ sec. 18, T. 12 N., R. 5 E.; Meagher County; roadcut. Mapped as Tertiary alluvium of Miocene age by McClernan (1969, pp. 26-27, Pl. 1). Strike north 40° west; dip 2.5° east.

Unit		Measured thick. (ft)
6.	Siltstone; medium yellowish brown; slope former	9.2
5.	Siltstone, tuffaceous; slope former. Contains pumice clasts ranging from coarse sand to pebble size	23
4.	Sandstone, silty and conglomeratic; medium gray (weathers to medium orangish brown; medium grained, very poorly sorted, with pebbles of pumice; ledge former; porous	2
3.	Siltstone, micaceous; medium brown; medium hard; slope former; slightly calcareous. Subordinate mica in lower 2 feet	8
2.	Lithic-vitric tuff/tuffaceous sandstone; grayish yellow (weathers to medium gray); very coarse grained, poorly sorted, with subangular grains of pumice; medium hard, friable; slope former; porous; banded with iron-staining 2 to 4 feet above base; tabular even; internal parallel even, medium beds. Lower contact sharp. Minor smokey bipyramidal quartz. Sample 335-2	8.3

LOCALITY 335. (continued)

Unit		Measured thick. (ft)
1.	Siltstone, tuffaceous; grayish orange (weathers to light gray); soft, brittle; slope former; permeable; internally massive. Contains<5% very coarse grained, subrounded grains of pumice in upper 2 feet. Sample 335-1	12.3
	Total measured thickness	62.8

LOCALITY 336. SOUTH OF SHEEP CREEK No. 2

NE¼SE¼NE¼ sec. 24, T. 12 N., R. 4 E.; Meagher County; roadcut. Mapped as Tertiary allumium of Miocene age by McClernan (1969, pp. 26-27, Pl. 1). Strike north 65° west; dip 4° south. Lithologically similar to unit 2 of locality 335.

Unit		Estimated thick. (ft)
2.	Lithic-vitric tuff/pumice conglomerate; pale greenish yellow (weathers to medium grayish brown); with subrounded to subangular pebbles of pumice in a matrix of poorly sorted, very coarse grained, pumiceous sandstone; soft, friable; slope former; permeable; tabular even; internal parallel even medium to thick beds. Lower contact sharp. Contains localized intergranular concentrations of soft, powdery, black, organic(?) material and a trace of smokey, bipyramidal quartz crystals. Sample 336-2	10.5
1.	Lithic-vitric tuff/pumiceous sandstone; dark yellowish orange (weathers to moderate yellowish brown); coarse to very coarse grained, poorly sorted, with subangular to subrounded grains and pebbles of pumice; soft, friable; slope former; heavily iron-stained; tabular even; internally massive. Trace smokey, bipyramidal quartz crystals. Sample 336-1	4
	Total estimated thickness	14.5

LOCALITY 337. HIGHWAY 12 SPRING

SW¼NE¼SE¼ sec. 3, T. 9 N., R. 7 E.; Meagher County; north side of U.S. Highway 12. Water sample 337-1 from spring. Water probably rising from pre-Tertiary rocks.

LOCALITY 338. HANSON'S SPRING

N½SW¼NE¼ sec. 34, T. 10 N., R. 6 E.; Meagher County; spring (water sample 338-1) in the bottom of a drainageway cut in Tertiary sediments mapped by Groff (1965, p. 20, Pl. 1) and Phelps (1969, pp. 27-28, Pl. 1).

Unit		Estimated thick. (ft)
2.	Siltstone, sandy and pebbly; light brown; calcareous	6

LOCALITY 338. (continued)

Unit		Estimated thick. (ft)
1.	Conglomerate, with angular to subangular pebbles and cobbles of limestone (95%) and Belt Series rocks (5%); in a calcareous cemented matrix; non-permeable	8.5
	Total estimated thickness	14.5

LOCALITY 339. STOYONOFF LAKE

NE¼SW¼SW¼ sec. 20, T. 11 N., R. 4 E.; Meagher County; low hill just north of lake. Mapped as Miocene tuffs by Birkholtz (1967, pp. 26-28, Pl. 1). Strike north 10° west; dip 4° east. Hand level used to estimate thickness.

Unit		Estimated thick. (ft)
4.	Siltstone, similar to unit 2, but the pumice clasts are coarse sand-sized and make up less than 2% of the rock	13
3.	Conglomerate, sandy, limestone; yellowish gray; with angular to subangular pebbles (and some cobbles) of limestone (85%), quartzite, sandstone, and siltstone, in a matrix of medium grained lithic sandstone; calcareous cemented; channel. Lower contact sharp, and erosional (15-20 feet relief). Locally contains thin lenses of sandstone. Sample 339-1	7
2.	Siltstone; medium brown; slope former; locally calcareous cemented (1-2 foot thick beds); internally massive where not cemented. Slightly bentonitic. Locally conglomeratic with pebbles of pumice	83
1.	Conglomerate (50%), sandy; with angular to subangular pebbles of limestone (90%+), siltstone, and sandstone; in a matrix of coarse to medium grained sandstone; ledge former; calcareous cemented; in medium thick beds. Siltstone (50%), medium brown; in medium thick beds. In a few places, loose to well cemented, coarse sandstone is interbedded with the conglomerate, instead of siltstone	18
	Total estimated thickness	121

LOCALITY 340. LITTLE ANTELOPE CREEK

NE¼SE¼SE¼ sec. 15, T. 1 S., R. 2 W.; Madison County; north side of gully, about 20-30 feet west of line between sections 14 and 15. Mapped as Tertiary "Lake Beds" by Berry (1943, p. 22, Pl. 1).

Unit		Estimated thick. (ft)
1.	Sandstone, pebbly, feldspathic; yellowish brown (weathers to dark gray); medium to coarse grained, poorly sorted; soft, friable; ledge former; iron cemented and stained; tabular even; internal parallel even bedding. Sample 340-1	5

LOCALITY 341. BEALS HOT SPOT

NW¼NE¼NE¼ sec. 23, T. 1 S., R. 2 W.; Madison County; small barrow pit just north of old road bed of Highway 359. Mapped as Tertiary "Lake Beds" by Berry (1943, p. 22, Pl. 1); may be equivalent to the coarse, basin-edge facies of the Climbing Arrow Formation of Robinson (1963, pp. 69-77, Pl. 1).

Unit		Estimated thick. (ft)
2.	Sandstone, conglomeratic, feldspathic; pale greenish yellow (weathers to medium brown); very coarse grained, poorly sorted; with subrounded pebbles of felsic igneous rocks (65%), smokey quartz (30%), and feldspar; lower 2 feet soft, loose, slope former; upper 2 feet hard, brittle, ledge former; upper 2 feet silica cemented; lentic channel; internal trough cross-bedding. Lower contact erosional (greater than 1 foot relief). Trace of magnetite, biotite, and pink garnet. Minor smokey quartz. Sample 341-4 of soft, loose material; sample 341-5 of silicified material	4
1.	Sandstone, locally pebbly, feldspathic; light yellowish gray; medium to very coarse grained, moderately sorted, with angular grains, with pebbles of smokey quartz (95%) and feldspar (5%); soft, friable; slope former (locally silica cemented; hard, brittle; ledge former); lentic channel; internally trough cross-bedded. Trace magnetite and pink garnet; trace of silicified wood partially replaced with secondary uranium minerals (carnotite). Sample 341-1 of petrified wood. Sample 341-2 of soft, friable material; sample 341-3 of silicified material	8-9
	Total estimated thickness	12-13

LOCALITY 342. BEALS SECTION

NW¼NW¼NE¼ sec. 23, T. 1 S., R. 2 W.; Madison County; north side of old road bed of Highway 359, in large reentrant about 200 yards east of the railroad. Mapped as Tertiary "Lake Beds" by Berry (1943, p. 22, Pl. 1); may be equivalent to the coarse, basin-edge facies of the Climbing Arrow Formation of Robinson (1963, pp. 69-77, Pl. 1). Strike north 10° west; dip 9° west.

Unit		Measured thick. (ft)
5.	Conglomerate, sandy, feldspathic; pale greenish yellow (weathers to light brown); with subrounded pebbles of quartz (45%), feldspar (45%), and granitic rocks (10%), in a matrix of moderately to poorly sorted, medium to very coarse grained sandstone; hard, brittle (soft, friable where uncemented); ledge former (slope former where uncemented); silica cemented (25%) uncemented); tabular uneven; internally thin bedded with planar cross-bedding. Lower contact sharp, irregular. Trace magnetite, biotite, and pink garnet. Silicified beds make up 75% of unit and range in thickness from 2 to 5 feet thick. Uncemented beds range in thickness from 0.5 to 1.5 feet thick. Unit becomes less conglomeratic upward. Sample 342-4 taken near base	25.5

LOCALITY 342. (continued)

Unit		Measured thick. (ft)
4.	Siltstone (coarsens to fine sandstone in upper 5-10 feet), tuffaceous; light yellowish gray; soft, friable or loose; slope former; tabular uneven; internally massive. Contains some pebbly lenses. Lower contact covered. Minor biotite. Sample 342-3 taken in fine sand near top	33.2
	Sample 342-5 taken of very hard, brittle, black to greenish yellow, radioactive silicified wood; probably from this unit. The greenish-yellow part consists of dominant copper and silican, subordinate aluminum and calcium, with minor iron.	
3.	Sandstone, feldspathic; medium to very coarse grained, poorly sorted, with subangular grains; internally cross-bedded. 75% light gray to light greenish gray; soft, loose; slope former, permeable. 25% light greenish gray (weathers to dark reddish gray); hard, brittle; ledge former; silica cemented. Contains much smokey quartz	15.7
2.	Siltstone, tuffaceous; light yellowish gray; soft, friable; slope former; porous; tabular uneven; internally massive (except upper 2.5 feet which is very thin to thin bedded). Lower contact sharp, irregular. Predominantly silt-sized glass shards. Trace of plant remains. Sample 342-2	14.2
1.	Sandstone, feldspathic; light gray and streaked with iron oxide; medium grained, moderately sorted, with subangular grains; soft, friable; slope former; permeable; iron-stained; lentic channel, internally massive. Trace of magnetite, biotite, and pink garnet. Sample 342-1	4
	Total measured thickness	92.6

LOCALITY 343. WILSON PARK ROAD

N½ sec. 26, T. 3 N., R. 3 W.; Jefferson County; 1/2 mile south of Wilson Park Road and 1/2 mile north and northwest of buildings along east side of section 26. Units 2, 3, and 4 described below probably correspond to units 3, 2, and 1, respectively, of measured section number 16 of Alexander (1955 p. xxiii). Alexander considers the rocks in this section to be of Miocene age (pp. 74-79, xxiii).

Unit		Estimated thick. (ft)
4.	Siltstone (75%), sandy, tuffaceous; very pale orange; with subangular, medium to coarse grained, lithic sand grains; medium hard, compact; slope former; locally calcareous cemented; tabular even; internally massive. Lower contact gradational. Predominately glass shards. Sample 343-2 from middle	
	Conglomerate (25%), silty; medium light gray; with subrounded pebbles of dark gray volcanic rocks in a brown matrix of silt or poorly sorted very fine sand; soft, loose; slope former; lentic channel; internally thin bedded with trough cross-bedding. Lower contact sharp, irregular. Minor magnetite. Occurs in lenses up to 6 ft thick. Sample 343-3 from middle.	*100

LOCALITY 343. (continued)

Unit		Estimated thick. (ft)
3.	Not described	*39
2.	Siltstone (90%+), sandy; medium pinkish brown; medium hard; permeable; internally massive Sandstone (10%-), arkosic; pale yellowish brown; coarse grained, moderately to well sorted, with subangular grains; soft, loose; slope former; medium thick; tabular even; internally massive. Lower contact sharp. Trace magnetite, and amphibole. Sample 343-1	*60
1.	Sandstone (75%); light gray to very light salmon pink; very fine to fine grained, poorly sorted Siltstone (15%); light pinkish brown. Slightly bentonitic. Occurs at top of unit Sandstone (10%); medium to coarse grained. Occurs as medium thick lenses	60
	Total estimated thickness	259

*Thickness from Alexander (1955, p. xxiii).

LOCALITY 344. DRY COTTONWOOD CREEK

SW¼SE¼NW¼ sec. 7, T. 3 N., R. 2 W.; Jefferson County; base of steep bank on north side of creek. Mapped as Tertiary sedimentary rock (Oligocene or younger) by Weeks (1974). Unconformably overlain by 10 to 15 feet of late Tertiary or Quaternary gravel.

Unit		Estimated thick. (ft)
2.	Conglomerate, pebble; soft, loose; slope former; internally thin bedded with trough cross-bedding. Lower contact erosional with about 1 foot relief	6-7
1.	Sandstone, feldspathic; light grayish orange; medium to very coarse grained, poorly sorted, with subangular grains; soft, loose; slope former; lentic bed; internally trough cross-bedded. Minor magnetite and biotite. Contains clay balls up to 2 inches in diameter. Sample 344-1	8
	Total estimated thickness	14-15

LOCALITY 345. WILLOW SPRINGS WATER SAMPLE

NW¼NW¼SE¼ sec. 16, T. 4 N., R. 2 W.; Jefferson County; water sample 345-1. Water rises from sediments mapped as Oligocene and Miocene tuff and gravel by Klepper and others (1957, p. 42, Pl. 3).

LOCALITY 346. NEW NEGRO HOLLOW ROAD

SW¼NW¼NW¼ sec. 32, T. 3 N., R. 2 W.; Jefferson County; roadcut on private road which runs south from Negro Hollow Road, just east of Boulder River. Mapped by Richard (1966, Pl. 1) as the Bozeman group of Tertiary age.

Unit		Estimated thick. (ft)
2.	Siltstone, pebbly; yellowish gray (weathers to light brownish gray); soft, brittle; slope former; permeable; internally massive. Lower contact covered. Trace of silicified bone fragments. Sample 346-2	6-8
1.	Sandstone, conglomeratic, arkosic; grayish orange and streaked with iron-staining; very coarse grained, poorly sorted, with subangular pebbles; soft, friable; slope former; permeable; lentic channel; internally laminated to very thin bedded with trough cross-bedding. Trace of petrified wood and a few clay balls. Minor magnetite. Trace of biotite and hornblende. Sample 346-1	3-4
	Total estimated thickness	9-12

LOCALITY 347. DOHERTY MOUNTAIN

SW¼NE¼SE¼ sec. 7, T. 2 N., R. 2 W.; Jefferson County; at head of northwest draining valley. Bozeman group of Richard (1966, Pl. 1); early Oligocene age (Alexander, 1955, p. 76). Strike north 54° west; dip 11° north.

Unit		Measured thick. (ft)
8.	Siltstone; medium yellowish brown; soft, loose; slope former; tabular even. Lower contact sharp	8.6
7.	Sandstone (50%); medium gray; fine to medium grained, moderately sorted; soft, loose; slope former; tabular even. Lower contact sharp. Parallel even very thin beds of sandstone are interbedded with very thin beds of ash. Sand predominates near base of unit Ash (50%); light yellowish gray; soft, loose; slope former. Interbedded with sandstone. Ash predominates near top of unit	6.8
6.	Claystone, sandy; yellowish white; soft, frangible; slope former; tabular even. Lower contact sharp	3.7
5.	Claystone, bentonitic; medium yellowish brown; with pebbles of pumice and volcanic rocks; soft, brittle; slope former	1.8
4.	Sandstone, conglomeratic; medium gray; medium to very coarse grained, poorly sorted; with angular pebbles of volcanic rocks (95%), soft; slope former (lower 2 feet locally silica cemented; ledge former); tabular even; internal parallel even beds. Lower contact sharp	8

LOCALITY 347. (continued)

Unit		Measured thick. (ft)
3.	Sandstone (pebbly near base, fines in upper 2 feet to claystone); medium gray; coarse grained; soft, loose; slope former; clay matrix; tabular even; internal parallel even beds. Lower contact gradational	6.3
2.	Sandstone (70%), conglomeratic, tuffaceous; very light gray; fine grained, very poorly sorted, with rounded pebbles and sand grains of pumice in a tuffaceous matrix; medium hard, friable; cliff former; porous; tabular even; internal thin to laminated, parallel even beds. Lower contact gradational. Minor biotite. Sample 347-3	
	Claystone (30%), very thin beds	8.6
1.	Claystone (55%); varous beds are dark gray, medium greenish brown, dark brownish green, medium green, or pink; locally sandy, micaceous, or tuffaceous. Beds range from 0.5 to 5.7 feet thick. Sample 347-1 of claystone, sandy; grayish olive (weathers to light gray); with medium-size, angular grains of volcanic glass, quartz, feldspar and biotite; medium hard, brittle (weathers to soft, loose); slope former; tabular even; internally massive; from near contact with sandstone of sample 347-2	
	Sandstone (45%); light yellowish brown, light gray, or medium greenish yellow; medium to very coarse grained, poorly sorted, with angular grains. Locally silty, pebbly, iron-stained. Smokey quartz observed in one bed. Bed thickness ranges from 0.5 to 5.1 feet. Sample 347-2 of sandstone, subfeldspathic; dusky yellow (weathers to light gray); medium grained, poorly sorted, with angular grains; soft, loose; slope former; very slightly iron-stained; tabular even; internally massive; lower contact sharp; contains sand-sized grains of pumice and some clay balls; minor biotite	39.6
	Total measured thickness	83.4

LOCALITY 348. SOUTHWEST NEGRO HOLLOW

SE¼NW¼NE¼ sec. 5, T. 2 N., R. 2 W.; Jefferson County, north wall of gully. Hand-level used to estimate thickness. Mapped as Bozeman group of Tertiary age by Richard (1966, Pl. 1); probably of Miocene age (Kay and Fields, 1958, p. 14, see Stop 2). Strike N. 17° west; dip 10° east.

Unit		Estimated thick. (ft)
1.	Siltstone (97%), sandy (locally pebbly), tuffaceous; pale orange (weathers to light orangish brown); with medium to very coarse grained sand; medium hard, friable; cliff former; porous; locally very lightly iron-stained; tabular even; internal parallel even thick beds. Lower contact covered. Predominantly silt-sized glass shards. Sample 348-1	

LOCALITY 348. (continued)

Unit		Estimated thick. (ft)
1.	Sandstone (3%), silty, feldspathic; pale yellowish brown with medium orangish brown bands of iron-staining; coarse to very coarse grained, poorly sorted, with subangular grains; medium hard, friable; slope former; porous; iron-stained; lentic channel; internal parallel even very thin beds. Lower contact sharp; upper contact gradational with sandy siltstone. Trace of magnetite and biotite. Contains zones wherein the sand grains are coated with black iron or manganese oxides. Sandstone typically occurs as lenses 2 to 3 feet thick and 20 to 40 feet wide. Sample 348-2	220

LOCALITY 349. OLD NEGRO HOLLOW ROAD

SE¼NW¼SE¼ sec. 28, T. 3 N., R. 2 W.; Jefferson County; in reentrant on south side of bench north of road. Mapped as Bozeman group of Tertiary age by Richard (1966, Pl. 1); Miocene age (Kay and Fields, 1958, p. 14, see stop 2). Strike N. 45° east; dip 13° W.

Unit		Estimated thick. (ft)
2.	Siltstone (55%), conglomeratic; similar to conglomeratic siltstone of unit 1, but contains more sand and pebbles; thin to medium bedded; slightly calcareous. Thickness ranges from 10 to 20 feet.	
	Sandstone (25%), conglomeratic; similar to conglomeratic sandstone of unit 1, but is more tabular. Occurs most frequently in lower half of unit. Up to 6 feet thick.	
	Sandstone (15%), silty; similar to silty sandstone in unit 1.	
	Conglomerate (5%); with cobbles of limestone (95%); hard, brittle; ledge former; calcareous cemented. Occurs as two 3 to 4 foot thick beds in upper 40 feet of unit	150-200
1.	Siltstone (90%), conglomeratic; light grayish orange; with angular pebbles of quartz (50%), and granite (40%); medium hard, friable; slope former (locally more resistant; cliff former) tabular even; internally massive. Lower contact sharp. Contains some clay balls and minor mica. Sample 349-1.	
	Sandstone (8-9%), silty, feldspathic; light grayish orange; very fine to very coarse grained, very poorly sorted, with subangular grains; soft, loose; slope former; lentic bed; internally massive. Lower contact sharp. Occurs as lenses of undetermined width, 1 to 6 feet thick. Trace magnetite and biotite; minor green hornblende. Sample 349-3	
	Sandstone (1-2%), conglomeratic, subfeldspathic to feldspathic; yellowish gray (weathers to light gray); very coarse grained, poorly sorted, with angular pebbles; very hard, brittle; ledge former; calcareous cemented; lentic channel; internally thin bedded with planar cross-bedding. Lower contact sharp, irregular. Occurs as small lenses 15 to 20 feet wide and 2 to 7 feet thick. Trace of magnetite. Sample 349-2	150-200
	Total estimated thickness	300-400

LOCALITY 350. RED HILL RED BEDS

NW¼SE¼SE¼ sec. 22, T. 2 N., R. 3 W.; Jefferson County; behind residence on southeast side of hill. Mapped by Richard (1966, Pl. 1) as Bozeman group; early Oligocene age (Alexander, 1955, p. 76). Water sample 350-3 taken from spring that rises about 150 feet east of the outcrop.

Unit		Estimated thick. (ft)
1.	Sandstone (60%), feldspathic to arkosic; light orange pink (weathers to moderate orange pink); coarse to very coarse grained, moderate to poorly sorted, with angular grains of quartz and feldspar; hard, brittle; ledge former; calcareous cemented; tabular even; internal parallel even medium to thin beds. Lower contact sharp. Contains 10-15% sand-sized grains of devitrified pumice. Thick beds. Sample 350-2 ... Siltstone (40%), micaceous; pale reddish brown; hard, brittle; slope former; porous; tabular uneven; internally massive. Locally sandy. Sample 350-1 ...	60

LOCALITY 351. UPPER WILLOW SPRINGS ROAD SPRING

CenterSW¼NW¼ sec. 23, T. 4 N., R. 2 W.; Jefferson County; water sample 351-1 from spring about 100 feet south of road. Water rises from sediments mapped as Oligocene and Miocene tuff and gravel by Klepper and others (1957, p. 42, Pl. 3).

LOCALITY 352. LOWER WILLOW SPRINGS ROAD SPRING

NW¼SW¼NE¼ sec. 21, T. 4 N., R. 2 W.; Jefferson County; water sample 352-1 taken from pond below spring on the south side of road. Water rises from sediments mapped as Oligocene and Miocene tuff and gravel by Klepper and others (1957, p. 42, Pl. 3).

LOCALITY 353. NORTHEAST OF RED HILL

NE¼NW¼NE¼ sec. 23, T. 2 N., R. 3 W.; Jefferson County; southeast side of knob. Mapped as the Bozeman group by Richard (1966, Pl. 1).

Unit		Measured thick. (ft)
3.	Siltstone; light brown; medium hard, brittle; (weathers to soft, loose); slope former; tabular even; internally massive. Lower contact gradational ...	6.3
2.	Sandstone, feldspathic; moderate yellowish brown; medium to very coarse grained, very poorly sorted, with subangular to subrounded grains; soft, loose; slope former; lentic channel; internally massive. Lower contact sharp. Sample 353-2 ...	3.9
1.	Siltstone, sandy, tuffaceous; pinkish gray; with angular, coarse to very coarse sand grains; medium hard, brittle (weathers to medium hard to soft, friable to loose); slope to cliff former; more resistant beds carbonate cemented; tabular even; internal parallel even thick beds. Predominately glass shards. Sample 353-1 ...	33.5

LOCALITY 353. (continued)

Unit		Measured thick. (ft)
	Total measured thickness ...	40.7

LOCALITY 354. LOWER GARDEN GULCH

SE¼SW¼NE¼ sec. 20, T. 4 N., R. 3 E.; Gallatin County; in reentrant on north side of gulch. Sixmile Creek Formation of Robinson (1967).

Unit		Estimated thick. (ft)
3.	Conglomerate, sandy; yellowish gray; with angular pebbles of Belt Series rocks and angular cobbles of limestone in a matrix of calcareous-cemented, angular, very coarse-grained lithic sandstone; hard; ledge former. Lower contact erosional (greater than one foot relief). Sample 354-1 ...	25
2.	Sandstone; very pale orange; medium grained, well sorted, with subrounded grains of quartz (60%) and rock fragments (40%), in a carbonate cement matrix; slope former; poorly exposed. Lower contact sharp. Sample 354-2 ...	10
1.	Conglomerate; with subangular pebbles and cobbles of quartzite, shale, limestone, sandstone, and porphyritic volcanic rocks; hard; ledge former; carbonate cemented...	15
	Total estimated thickness ...	50

LOCALITY 355. CRANE SCHOOL FAULT BLOCK

SE¼SW¼SE¼ sec. 2, T. 4 N., R. 3 E.; Gallatin County; south side of small ridge, about 25-50 yards west of the dead-end of private road that connects with Roy Gulch. Lower member of Oligocene Climbing Arrow Formation of Robinson (1967). The Climbing Arrow Formation in this locality underlies an area of approximately 1 square mile. The size of the outcrop area, the sinuous depositional contacts with the older rocks (excepting the fault contacts), and the inliers of older rocks all suggest that the Climbing Arrow Formation is relatively thin in the area. Dips 30^{o} or more to both east and west. Carbonaceous beds such as described below are relatively few in the area.

Unit		Estimated thick. (ft)
1.	Claystone, silty, carbonaceous; light brown; soft, friable; slope former; locally iron-stained; tabular even; internal parallel even laminae. Subordinate carbonaceous material. Sample 355-1 ...	2

LOCALITY 356. CRANE SCHOOL FAULT BLOCK SPRING

Center sec. 11, T. 4 N., R. 3 E.; Gallatin County; water sample 356-1 from spring in sediments of the lower member of the Climbing Arrow Formation (Robinson, 1967); about 100 yards west of private road that connects with Roy Gulch.

LOCALITY 357. LAKE HELENA-HAUSER SPRING

SW¼NW¼NW¼ sec. 28, T. 11 N., R. 2 W.; Lewis and Clark County; water sample 357-1 from pond which is probably fed by springs in the Oligocene age "Lake Beds" mapped by Lorenz and Swenson (1951, pp. 16-18, Pl. 1).

LOCALITY 358. LAKE HELENA-HAUSER B

SW¼SW¼NW¼ sec. 28, T. 11 N., R. 2 W.; Lewis and Clark County; 35 feet south of center of road that runs along irrigation ditch, and 160 feet east of line between sections 28 and 29. Hand-level used to estimate thickness. Mapped as Oligocene "Lake Beds" by Lorenz and Swenson (1951, pp. 16-18, Pl. 1). Strike north 40° east; dip 12° east.

Unit		Estimated thick. (ft)
6.	Sandstone, pebbly; medium to coarse grained; slope former. One foot thick, dark red iron-stained layer in middle	20
5.	Claystone, bentonitic; slope former; iron-stained to dark brownish red in center	10
4.	Sandstone, locally pebbly; medium to coarse grained, with angular grains; medium hard; ledge former; internally cross-bedded. Contains laminae of bentonitic clay (10% of unit)..	3.5
3.	Claystone and siltstone; medium gray to grayish brown (weathers to medium brownish gray); lentic bed. Lower contact gradational	3
2.	Sandstone, pebbly, feldspathic, tuffaceous; yellowish gray (weathers to light gray); medium grained, very poorly sorted, with subangular to angular grains; medium hard to soft; friable; steep slope former; porous; slightly iron-stained near base, lentic bed; internally very thin bedded, with trough cross-bedding. Lower contact sharp. Minor biotite; anomalously radioactive. Sample 358-1 of bleached center portion	5
1.	Claystone, sandy; pale olive (weathers to light greenish gray); soft, frangible; slope former; tabular uneven; internally massive. Sample 358-2....................................	3
	Total estimated thickness	44.5

LOCALITY 359. LAKE HELENA-HAUSER C

NW¼SE¼NW¼ sec. 28, T. 11 N., R. 2 W.; Lewis and Clark County; about 50 feet south of irrigation ditch, just east of drainageway. Mapped as Oligocene "Lake Beds" by Lorenz and Swenson (1951, pp. 16-18, Pl. 1). Strike about due east; dip 8 to 10° south. Possible host rocks, ranging in thickness from 0.6 to 44.3 feet, make up 56% of the section.

Unit		Measured thick. (ft)
17.	Sandstone, pebbly; slope former; poorly exposed	10.6

LOCALITY 359. (continued)

Unit		Measured thick. (ft)
16.	Claystone, sandy, bentonitic; dark brownish gray; slope former. Contains a 3 foot thick lens of sandstone (similar to unit 15) about 10 feet below the upper contact	42.8
15.	Sandstone; light orangish gray (weathers to very light gray); medium to coarse grained, moderately sorted, with angular grains; soft, loose; slope former	1.5
14.	Claystone, bentonitic; dark greenish gray (weathers to light gray); slope former	1.5
13.	Sandstone (upper 1/3), conglomeratic. Similar to lower 1/3, grades into middle 1/3 .... Conglomerate (middle 1/3), sandy; dark pinkish brown (weathers to light pinkish gray); with pebbles of volcanic rocks (50%), quartz, and sedimentary rocks, in a matrix of poorly sorted, silty sand. Grades into lower 1/3 .... Sandstone (lower 1/3), conglomeratic; light orangish brown (weathers to light gray); very coarse grained, moderately sorted, with angular grains	32.9
12.	Claystone, sandy; medium orangish brown (weathers to medium grayish brown); locally iron-stained. Contains some sand-sized grains of pumice	8.3
11.	Sandstone (upper 1/3), pebbly; medium yellowish gray (weathers to light gray); medium to coarse grained, poorly sorted, with angular grains. Grades into middle 1/3 .... Claystone (middle 1/3), sandy; dark grayish green (weathers to medium gray). Grades into lower 1/3 .... Claystone (lower 1/3), silty, bentonitic; medium yellowish green (weathers to dark red)	26.9
10.	Sandstone, pebbly, arkosic; yellowish gray (weathers to light gray); medium to very coarse grained, poorly sorted, with angular grains, with subangular pebbles of volcanic rocks (95%); soft, loose; slope former; porous; locally iron-stained; tabular even. Lower contact sharp. Trace of petrified wood. Anomalously radioactive. 3 foot clay lens 11 feet above base. Sample 359-4 taken below clay lens	47.2
9.	Claystone, bentonitic; dark yellowish brown (weathers to medium brown); soft, plastic (weathers to soft, loose); slope former; iron-stained near top; tabular even. Lower contact sharp. Very thin pinkish-brown carbonaceous layer at the top. Anomalously radioactive. Sample 359-3	3.5
8.	Sandstone, pebbly, arkosic; yellowish gray and streaked with iron-staining (weathers to light yellowish gray); coarse grained, poorly sorted, with angular grains and pebbles; medium hard, friable; cliff former; porous; iron-stained along upper contact; lentic bed; internally thin to medium bedded with planar cross-bedding. Lower contact sharp. Contains	

LOCALITY 359. (continued)

Unit		Measured thick. (ft)
8.	(cont.) several very thin clay lenses, some clay balls, minor biotite, and a trace of carbonaceous material. Sample 359-2.	7.7
7.	Claystone, silty, bentonitic; grayish olive; soft to medium hard, plastic (weathers to soft, loose); slope former; lentic bed; internally massive. Lower contact sharp. Sample 359-1.	10.2
6.	Sandstone, conglomeratic; medium orangish brown (weathers to light yellowish gray); medium to coarse grained, poorly sorted, with angular grains, with pebbles of red, green, and gray volcanic rocks; iron-stained. Minor reworked petrified wood	10.9
5.	Claystone; dark greenish gray	4.1
4.	Claystone (70%), sandy; dark grayish green (weathers to dark gray); steep slope former ... Sandstone (30%), silty, micaceous; very fine grained. Occurs as three thin lenses in the claystone	4.8
3.	Sandstone, conglomeratic; medium to very coarse grained, moderately sorted, with angular grains, with pebbles of gray, green, and red volcanic rocks; minor clay lenses	12.3
2.	Claystone, medium greenish gray; steep slope former	7.4
1.	Sandstone, quartz; light yellow (weathers to light gray); medium grained, with angular grains; soft, friable; slope former. Minor heavy minerals	1.5
	Total measured thickness	234.1

LOCALITY 360. LAKE HELENA-HAUSER D

NW¼NE¼SE¼ sec. 28, T. 11 N., R. 2 W.; Lewis and Clark County; east of irrigation ditch. Mapped by Lorenz and Swenson (1951, pp. 16-18, Pl. 1), as Oligocene age "Lake Beds". Strike north 66° west; dip 12 to 15° south (Becraft, 1958, Fig. 17, has the dips reversed for this outcrop).

Unit		Measured thick. (ft)
13.	Claystone, bentonitic; dark green at base; yellowish green and silty in middle; yellowish tan and pebbly near top	14.3
12.	Siltstone, sandy, pebbly; grayish yellow (weathers to medium gray); with very poorly sorted, medium to very coarse grained sand; medium hard, brittle; slope former; locally iron-stained, tabular even; internally massive. Lower contact gradational. Upper 1/2 bentonitic. Unit capped by a tabular even 1.5 foot thick bed of very hard, brittle, white to medium gray chalcedony or silicified siltstone. Sample 360-3 taken at base	24.1

LOCALITY 360. (continued)

Unit		Measured thick. (ft)
11.	Sandstone, silty, tuffaceous; yellowish gray; coarse grained, poorly sorted, with angular grains; medium hard, friable; slope former; porous; tabular even. Lower contact sharp. Minor biotite. Sample 360-2	14.4
10.	Siltstone, sandy, pebbly; medium purplish gray (weathers to medium greenish gray); with angular pebbles of greenish-gray volcanic rocks. Slightly bentonitic. Contains minor carbonaceous plant stems and some medium to coarse sand-sized clasts of pumice in lower 1/2	7.8
9.	Shale, carbonaceous, clayey; ledge former; tabular even; internal very thin to laminated parallel even beds. Lower contact sharp. Subordinate carbonaceous material	10
8.	Claystone, tuffaceous; medium brownish gray; iron-stained in middle. Contains smokey quartz and sand-sized clasts of pumice. Upper 1/2 contains subordinate non-tuffaceous claystone interbedded with the tuffaceous claystone and is locally pebbly. Lower 1/2 contains a trace of silicified bones	22.3
7.	Claystone, sandy; medium yellowish gray (weathers to light gray); with coarse sand-sized grains of pumice. Slightly bentonitic	49.0
6.	Claystone, silty to sandy; weathers to light yellowish gray; with grains of pumice. Upper 25% banded with partially silicified shaley material	8.4
5.	Shale (becomes very carbonaceous at top); medium orangish brown at base to grayish pink at top (weathers to light whitish yellow); hard, brittle; ledge former; tabular even; internally laminated. Lower contact sharp. Anomalously radioactive. Sample 360-1 of carbonaceous upper portion	1.2
4.	Claystone, sandy; dark brownish orange (dark purplish brown where locally carbonaceous); slope former	3.8
3.	Shale; light purplish white; hard, brittle. Probably carbonaceous	0.6
2.	Claystone, sandy; medium brownish yellow (weathers to light gray); slightly bentonitic. Contains smokey quartz	5.8
1.	Claystone, bentonitic; medium yellowish-greenish gray (weathers to light greenish gray)	7.3
	Total measured thickness	169.0

LOCALITY 361. BEACON HILL CROSS-BEDS

CenterNE¼SW¼ sec. 10, T. 2 S., R. 6 E.; Gallatin County; prominant outcrop on north wall of East Gallatin River valley. Unit 4 probably corresponds to unit 4 of the stratigraphic section of Glancy (1964, pp. 58-63) in the Beacon Hill sub-area. The units are in the late Miocene to early Pliocene age sediments of the Bozeman Group (pp. 9 and 31). Strike north 70° west; dip 15° north.

Unit		Estimated thick. (ft)
4.	Sandstone; light brown to medium gray; medium to coarse grained, well sorted, composed of angular glass shards; medium hard, friable; cliff former; porous; internally laminated to very thin bedded, with large scale cross-beds. Possible eolion origin	35
3.	Siltstone (86%), tuffaceous, locally conglomeratic; compact. Forms upper 1/3 of unit and 80% of lower 2/3's of unit. In lower 2/3's of unit, the siltstone occurs in 2 to 5 foot beds, interbedded with sandstone and conglomerate .... Sandstone (7%), tuffaceous; similar to unit 1. Interbedded with conglomerate and siltstone. Occurs in lower 2/3 of unit. Conglomerate (7%); similar to unit 2. Occurs in lower 2/3 of unit	65
2.	Conglomerate; with a matrix of medium to fine grained, poorly sorted, quartz sand	9
1.	Sandstone, tuffaceous; light brown; fine grained; friable	4
	Total estimated thickness	113.0

LOCALITY 362. LITTLE HORSESHOE BASIN

NE¼SW¼NE¼ sec. 27, T. 3 N., R. 4 E.; Gallatin County; on west-facing slope at east end of basin. Hand level used to estimate thickness. The rocks are of Oligocene age (Klemme, 1949, p. 69; Verrall, 1955, p. 172-173). Strike north 11° east; dip 10° east.

Unit		Estimated thick. (ft)
7.	Siltstone; medium orangish brown; medium hard; cliff former; calcareous and sandy at the top	8
6.	Siltstone; brown to grayish brown; medium hard, friable; very thinly bedded and calcareous at top	6.5
5.	Limestone; white; flaggy	1.0
4.	Siltstone; porous. Contains distinctive 1/4 to 1/2 inch diameter silt balls	11
3.	Siltstone; ledge former. Root casts. Lower 3 feet covered...	5
2.	Sandstone; medium orangish brown; very fine grained; slightly calcareous. 6 inch bed of limestone at top	15

LOCALITY 362. (continued)

Unit		Estimated thick. (ft)
1.	Limestone; light yellowish gray; laminated; fissile	41
	Total estimated thickness	87.5

LOCALITY 364. MILLIGAN CANYON ROAD EXIT No. 4

NE¼NE¼NE¼ sec. 17, T. 2 N., R. 1 W.; Jefferson County; Hand level used to estimate thickness. Climbing Arrow Formation of Robinson (1963, pp. 69-77, Pl. 1). Strike north 2° west; dip 5° east.

Unit		Estimated thick. (ft)
10.	Sandstone, pebbly; coarse grained. Contains petrified wood...	8
9.	Claystone, bentonitic; westhers to medium yellowish gray. 0.5 foot thick lenses of sandstone make up less than 5% of the unit	24.9
8.	Sandstone, pebbly; alternating fine and coarse grained beds; porous; iron-stained; lentic channel	5
7.	Claystone; medium yellowish green; iron-stained	2
6.	Sandstone; light grayish yellow; medium grained, with angular grains. Top 2 inches cemented with iron oxides	10.8
5.	Sandstone, conglomeratic, subfeldspathic; weathers to medium brownish red; medium to coarse grained, poorly sorted, with angular grains and rounded pebbles; medium hard; ledge former. Contains a minor biotite and some smokey quartz ...	1.0
4.	Sandstone, conglomeratic; medium to dark orangish brown; coarse grained, poorly sorted, with subangular to subrounded pebbles and cobbles of igneous rocks, metamorphic rocks, and quartzite; soft, loose	13
3.	Siltstone, clayey, tuffaceous; white. Composed of glass shards	8
2.	Sandstone, light orangish gray (weathers to medium gray); medium grained, poorly sorted. Contains a 2 foot thick layer of bentonitic clay 8 feet above base. Upper 1/2 of unit is pebbly	24.9
1.	Claystone, silty and sandy, bentonitic; dark greenish brown (weathers to medium gray); poorly sorted, with grains of pumice. Several medium thick lenses composed of silt to very poorly sorted, coarse-grained sand make up less than 10% of the unit	18.4
	Total estimated thickness	116.0

LOCALITY 366. WINSTON BADLANDS No. 2

NE¼NE¼NE¼ sec. 19, T. 9 N., R. 1 E.; Broadwater County; south side of gulch. Hand level used to estimate thickness. Basal portion of Tertiary unit 2 of Oligocene age (Mertie and others, 1951, p. 33-35, Pl. 1 and 2) and Becraft (1958, pp. 151-159, Pl. 3). Strike north 20° west; dip 14° east.

Unit		Estimated thick. (ft)
7.	Sandstone, tuffaceous; white; fine to medium grained; ledge former. Composed of sand-sized pumice (90%) and quartz (10%) grains	2
6.	Claystone; dark greenish brown (weathers to medium greenish brown); slope former. 2 inches of chalcedony at base; silicification decreases upward	8.3
5.	Siltstone; similar to unit 3	3.9
4.	Siltstone, tuffaceous; light greenish gray (weathers to white); slope former	5.3
3.	Siltstone, sandy, tuffaceous; white, medium hard; ledge former.	1.4
2.	Sandstone (upper 1/2), tuffaceous; medium yellowish gray; medium size grains of pumice (90%), quartz, and rock fragments; slope former	
	Shale (lower 1/2), dark gray (weathers to light yellowish gray); slope former	11.1
1.	Conglomerate, tuffaceous; white; with well rounded pebbles of pumice (95%) and subangular to subrounded pebbles to coarse-sand-sized grains of dark volcanic rocks (5%), in a tuffaceous matrix; medium hard, ledge former	4.8
	Total estimated thickness	36.8

LOCALITY 367. RABBIT CREEK ROADCUT

S½SW¼SW¼ sec. 3, T. 10 N., R. 5 E.; Meagher County; roadcut along Highway 360, just north of creek. Tertiary sediments mapped by Phelps (1969, pp. 27 and 28, Pl. 1); close to contact between the Miocene Deep River and Fort Logan Formations of Koerner (1939, Plate XXVI). This unit is characteristic of the Tertiary in the Smith River Valley.

Unit		Estimated thick. (ft)
1.	Siltstone, medium brown; medium hard, compact; internally massive; porous; slightly calcareous; composed of glass shards	18

LOCALITY 368. BEAVER CREEK ROADCUT

NW¼SW¼NE¼ sec. 3, T. 11 N., R. 4 E.; Meagher County; along road just north of creek. Tertiary sediments mapped by Hruska (1967, pp. 43-51, Pl. 1) and considered "most likely to belong to the Fort Logan Formations" (p. 49) of early Miocene age (Koerner, 1939, pp. 30-36).

LOCALITY 368. (continued)

Unit		Estimated thick. (ft)
1.	Siltstone to fine grained sandstone, tuffaceous; medium brown; medium hard, compact; massive; predominately glass shards. Contains medium thick gray ash or tuff bed	35-40

LOCALITY 369. UNNAMED GULLY

N½NE¼SE¼ sec. 26, T. 12 N., R. 4 E.; Meagher County; east of road. Tertiary sediments mapped by Hruska (1967, pp. 43-51, Pl. 1); "most likely to belong to the Fort Logan Formation" (p. 49) of early Miocene age (Koerner, 1939, pp. 30-36).

Unit		Estimated thick. (ft)
1.	Siltstone to fine grained sandstone; medium brown; medium hard, compact; generally massive, but thin bedding locally visible. Contains thick lens of soft, loose, medium grained quartz sand that fines upward into the siltstone	20

LOCALITY 372. HIGHWAY 12 INTERSECTION

SW¼NW¼SW¼ sec. 3, T. 9 N., R. 7 E.; Meagher County; north side of highway, just east of highway maintenance building. Mapped as Tertiary sediments by Dahl (1971, p. 23, Pl. 1) and as Miocene Deep River Formation by Tanner (1949, pp. 87-90, Pl. 1).

Unit		Estimated thick. (ft)
1.	Siltstone (90%); medium to light brown; massive (locally laminated)	
	Sandstone (10%), pebbly; medium yellowish green; coarse grained; medium hard; permeable. Thin to very thin bedded, lenticular	20-25

LOCALITY 373. CAMAS CREEK SECTION

NW¼SW¼SE¼ sec. 26, T. 11 N., R. 4 E.; Meagher County; approximately 75 yards north of house, on west bank of creek. Hand level used to estimate thickness. Mapped as Miocene tuffs by Birkholz (1967, pp. 26-28, Pl. 1). Strike north 66° east; dip 6° east.

Unit		Estimated thick. (ft)
3.	Siltstone, sandy, and very fine grained sandstone; light brown; permeable. Lower contact gradational	16
2.	Siltstone; medium gray; permeable; composed of glass shards. Lower contact sharp, regular	2
1.	Siltstone; dark brown (weathers to light brown), permeable. Predominantly glass shards	22.8
	Total estimated thickness	40.8

LOCALITY 374. ROCK SPRINGS CREEK SECTION

NW¼NW¼NW¼ sec. 9, T. 10 N., R. 5 E.; Meagher County; on southeast side of point. Hand level used to estimate thickness. Unit 1 described below probably corresponds with the lower Miocene Fort Logan Formation of Koerner (1939, pp. 29-36, Pl. XXVI); units 2 and 3 probably correspond to the upper Miocene Deep River Formation of Koerner (p. 29, pp. 46-54, Pl. XXVI).

Unit		Estimated thick. (ft)
3.	Siltstone and very fine grained sandstone; brown; medium hard to soft, friable; steep slope former; generally massive (bedding becomes more distinct near base). Lower contact gradational	41
2.	Sandstone, pebbly; coarse to very coarse grained, with angular grains, with angular flat pebbles of shale; parallel even thin beds interbedded with fine grained sandstone; cliff former. Lower contact erosional; unconformable on unit 1	8
1.	Siltstone; light medium brown to light brownish gray; soft to medium hard, friable; steep slope former; permeable, locally calcareous; massive; very thick bedding; predominantly glass shards	78
	Total estimated thickness	127

LOCALITY 375. WHITETAIL DEER CREEK GULLY

NW¼SE¼SW¼ sec. 8, T. 11 N., R. 5 E.; Meagher County; east side of gully that parallels road. Mapped as Tertiary sediments by Phelps (1969, pp. 27-28, Pl. 1) and as lower Miocene Fort Logan Formation by Koerner (1939, pp. 46-54, Pl. XXVI).

Unit		Estimated thick. (ft)
3.	Siltstone; tuffaceous; very hard; ledge former; calcareous cemented. Manganese oxide dendrites	7-8
2.	Covered	15
1.	Siltstone; soft, friable, slope former; internally medium to thick bedded. Medium thick ash beds make up 25-30% of unit.	35
	Total estimated thickness	57-58

LOCALITY 376. WHITETAIL DEER CREEK KNOB

N½NE¼SW¼ sec. 17, T. 11 N., R. 5 E.; Meagher County; knob on east side of gully west of road. Mapped as Tertiary sediments by Phelps (1969, pp. 27-28, Pl. 1) and as the lower Miocene Fort Logan Formation by Koerner (1939, pp. 46-54, Pl. XXVI).

LOCALITY 376. (continued)

Unit		Estimated thick. (ft)
1.	Siltstone; light to medium brown; medium hard; 30% of beds calcareous; internal parallel even, medium beds. Predominantly glass shards. Relatively resistant, gray, fine grained tuff beds make up 20% of lower half of unit	60-70

LOCALITY 377. HARRISON CEMETARY

SW¼NW¼SE¼ sec. 24, T. 1 S., R. 2 W.; Jefferson County; west-facing slope. Mapped as Tertiary "Lake Beds" by Berry (1943, p. 22, Pl. 1).

Unit		Estimated thick. (ft)
1.	Siltstone, sandy; medium hard, brittle	40

LOCALITY 378. NORTHERN PACIFIC RAILROAD CUT

SW¼NE¼NE¼ sec. 23, T. 1 S., R. 2 W.; Jefferson County; railroad cut north of county highway 359, 100-200 yards west of intersection of highway and railroad. Mapped as Tertiary "Lake Beds" by Berry (1943, p. 22, Pl. 1).

Unit		Estimated thick. (ft)
2.	Sandstone, pebbly; soft, loose (locally hard, brittle; silica cemented); slope former. Anomalously radioactive. Contains trace of petrified wood with secondary uranium mineralization (carnotite?)	2-3
1.	Siltstone; light greenish gray; medium hard; porous; internally massive. Locally pebbly, bentonitic	10
	Total estimated thickness	12-13

LOCALITY 381. POLE GULCH CONGLOMERATE

SW¼NW¼NW¼ sec. 5, T. 3 N., R. 3 E.; Gallatin County; on north wall of gulch. Mapped by Robinson (1967) as the rounded sand and gravel member of the Miocene and Pliocene age Sixmile Creek Formation.

Unit		Estimated thick. (ft)
1.	Sandstone (60%), conglomeratic, subfeldspathic; medium grained, moderately sorted, with angular grains; hard; ledge former; cross-bedded. Minor heavy minerals. Conglomerate (40%); with well rounded pebbles and cobbles of quartzite and quartz (75%), and subordinate amounts of granite, metamorphic rocks and volcanic rocks in a matrix of calcareous-cemented sandstone; hard; ledge former. Medium thick, lenticular	15

APPENDIX B

SELECTED STRATIGRAPHIC AND LITHOLOGIC DATA FOR STRATIGRAPHIC SECTIONS DESCRIBED IN THE LITERATURE

APPENDIX B

STRATIGRAPHIC SECTIONS DESCRIBED IN THE LITERATURE[a]

Section number	Reference	Section name or number	Age[b]	Total thickness of section (ft)	Total thickness of described section (ft)	Potential host rocks[c]						Organic material		Tuffaceous rocks in section[f]	Other characteristics	Examined by authors?	Locality this report (App. A)
						% of desc. sec.	Thick. of beds (ft)	Fld or ark[d]	Sorting[e]	Cal-careous	Iron staining	In coarse rocks	In fine rocks				
Flint Creek basin																	
1	Rasmussen, 1969, p. 159	B of MV6549	M-P	46	46	100	46	ark	VW-VP	no	yes	-	-	T		yes	110
2	Rasmussen, 1969, p. 151-155	MU6554, Part III	M-P	102	102	21	2-10	ark	M	no	no	-	A	S-D		yes	111
3	Rasmussen, 1969, p. 155-159	MU6554, Part IV	M-P	174	174	15	1-4	ark	W-P	-	-	-	-	D	opalized wood	no	
4	Rasmussen, 1969, p. 160-167	MU6558, Part I	M-P	1161.5	427.5	04	3-9	ark	P-W	-	yes	-	-	D	plant fragments	no	
5	Rasmussen, 1969, p. 167-174	MU6504, Part II	M-P	438	393	04	3-4	ark	P	-	yes	-	-	D	wood fragments	no	
6	Rasmussen, 1969, p. 174-180	MU6552, Sec. D	M-P	86.3	86.3	02	1	-	-	-	-	-	P	D		no	
Bitterroot basin																	
7	McMurtrey and others, 1972, p. 19-20		M-P	152.1	152.1	80	2-30	fld	P	no	yes	-	T	-		yes	125
8	McMurtrey and others, 1972, p. 15		M-P	227	142	61	5-30	ark	P-M	no	no	-	-	S		yes	128
Jefferson River, Beaverhead River, and Lower Ruby River basins																	
9	Kuenzi, 1966, p. 269-270	Sunlight Mine, sec. 1	E-O	61	61	13	1-3	ark	M-P	yes	no	N	T	T		yes	201
10	Kuenzi, 1966, p. 271-273	Sunlight Mine, sec. 2	E-O	145	145	0	0	-	-	-	-	-	-	A			
11	Kuenzi, 1966, p. 220-242	Parrot Bench	M-P	2419	919	64	1-33	fld	P-W	yes	no	N	T	S		yes	202
12	Kuenzi, 1966, p. 220-262	Parrot Bench	E-O	776	776	10	11	fld	P-W	yes	-	-	-	S		no	
13	Kuenzi, 1966, p. 200-219	Jefferson River	E-O	965	873	28	1-22	fld	M-W	yes	no	N	N	A		yes	203
14	Kuenzi, 1966, p. 277-286	Palisade Cliffs	M-P	48	48	91	1-38	ark	VP	no	no	N	T	N		yes	204
15	Kuenzi, 1966, p. 277-286	Palisade Cliffs	E-O	320	292	10	1-5	ark	M-P	no	no	N	N	S		yes	
16	Kuenzi, 1966, p. 274-276	Easter Lily	E-O	275	275	12	1-27	fld	M-P	no	no	N	N	A		yes	
17	Kuenzi, 1966, p. 263-264	Pipestone Springs	E-O	176	176	01	1	fld	P	-	-	-	-	A		no	
18	Kuenzi, 1966, p. 265-266	Little Pipestone sec. 1	E-O	178	173	04	7	fld	P	yes	no	N	N	A		yes	
19	Kuenzi, 1966, p. 267-268	Little Pipestone sec. 2	E-O	48	48	26	4-8	fld	M-P	yes	yes	N	N	T		yes	206
20	Petkewich, 1972, p. 300-303	Williams Creek sec., segment E.	M-P	2130	780	100	5-340	-	P	yes	yes	-	-	A		no	
21	Petkewich, 1972, p. 303-308	Williams Creek sec., segments A, B and D	E-O	1740	1310	01	8	-	P	yes	-	-	-	A		no	
22	Petkewich, 1972, p. 308-310	Burnt Hills Reservior	E-O	745	467	2	5	-	-	-	-	-	-	A		no	
23	Petkewich, 1972, p. 310-315	Borofsky Ranch sec., excluding upper 10 ft	E-O	845	687	30	1-45	fld	M-P	yes	yes	-	-	A		no	
24	Petkewich, 1972, p. 315-318	Plant Locality	E-O	198	198	39	26	-	M-P	yes	yes	-	-	A		no	
25	Petkewich, 1972, p. 318-326	Descheemaeker Ranch	M-P	1467	657	47	47	-	M-P	yes	-	-	-	S		no	
26	Petkewich, 1972, p. 326-332	Mule Shoe Ditch	M-P	740	417	55	1-35	-	M-P	yes	-	-	-	S		no	
27	Petkewich, 1972, p. 332-334	Swan Ranch	M-P	46	46	50	2-16	fld	M-P	-	-	-	-	A		no	
28	Petkewich, 1972, p. 334-336	Confusion	M-P	355	140	23	12-20	fld	P	yes	no	N	N	A		yes	217
29	Petkewich, 1972, p. 337	Rattlesnake	M-P	64	64	100	3-29	fld	P	yes	-	-	-	A		no	
30	Petkewich, 1972, p. 338-340	Bliss	M-P	140	140	85	1-64	fld	P	yes	-	-	-	A		no	
31	Petkewich, 1972, p. 340-344	Georgia Gulches	M-P	965	881	78	1-47	fld	W-P	yes	-	-	-	S		no	
32	Hoffman, 1972, p. 146-151	Diamond O Ranch A-O	E-O	87	87	26	2-10	-	M-W	-	yes	-	-	A		no	
33	Hoffman, 1972, p. 152	Van Deren Ranch sec. F	E-O	73	73	10	10	-	-	-	-	-	-	-		no	
34	Hoffman, 1972, p. 154	Biltmore Duck Pond sec. H	M-P	120	120	26	5-16	-	-	-	yes	-	-	A		no	

[a]Dash means information not available.

[b]M-P, Miocene and Pliocene; E-O, Eocene and Oligocene

[c]M[illegible] to coarse grained or conglomeratic.

[d]NF - 0-10% feldspar; fld - feldspathic; ark - arkosic

[e]V = very; W = well; M = moderate; P = poor

[f]P = present but amount unknown; T = trace (<1%); A = accessory (1-10%); S = subordinate (10%-50%); D = dominant (>50%)

APPENDIX B (continued)

Section number	Reference	Section name or number	Age[b]	Total thickness of section (ft)	Total thickness of described section (ft)	Potential host rocks[c]: % of desc. sec.	Thick. of beds (ft)	Fld or ark[d]	Sorting[e]	Cal-careous	Iron staining	Organic material: In coarse rocks	Organic material: In fine rocks	Tuffaceous rocks in section[f]	Other characteristics	Examined by authors?	Locality this report (App. A)
35	Hoffman, 1972, p. 155	North Bench Gravel Pit sec. I	M-P	318	171	47	11-70	-	-	-	-	T	-	-		no	
36	Hoffman, 1972, p. 156-158	Fox Hollow sec. J	M-P	356	272	02	1-3	-	-	yes	-	-	-	A		no	
Upper Ruby River and Sage Creek basins																	
37	Dorr and Wheeler, 1964, p. 309-312	Sweetwater Creek	M-P	252	252	82	202	-	P	-	-	-	-	-		no	
38	Dorr and Wheeler, 1964, p. 309-312	Sweetwater Creek	E-O	130	130	16	8-12	-	-	yes	yes	-	-	S		no	
39	Dorr and Wheeler, 1964, p. 312-314	Belmont Ranch	M-P	1136	482	38	3-30	NF	P	yes	no	N	N	A		yes	240
40	Dorr and Wheeler, 1964, p. 314-317	Idaho Creek	M-P	749	442	83	1-25	fld	-	yes	-	-	-	S		yes	
41	Dorr and Wheeler, 1964, p. 317-319	Barton Creek	M-P	369	369	74	3-58	NF	P	no	no	N	N	D	fossils	yes	221
42	Hibbard and Keenmon, 1950, p. 195-198	Blacktail Deer Creek	M-P	400	400	10	1-6	fld	P	yes	yes	N	N	A		yes	229
Grasshopper Creek and Horse Prairie basins																	
43	M'Gonigle, 1965, p. 139-140	Table 8	M-P	1326	1326	04	1-42	-	-	yes	-	-	T	A		no	
44	M'Gonigle, 1965, p. 141-146	Table 9	M-P	6181	5480	10	1-198	-	-	-	-	-	T	T		no	
Three Forks basin																	
45	Robinson, 1963, p. 78	Dunbar Creek Fm Type Area	E-O	315	260	20	2-22	-	-	no	-	-	-	D		yes	311
46	Feichtinger, 1970, p. 65-68	partial stratigraphic sec. I	E-O	387	330	39	1-30	-	-	yes	-	-	-	S		yes	313
47	Feichtinger, 1970, p. 74-78	partial stratigraphic sec. IV	E-O	387	273	08	0.3-5	-	-	yes	yes	-	-	S		yes	315
48	Schneider, 1970, p. 54-56	partial stratigraphic sec. III	M-P	289	274	63	2-35	-	-	yes	yes	T	-	S	clayballs	yes	316
49	Schneider, 1970, p. 59	partial stratigraphic sec. V	M-P	146	146	50	-	-	-	yes	-	-	-	D		yes	
50	Schneider, 1970, p. 60-61	partial stratigraphic sec. VI	M-P	530	480	27	-	-	-	yes	-	T	T	D	clayballs, bone chips	yes	
51	Hackett and others, 1960, p. 37	Section of Unit 1	M-P	921.5	671.5	15	3-62	fld	-	yes	yes	-	T	D	underlies sec. 52	no	
52	Hackett and others, 1960, p. 38-39	Section of Unit 2	M-P	373	318	30	1.5-44	-	-	yes	-	T	-	S	bone fragments; overlies sec. 51	no	
53	Mifflin, 1963, p. 17-18	Section No. 1	M-P	113	113	0	-	-	-	-	-	-	T	D		yes	
54	Mifflin, 1963, p. 18-19	Section No. 2	M-P	200	162	07	6	-	-	yes	-	T	T	D	silicified wood	yes	
55	Glancy, 1964, p. 58-63	Beacon Hill	M-P	2016	717	67	2-85	NF-fld	P	yes	no	T	T	D	bone fragments	yes	361
Boulder River basin																	
56	Alexander, 1955, p. xxii	Section 15	M-P	141	141	0	-	-	-	-	-	-	-	D	underlies sec. 57	yes	
57	Alexander, 1955, p. xxiii	Section 16	M-P	199	199	05	up to 2	NF	P	yes	no	-	-	D	overlies sec. 56	yes	343

[a] Dash mean information not available.

[b] M-P, Miocene and Pliocene; E-O, Eocene and Oligocene

[c] Medium to coarse grained or conglomeratic.

[d] NF - 0-10% feldspar; fld - feldspathic; ark - arkosic

[e] V = very; W = well; M = moderate; P = poor

[f] P = present but amount unknown; T = trace (<1%); A = accessory (1%-10%); S = subordinate (10%-50%); D = dominant (>50%)

APPENDIX B (continued)

Section number	Reference	Section name or number	Age[b]	Total thickness of section (ft)	Total thickness of described section (ft)	Potential host rocks[c]: % of desc. sec.	Thick. of beds (ft)	Fld or ark[d]	Sorting[e]	Cal-careous	Iron staining	Organic material: In coarse rocks	Organic material: In fine rocks	Tuffaceous rocks in section[f]	Other characteristics	Examined by authors?	Locality this report (App. A)
Townsend and Clarkston basins																	
58	Pardee, 1925, p. 22	Section on ridge, north of Sixmile Creek, sec. 12 T. 5 N., R. 2 E.	E-O	624	624	11	70	-	-	yes	-	-	A	D	coal in equiv. beds 2 miles SE (Pardee, 1925, p. 23)	no	
59	Pardee, 1925, p. 25	Section north of Greyson Cr., east line of sec. 13, T. 6 N., R. 2 E.	M-P[g]	575	575	23	1-50	NF	-	yes	-	-	-	D		no	
60	Klemme, 1949, p. 191-196	Section 20, formation A	E-O	2537	2537	27	2-36	-	-	yes	-	-	A	S		no	
61	Klemme, 1949, p. 188-191	Section 20, formation B	M-P	1664	1664	65	15-470	-	-	yes	-	-	T	S		yes	

[a]Dash means information not available.

[b]M-P, Miocene and Pliocene; E-O, Eocene and Oligocene

[c]Medium to coarse grained or conglomeratic.

[d]NF - 0-10% feldspar; fld - feldspathic; ark - arkosic

[e]V = very; W = well; M = moderate; P = poor

[f]P = present but amount unknown: T = trace (<1%); A = accessory (1%-10%); S = subordinate (10%-50%); D = dominant (>50%)

[g]Age determined by subsequent investigators.

APPENDIX C

GAMMA-RAY SPECTROMETRIC ANALYSES OF ROCK SAMPLES

APPENDIX C

GAMMA-RAY SPECTROMETRIC ANALYSES OF ROCK SAMPLES

Sample number	eU (ppm)	eTh (ppm)	eK (pct)
101-1	8.7	10.0	2.19
101-2	1.8	6.1	2.66
102-1	5.4	10.1	0.60
102-2	1.8	9.9	2.49
102-3	2.2	9.2	2.76
102-4	3.4	9.6	1.47
102-5	2.1	3.6	2.72
103-1	1.9	5.6	2.66
103-2	3.3	19.8	1.80
104-1	2.9	7.0	2.42
104-2	4.9	12.1	1.99
104-3	3.2	11.7	1.99
104-4	1.6	4.4	2.16
105-1	3.0	7.3	2.35
106-1	5.2	5.4	3.00
106-2	3.9	14.8	2.34
106-3	3.6	6.9	2.84
106-4	3.4	7.9	2.43
107-1	3.0	10.1	1.89
108-1	3.0	6.8	2.13
108-2	2.8	6.9	1.87
108-3	3.4	10.7	2.83
109-1	3.9	22.4	1.77
110-1	2.1	6.7	2.34
111-1	5.3	11.1	1.26
111-2	2.1	6.1	2.28
111-3	3.3	11.9	1.35
111-4	2.0	8.8	2.02
112-1	1.2	4.6	2.52
113-1	2.0	6.9	2.00
113-2	1.5	7.0	2.04
114-1	1.0	4.8	1.84
115-1	2.3	12.9	1.15
115-2	2.2	9.5	1.29
116-1	2.5	6.6	2.28
116-2	4.6	7.0	0.61
117-1	6.0	9.6	1.16
118-1	3.9	15.5	2.22
118-2	1.5	9.5	2.61
119-1	4.4	13.2	1.61
119-2	0.9	5.0	2.13
119-3	8.3	7.0	0.62
119-4	3.7	4.4	2.30
119-5	20.9	12.8	1.08
119-6	7.1	5.7	2.17
119-7	1.1	4.4	2.10
119-8	19.5	14.3	0.92
119-9	3.4	5.5	1.92
120-1	0.7	6.4	1.91
120-2	3.6	21.0	1.74
121-1	2.6	12.9	2.08
121-2	2.0	10.2	2.21
122-1	1.5	13.9	2.09
123-1	3.3	12.6	3.53
124-1	2.1	8.3	2.29
125-1	4.9	9.5	2.57
125-2	13.9	22.8	2.13
125-3	3.7	6.7	2.57
126-1	3.6	19.8	2.73
126-2	1.7	9.9	2.46
127-1	3.4	11.8	2.58
128-1	2.3	11.6	2.35
128-2	5.8	28.4	2.37
129-1	5.7	9.6	2.14
129-2	2.6	8.3	3.06
130-1	2.4	10.8	2.52
131-1	5.3	36.4	2.87
132-1	2.1	9.7	0.97
132-2	1.6	6.3	0.93
133-1	2.7	6.0	2.01
133-2	1.6	6.2	2.29
134-1	3.5	5.7	3.10
135-1	2.4	3.0	1.08
136-1	3.0	11.9	2.13
136-2	3.0	7.7	2.44
137-1	2.4	9.0	2.09
138-1	6.1	21.8	2.35
139-1	1.4	9.3	2.63
140-1	6.1	33.7	3.15
140-2	6.2	31.5	3.97
141-1	5.9	12.9	1.81
142-1	3.7	14.1	1.40
142-2	4.1	10.7	2.18
143-1	3.0	9.6	1.87
144-1	1.4	6.5	2.05
145-1	1.7	4.8	1.92
146-1	3.6	8.3	2.34
147-1	2.0	8.0	3.27
148-1	4.1	12.3	3.64
148-2	5.7	7.3	2.51
149-1	6.4	14.9	1.89
149-2	3.9	11.3	2.39
150-1	1.3	4.1	1.22
151-1	2.2	10.1	3.24
151-2	2.9	18.2	3.19
201-1	3.7	16.2	0.80
201-2	6.0	23.5	3.15
202-1	4.7	25.1	3.45
203-1	4.4	8.7	1.33
203-2	2.0	5.4	1.71
204-1	4.4	11.8	1.42
204-2	1.7	12.1	3.00
205-1	4.1	24.8	2.15
205-2	13.2	21.4	3.22
206-1	4.3	19.3	1.76
206-2	3.4	14.6	2.75
207-1	4.5	34.3	2.56
208-1	3.1	15.3	3.64
209-1	2.6	9.1	2.21
210-1	1.8	6.4	1.28
210-2	1.1	4.4	1.59
211-1	1.4	5.8	2.22
212-1	1.1	4.3	1.80
213-1	1.9	5.6	1.68
214-1	0.9	7.4	1.32
215-1	1.6	8.7	1.68
216-1	1.3	5.8	1.28
217-1	3.4	9.5	3.04
217-2	1.4	7.1	1.50
218-1	3.9	26.5	1.69
218-2	2.3	10.4	2.80
219-1	7.0	7.3	1.41
220-1	2.2	9.5	1.84
221-1	2.4	7.3	1.15
222-1	15.4	7.2	2.01
223-1	1.9	6.5	1.[illegible]
224-1	6.6	45.5	3.[illegible]
225-1	2.8	15.2	2.00

APPENDIX C (continued)

Sample number	eU (ppm)	eTh (ppm)	eK (pct)
225-2	2.9	15.3	2.17
227-1	4.1	21.8	3.51
227-2	1.5	6.1	1.26
227-3	1.8	10.5	1.50
227-4	7.0	38.5	4.58
229-1	2.2	9.4	2.96
229-2	3.1	7.7	2.47
230-1	5.6	30.2	4.40
231-1	2.0	20.0	3.03
232-1	4.8	12.5	1.65
232-2	3.4	13.3	1.12
232-3	2.1	9.5	1.92
233-1	9.6	13.7	1.54
233-2	3.6	3.6	2.35
234-1	3.7	12.9	2.95
235-1	1.4	4.9	1.88
236-1	2.7	1.4	1.84
237-1	1.4	10.1	2.86
238-1	107.0	13.3	1.65
239-1	8.9	5.0	1.19
240-1	3.4	14.7	2.77
240-2	0.8	6.0	2.10
241-1	0.3	4.6	0.50
242-1	3.3	11.7	2.25
242-2	1.8	9.8	2.43
243-1	3.3	13.6	1.93
243-2	1.9	5.4	1.00
244-1	1.5	5.5	0.87
245-1	1.8	35.4	3.71
246-1	2.2	14.5	2.01
247-1	0.8	2.7	0.25
248-1	0.9	3.6	0.30
249-1	2.4	5.8	0.41
249-2	8.2	29.0	2.82
250-1	26.6	12.7	4.57
251-1	1.0	2.1	0.39
251-2	1.8	1.3	0.22
251-3	-0.1	1.5	0.18
252-1	0.6	0.8	0.08
253-1	1.5	5.4	1.33
254-1	5.5	25.2	3.30
255-1	1.3	5.2	0.81
255-2	1.0	2.8	0.59
256-1	0.8	4.6	1.05
257-1	2.5	14.5	2.19
258-1	4.0	13.1	2.50
260-1	6.7	24.6	1.89
261-1	3.8	11.5	2.65
261-2	2.5	6.6	1.58
262-1	1.7	12.2	1.58
262-2	6.0	32.7	3.77
262-3	2.4	14.0	1.34
262-4	1.0	5.7	0.75
301-1	7.9	9.8	3.28
301-2	9.6	9.4	3.24
301-3	4.5	15.0	2.71
301-4	5.3	13.0	2.62
301-5	3.8	12.7	2.42
301-6	15.7	11.2	2.78
302-1	11.9	7.6	2.98
302-2	3.5	7.9	3.17
302-3	2.3	5.8	3.53
302-4	4.3	19.1	1.71
302-5	6.1	18.9	1.60
302-6	25.8	11.3	2.79
302-7	2.6	7.7	3.32
302-8	4.8	9.1	2.93
302-9	4.0	12.1	2.25
303-1	40.6	69.5	2.73
303-2	6.4	3.3	3.45
304-1	7.7	23.3	1.61
304-2	3.9	17.0	3.45
304-3	14.6	79.2	2.15
304-4	16.9	80.1	2.30
305-1	5.8	11.1	2.79
305-2	57.8	12.8	2.54
306-1	7.4	12.7	3.05
309-1	3.6	33.0	1.45
309-2	2.3	15.9	2.95
309-3	11.5	39.0	3.33
310-1	14.8	41.2	3.16
310-2	13.9	14.9	1.72
310-3	8.8	15.0	2.41
310-4	9.3	24.2	2.85
311-1	1.9	7.4	2.25
312-1	303.4	10.6	0.02
312-2	46.3	1.9	0.02
313-1	1.3	17.0	1.56
313-2	0.6	4.3	2.05
314-1	4.7	11.3	2.68
314-2	31.7	7.7	1.76
314-3	3.1	10.6	2.11
314-4	1.4	5.8	2.38
315-1	3.6	10.8	2.77
315-2	3.4	4.8	2.56
316-1	2.7	10.6	2.79
316-2	22.6	6.9	2.19
316-3	4.4	6.8	2.58
316-4	11.1	6.5	2.53
316-5	6.6	7.6	2.37
317-1	2.9	6.4	1.60
318-1	85.6	25.2	1.39
318-2	2.9	4.9	2.60
320-1	25.1	3.5	0.72
321-1	69.8	15.8	2.44
322-1	5.8	24.5	3.50
323-1	9.5	49.5	3.06
324-1	365.8	30.2	1.13
324-2	466.7	30.9	2.23
324-3	73.1	12.7	3.39
325-1	9.5	19.7	1.81
325-2	138.0	21.6	2.00
325-3	155.0	21.5	1.59
325-4	359.3	24.3	3.25
326-1	49.8	33.8	2.36
326-2	73.1	16.6	2.35
326-3	4.0	9.9	3.33
327-1	1.4	11.6	1.85
327-2	1.6	10.0	1.91
328-1	2.5	17.0	2.84
328-2	1.5	12.1	3.22
329-1	3.1	10.0	2.26
330-2	604.4	42.1	2.57
330-3	10.5	44.8	3.70
330-4	25.3	47.5	3.90
331-1	21.7	31.7	4.33
332-1	17.7	55.7	3.68
333-1	18.2	100.4	3.33

APPENDIX C (continued)

Sample number	eU (ppm)	eTh (ppm)	eK (pct)
334-1	1.4	9.5	2.51
335-1	3.5	35.7	1.43
335-2	28.8	100.7	4.66
336-1	24.9	90.6	3.84
336-2	30.9	104.2	4.77
339-1	1.8	8.0	1.61
340-1	24.2	13.5	1.90
341-2	9.4	12.1	1.90
341-3	8.1	5.6	1.84
341-4	16.7	8.7	2.94
341-5	8.7	6.8	2.45
342-1	2.0	6.4	1.83
342-2	15.6	22.2	1.40
342-3	7.7	12.9	1.87
342-4	18.2	9.0	2.31
343-1	1.4	8.2	3.73
343-2	3.5	12.5	2.00
343-3	2.3	7.2	2.83
344-1	1.7	9.7	3.38
346-1	1.1	11.7	3.32
346-2	3.3	16.6	2.67
347-1	4.4	19.7	2.17
347-2	2.7	11.7	3.00

Sample number	eU (ppm)	eTh (ppm)	eK (pct)
347-3	9.0	32.9	3.15
348-1	4.1	13.9	2.41
348-2	1.6	9.8	3.29
349-1	3.1	16.7	2.44
349-2	1.2	6.0	2.47
349-3	1.5	9.0	3.39
350-1	0.7	18.9	0.92
350-2	0.8	9.5	3.07
353-1	3.7	15.8	2.68
353-2	1.5	8.8	3.34
354-1	2.4	5.5	1.26
354-2	1.2	10.1	1.15
355-1	12.4	12.8	2.07
358-1	169.3	27.2	3.30
358-2	28.5	39.0	1.48
359-1	18.7	32.9	2.10
359-2	13.2	13.6	3.83
359-3	66.3	28.2	1.70
359-4	24.9	16.2	3.67
360-1	205.5	15.8	0.76
360-2	11.9	35.2	2.62
360-3	21.0	24.1	2.00

NOTE: The relative precision of the equivalent uranium analyses at the 95 percent confidence level (1.95 standard deviation), based on eight analyses of two standards analyzed repeatedly throughout the project, is 0.6 ppm at a mean level of 1.4 ppm and 0.9 ppm at a mean level of 3.7 ppm. The relative precision of the equivalent thorium analyses is 1.4 ppm at a mean level of 1.8 ppm and 1.7 ppm at a mean level of 0.9 ppm.

APPENDIX D

CHEMICAL URANIUM ANALYSES OF SELECTED ROCK SAMPLES

APPENDIX D

CHEMICAL URANIUM ANALYSES OF SELECTED ROCK SAMPLES

Sample Number	cU (ppm)[a] Fluorimetric method	cU (pct)[a] Colorimetric method
119-5	21	
119-6	7	
205-2	15	
222-1	14	
238-1	30	
250-1	19	
301-6	14	
302-6	8	
303-1	20	
304-3	14	
305-2	64	
312-1	306	
312-2	52	
314-2	38	
316-2	28	
318-1	90	
320-1	26	
321-1	94	
324-1		0.03
324-2		0.05
324-3	23	
325-2	113	
325-3	163	
325-4		0.04
325-5		0.94
326-1	61	
326-2	53	
330-2		0.06
330-4	18	
336-1	20	
336-2	29	
340-1	33	
341-1		2.58
341-4	22	
342-4	25	
358-1	170	
359-3	62	
359-4	20	
360-1	102	

[a] Converted to cU from cU_3O_8

APPENDIX E

SEMIQUANTITATIVE EMISSION SPECTROSCOPIC ANALYSES OF SELECTED ROCK SAMPLES

APPENDIX E
SEMIQUANTITATIVE EMISSION SPECTROSCOPIC ANALYSES OF SELECTED ROCK SAMPLES
(in percent)

Sample Number	As	B	Cr	Cu	Ga	Li	Mn	Nb	Pb	Sn	V	Y	Zn
101-1	0	0	0	0.0020	0	0.0001	0.0300	0	0.0001	0	0.0020	0.0030	0.0100
101-2	0	0	0	0.0010	0.0001	0.0001	0.0100	0.0010	0.0003	0	0.0030	0.0030	0
102-1	0	0.0005	0	0.0040	0.0001	0	0.0400	0	0.0002	0	0.0050	0.0030	0.0100
102-2	0	0	0.0010	0.0020	0.0001	0	0.0200	0.0010	0.0005	0	0.0080	0.0020	0
102-4	0	0.0020	0.0010	0.0040	0.0001	0.0001	0.0600	0	0.0010	0	0.0300	0.0040	0.0100
106-1	0	0	0.0010	0.0070	0.0001	0	>1.0000	0.0030	0.0010	0.0050	0.2000	0.0040	0.0300
108-1	0	0	0.0020	0.0020	0.0001	0.0008	0.0300	0.0010	0.0005	0	0.0030	0.0030	0
108-2	0	0	0.0020	0.0020	0.0001	0.0008	0.0100	0	0.0001	0	0.0040	0.0020	0
119-5	0	0	0	0.0010	0.0001	0	0.1500	0	0.0003	0	0.0030	0.0030	0.0100
119-6	0	0	0	0.0008	0.0001	0	0.2000	0	0.0010	0	0.0070	0.0020	0.0100
125-2	0	0	0.0080	0.0020	0.0003	0.0050	0.0300	0	0.0002	0	0.0100	0.0030	0.0100
125-3	0	0	0	0.0005	0.0001	0.0001	0.0300	0	0.0003	0	0.0030	0.0010	0.0100
205-1	0	0.0010	0.0030	0.0040	0.0005	0.0020	0.0300	0	0.0003	0	0.0200	0.0050	0.0100
205-2	0	0.0020	0.0020	0.0030	0.0001	0	0.0200	0	0.0005	0	0.0100	0.0010	0
206-1	0	0.0030	0.0020	0.0040	0.0001	0.0010	0.0100	0	0.0002	0	0.0050	0.0050	0.0100
206-2	0	0.0005	0.0010	0.0040	0.0001	0.0003	0.0800	0	0.0010	0	0.0200	0.0030	0.0100
219-1	0	0	0.0020	0.0030	0.0001	0.0003	0.0070	0.0010	0.0010	0	0.0600	0.0020	0
233-1	0	0	0.0010	0.0010	0.0001	0.0005	0.0100	0.0010	0.0010	0	0.0080	0.0040	0
233-2	0	0	0	0.0008	0.0001	0	0.0100	0	0.0005	0	0.0030	0.0020	0
236-1	0	0	0	0.0010	0.0001	0	0.0050	0	0.0040	0.0090	0.0040	0.0010	0
249-2	0	0	0.0020	0.0007	0.0001	0	0.3000	0.0005	0.0008	0	0.0050	0.0030	0.0100
301-3	0	0	0	0.0020	0.0001	0	0.0300	0	0.0010	0	0.0080	0.0020	0
301-6	0	0.0020	0.0010	0.0030	0.0001	0.0010	1.0000	0	0.0020	0.0005	0.0070	0.0070	0.0100
304-1	0	0	0.0010	0.0030	0.0001	0	0.0800	0.0010	0.0001	0	0.0050	0.0040	0
304-2	0	0	0.0010	0.0030	0	0	0.0300	0.0030	0.0010	0	0.0080	0.0030	0
310-2	0	0	0.0020	0.0010	0	0.0005	0.0100	0.0020	0.0003	0	0.0030	0.0020	0.0100
314-1	0	0	0.0010	0.0020	0.0001	0.0003	0.0600	0.0020	0.0030	0	0.0070	0.0040	0
316-3	0	0	0.0020	0.0010	0.0001	0.0004	0.0300	0.0020	0.0010	0	0.0100	0.0030	0
318-1	0	0	0.0050	0.0040	0.0001	0.0005	0.0030	0.0030	0.0005	0	0.0100	0.0030	0
324-1	0.0300	0.0050	0.0020	0.0040	0.0001	0.0010	0.0050	0	0.0010	0	0.0050	0.0020	0.0100
325-1	0.0300	0	0.0010	0.0040	0.0001	0.0001	0.0100	0.0060	0.0020	0	0.0100	0.0060	0
325-3	0	0.0030	0.0020	0.0030	0.0002	0.0020	0.0100	0.0020	0.0030	0	0.0100	0.0040	0.0100
326-1	0	0	0.0010	0.0020	0.0001	0.0008	0.0200	0.0080	0.0040	0.0010	0.0200	0.0040	0
335-1	0	0	0	0.0020	0.0005	0	0.0200	0.0200	0.0003	0	0.0100	0.0040	0.0100
342-2	0	0.0040	0.0020	0.0300	0.0001	0.0005	0.0100	0.0010	0.0020	0	0.0090	0.0030	0.0100
342-3	0	0.0060	0.0050	0.0100	0.0003	0.0003	0.0200	0.0010	0.0030	0.0003	0.0300	0.0040	0.0100
358-2	0	0.0040	0.0010	0.0030	0.0001	0.0005	0.0050	0.0030	0.0010	0.0004	0.0040	0.0020	0.0200
359-1	0	0.0030	0.0030	0.0050	0.0006	0.0030	0.0100	0.0020	0.0050	0.0003	0.0100	0.0040	0.0100
359-3	0.0300	0.0030	0	0.0050	0.0007	0	0.0030	0.0010	0.0050	0	0.0060	0.0030	0.0100
360-3	0.0300	0	0.0010	0.0040	0.0010	0.0001	0.0070	0.0050	0.0010	0.0005	0.0050	0.0050	0.0100
Mean of values detected	0.0300	0.0030	0.0020	0.0040	0.0002	0.0009	0.0630	0.0030	0.0013	0.0021	0.0150	0.0030	0.0100

Note: zero value means not detected; underline means anomalous value.

APPENDIX F

URANIUM ANALYSES OF WATER SAMPLES

APPENDIX F

URANIUM ANALYSES OF WATER SAMPLES

Sample number	U_3O_8 (ppb)
214-2	7
226-1	4
228-1	2
259-1	10
308-1	40
319-1	1
337-1	3
338-1	3
345-1	5
350-3	1
351-1	7
352-1	5
356-1	4
357-1	2

Mean = 7 ppb U_3O_8

Std. dev. = 10 ppb U_3O_8

APPENDIX G

LIST OF PETROLEUM TEST WELLS

APPENDIX G

LIST OF PETROLEUM TEST WELLS

Well number	Company and well name	Year drilled	Location	Ground level elev. (ft)	Total depth (ft)	Depth to pre-Tertiary rocks (ft)	Type of log(s)
1[a]	Ben Ryan Tom Tice #1	- -	NW¼NW¼NW¼ sec. 28, T. 1 N., R. 2 E.; Gallatin County	4,180	- -	2,300	- -
2	Montana Power Company; Frances #2	1952	NW¼NW¼NW¼ sec. 28, T. 1 N., R. 2 E.; Gallatin County	4,180	1,650	- -	Elect, neutron
3	Montana Power Company; Rice #2	- -	CtrNE¼NE¼ sec. 29, T. 1 N., R. 2 E.; Gallatin County	4,170	915	- -	Gamma, neutron
4	Montana Power Company; Rice #1	1952	SW¼SE¼NE¼ sec. 29, T. 1 N., R. 2 E.; Gallatin County	4,180	1,182	- -	Lith,[b] elect
5	Dunbar Oil Company; Dunbar #1	1950	SE¼SW¼SE¼ sec. 8, T. 2 N., R. 1 E.; Broadwater County	4,065	2,124	1,661	Lith
6	Elbert Malone; Roger Hansen #1	1960	CtrNE¼NE¼ sec. 9, T. 9 N., R. 6 E.; Meagher County	4,935	1,110	1,110	Lith
7	Luhman and others; Dunbar #1	1947	W½NE¼SW¼ sec. 8, T. 2 N., R. 1 W.; Jefferson County	4,840	1,260	1,214(?)	Lith
8	Montana Power Company; State 1-1-22	1961	SE¼SE¼SE¼ sec. 22, T. 7 N., R. 10 W.; Powell County	5,032	2,536	- -	Elect, gamma
9	Buffalo Oil Company; Nyhart #1	1953	CtrNE¼NE¼ sec. 3, T. 5 S., R. 7 W.; Madison County	4,800 est.	2,633	2,175(?)	Lith
10	Farmers Union Central Exchange; Stratigraphic Test #3	1971	NE¼NE¼ sec. 10, T. 7 S., R. 10 W.; Beaverhead County	5,736	800	- -	Lith
11	Farmers Union Central Exchange; State #11-16	1971	NE¼SW¼ sec. 16, T. 7 S., R. 10 W.; Beaverhead County	5,700	960	- -	Lith
12	Beaverhead Oil and Production Company; Hansen #1	1955	CtrSW¼SW¼ sec. 2, T. 10 S., R. 12 W.; Beaverhead County	6,390	4,130	- -	Elect
13	Able Oil Company; Monforton #1	1954	NE¼SW¼NW¼ sec. 9, T. 3 S., R. 4 E.; Gallatin County	5,000	1,301	593	Lith

[a] [illegible]is and others, 1965b, p. 3

[b] [illegible]kett and others, 1960, p. 184-186

APPENDIX H

LIST OF WATER WELLS

APPENDIX H

LIST OF WATER WELLS

Well no.	Owner or tenant	Driller	Year drilled	Location	County	Est. elev. (ft)	Total depth (ft)	Depth to pre-Tert. (ft)
1	Walter Steingruber	Barrus Drilling & Pump Co.	1970	NW¼NW¼NW¼ sec. 7, T. 1 N., R. 1 E.	Broadwater	4,200	200	- -
2[a]	- -	Contractor for U.S.G.S.	- -	NE¼SE¼ sec. 5, T. 1 N., R. 4 E.	Gallatin	4,250	207	- -
3[a]	- -	Contractor for U.S.G.S.	- -	NE¼SE¼ sec. 15, T. 1 N., R. 4 E.	Gallatin	4,315	315	- -
4[a]	- -	Contractor for U.S.G.S.	- -	NE¼SE¼ sec. 33, T. 2 N., R. 3 E.	Gallatin	4,200	450	300
5	William Williams	O'Keefe Contracting Co.	1974	NE¼SE¼ sec. 16, T. 4 N., R. 1 E.	Broadwater	4,200	450	- -
6	Alfred Edwards	Van Dyken Drilling Co.	1963	SW¼SW¼SE¼ sec. 26, T. 9 N., R. 6 E.	Meagher	4,970	300	- -
7	Raymond Shanholtzer	Barrus Drilling & Pump Co.	1970	SW¼NW¼ sec. 19, T. 2 N., R. 1 W.	Jefferson	4,650	160	- -
8	George Ballard	Barrus Drilling & Pump Co.	1970	W½SE¼SE¼ sec. 23, T. 2 N., R. 2 W.	Jefferson	4,840	195	- -
12	Jim Rowe	Barrus Drilling & Pump Co.	1972	NE¼SE¼SW¼ sec. 19, T. 3 N., R. 8 W.	Silver Bow	- -	200	- -
13	Victor Chemical Works	- -	- -	SE¼ sec. 23, T. 3 N., R. 9 W.	Silver Bow	- -	400	- -
15	- -	- -	- -	SW¼NW¼ sec. 26, T. 4 N., R. 10 W.	Deer Lodge	- -	450	- -
17	Dorothy Luedeche	Bill Preston	1973	SE¼NE¼ sec. 26, T. 7 N., R. 20 W.	Ravalli	- -	450	425
20	Lillias E. Schmidt	M.E. Jones	1968	NE¼SE¼SE¼ sec. 24, T. 9 N., R. 1 W.	Broadwater	4,520	400	- -
22	- -	- -	- -	NE¼ sec. 21, T. 10 N., R. 8 W.	Powell	- -	200	- -
23	Bible Baptist Church	Carl F. Hollensteiner	1967	NE¼ sec. 6, T. 10 N., R. 12 W.	Granite	- -	125	- -
24	Valley Cemetery	Liberty Drilling Co.	1965	NE¼NW¼ sec. 17, T. 10 N., R. 12 W.	Granite	4,200	227	- -
25	Douglas Olson	O'Keefe Contracting Co.	1973	SE¼SW¼ sec. 1, T. 10 N., R. 13 W.	Granite	- -	120	- -
26	Lamont Dupont	Ken Williams	1967	SE¼NE¼ sec. 10, T. 11 N., R. 9 W.	Powell	- -	136.5	- -
27	Lamont Dupont	Ken Williams	1971	SE¼NE¼ sec. 13, T. 11 N., R. 9 W.	Powell	- -	135	- -
28	- -	- -	- -	SW¼NW¼ sec. 34, T. 11 N., R. 20 W.	Missoula	- -	250	175
29	Great Northern Railway	- -	1943	SE¼SE¼NE¼ sec. 36, T. 12 N., R. 5 W.	Lewis & Clark	4,335	168	- -
30	Milton Shelley	W.D. Martin	1972	NW¼SW¼ sec. 33, T. 12 N., R. 12 W.	Powell	- -	125	- -
31	Ntnl. Park Service	Paul Vollmer and Son	1965	NE¼SW¼SE¼ sec. 24, T. 2 S., R. 17 W.	Beaverhead	- -	250	- -
32	Mark Clemow	O'Keefe Contracting Co.	1975	SE¼SW¼ sec. 16, T. 3 S., R. 15 W.	Beaverhead	6,145	205	- -
33	Win-Del Ranches	Gerald Stalenp	1962	NE¼NE¼ sec. 17, T. 5 S., R. 1 W.	Madison	3,000	193	- -
34	Dick South	Briggs Drilling Contractor	1973	SE¼SE¼ sec. 2, T. 5 S., R. 6 W.	Madison	- -	558	- -
35	Reece Silve Jr.	Donald C. Jones	1970	NE¼SW¼ sec. 9, T. 5 S., R. 6 W.	Madison	- -	506	- -
36	- -	- -	- -	SW¼NW¼ sec. 31, T. 5 S., R. 14 W.	Beaverhead	- -	509	- -
37	Don Todd	O'Keefe Contracting Company	1973	SE¼ sec. 8, T. 6 S., R. 1 W.	Madison	- -	110	- -
38	Berg Christansen Co.	Carl F. Hollensteiner	1964	NE¼NE¼ sec. 9, T. 8 S., R. 12 W.	Beaverhead	- -	325	- -
39	Bureau of Land Mgmt.	Briggs Drilling Contractor	1970	NW¼NW¼ sec. 6, T. 9 S., R. 12 W.	Beaverhead	- -	403	- -
40	Bureau of Land Mgmt.	Briggs Drilling Contractor	1968	NE¼SW¼ sec. 23, T. 10 S., R. 14 W.	Beaverhead	- -	243	- -
41	Don C. Detton	Briggs Drilling Contractor	1966	NW¼SW¼ sec. 3, T. 12 S., R. 8 W.	Beaverhead	- -	285	- -
42	Bureau of Land Mgmt.	Briggs Drilling Contractor	1968	NE¼SE¼ sec. 32, T. 12 S., R. 8 W.	Beaverhead	- -	240	- -
43	John Schutter	Van Dyken Drilling Company	1974	NW¼NW¼NE¼ sec. 10, T. 1 S., R. 2 E.	Gallatin	4,300	446	- -
44	Jake Droge	Van Dyken Drilling Company	1975	NW¼NW¼NW¼ sec. 4, T. 1 S., R. 3 E.	Gallatin	4,540	336	- -
45[a]	- -	Contractor for U.S.G.S.	- -	SW¼NW¼ sec. 36, T. 1 S., R. 3 E.	Gallatin	4,680	882	859
46[a]	- -	Contractor for U.S.G.S.	- -	NE¼NE¼ sec. 25, T. 1 S., R. 4 E.	Gallatin	4,575	280	- -
47[a]	- -	Contractor for U.S.G.S.	- -	SW¼SW¼ sec. 34, T. 1 S., R. 5 E.	Gallatin	4,700	250	- -
48[a]	- -	Contractor for U.S.G.S.	- -	SW¼NW¼ sec. 9, T. 2 S., R. 4 E.	Gallatin	4,890	600	575
49[a]	- -	Contractor for U.S.G.S.	- -	SE¼SW¼SW¼ sec. 22, T. 2 S., R. 5 E.	Gallatin	4,990	1,000	- -
50	Sun Ranch	C.F. Wroole	1959	NE¼SE¼ sec. 17, T. 10 S., R. 1 E.	Madison	- -	339	- -

ckett and others, 1960, p. 184-203

APPENDIX I

COMPILATION OF DATA FROM URANIUM EXPLORATION DRILLING PROJECTS IN PARTS OF THE THREE FORKS, TOWNSEND, AND UPPER RUBY RIVER BASINS

TABLE I-1. URANIUM EXPLORATION DRILL HOLES

Hole no.	Year drilled	Location	County	Est. elev. (ft)	Total depth (ft)	Depth to basement (ft)	Type of log(s)
1	1969	sec. 12, T. 1 N., R. 2 E.	Gallatin	4,320	602	- -	Lith, gamma, elect
2	1969	SW¼SE¼SE¼ sec. 7, T. 2 N., R. 1 E.	Broadwater	4,440	700	- -	Lith, gamma, elect
3	1969	NE¼NE¼NE¼ sec. 7, T. 2 N., R. 1 E.	Broadwater	4,340	720	- -	Lith, gamma
4	1969	SW¼SW¼NE¼ sec. 30, T. 3 N., R. 1 E.	Broadwater	4,440	540	470	Lith
5	1969	SW¼NE¼NW¼ sec. 18, T. 9 N., R. 1 E.	Broadwater	3,910	409	395	Lith, gamma, elect
6	1969	NE¼SE¼NW¼ sec. 18, T. 9 N., R. 1 E.	Broadwater	3,900	425	- -	Lith, gamma, elect
7	1969	NE¼SW¼SW¼ sec. 19, T. 9 N., R. 1 E.	Broadwater	4,480	449	365	Lith, gamma, elect
8	1969	SW¼SW¼NW¼ sec. 21, T. 9 N., R. 1 E.	Broadwater	4,050	660	- -	Lith, gamma
9	1969	NE¼SE¼NE¼ sec. 30, T. 9 N., R. 1 E.	Broadwater	4,100	690	- -	Lith, gamma, elect
10	1969	SE¼NE¼NE¼ sec. 2, T. 2 N., R. 1 W.	Jefferson	4,540	275	240	Lith, gamma, elect
11	1969	CtrNE¼NE¼ sec. 4, T. 2 N., R. 1 W.	Jefferson	4,760	535	535	Lith, gamma
12	1969	NE¼NE¼SE¼ sec. 8, T. 2 N., R. 1 W.	Jefferson	4,840	724	- -	Lith, gamma, elect
13	1969	E½NW¼NE¼ sec. 25, T. 3 N., R. 1 W.	Jefferson	4,600	300	- -	Lith, gamma, elect
14	1970	sec. 14, T. 2 S., R. 15 W.	Beaverhead	- -	1,290	- -	Gamma, elect
15	1969	SW¼NE¼NE¼ sec. 16, T. 7 S., R. 4 W.	Madison	5,800	1,000	- -	Lith, gamma, elect
16	1969	SE¼SE¼NE¼ sec. 21, T. 7 S., R. 4 W.	Madison	5,680	760	- -	Lith, gamma, elect
17	1969	NE¼SE¼NE¼ sec. 4, T. 8 S., R. 4 W.	Madison	6,260	700	- -	Lith, gamma, elect
18	1969	NE¼NW¼SW¼ sec. 9, T. 8 S., R. 4 W.	Madison	5,920	750	- -	Lith, gamma, elect
19	1969	NW¼SE¼SW¼ sec. 3, T. 8 S., R. 5 W.	Madison	5,940	400	- -	Lith, gamma, elect
20	1969	SW¼SW¼SE¼ sec. 12, T. 8 S., R. 5 W.	Madison	5,760	740	- -	Lith, gamma, elect
21	1969	NW¼SE¼SW¼ sec. 33, T. 8 S., R. 5 W.	Madison	5,860	580	- -	Lith, gamma, elect
22	1969	NE¼SE¼NE¼ sec. 12, T. 9 S., R. 4 W.	Madison	5,900	765	- -	Lith, gamma, elect
23	1969	NE¼SW¼NW¼ sec. 32, T. 9 S., R. 4 W.	Madison	6,900	800	- -	Lith, gamma, elect
24	1969	NE¼NW¼SW¼ sec. 16, T. 9 S., R. 5 W.	Madison	6,360	800	- -	Lith, gamma, elect

TABLE I-2. SUBSURFACE RADIOACTIVITY ANOMALIES IN PART OF THE THREE FORKS BASIN

Hole number	Radioactivity Anomaly: Depth to top (ft)	Thickness (ft)	Grade (% eU_3O_8)[a]	Lithology
2	190.0	2.5	0.006	Sand
	280.0	7.5	0.004	Sand (?)
	311.5	3.0	0.004	Sand
	320.0	21.0	0.004	Very fine sand and silt
	503.0	2.0	0.005	Silt (?), very fine sand (?)
	521.5	0.5	0.004	Silt or fine sand
	523.0	1.0	0.005	Silt or fine sand
	529.0	1.5	0.008	Silt or fine sand
	553.0	2.0	0.005	(unknown)
	557.0	0.5	0.004	(unknown)
	636.0	1.0	0.004	Clay
3	282.5	1.5	0.004	(unknown)
	314.0	4.0	0.004	(unknown)
	630.5	4.5	0.004	(unknown)
	692.0	9.0	0.004	(unknown)
11	29.0	2.0	0.004	(unknown)
	35.5	1.5	0.007	(unknown)
	60.0	2.0	0.012	Sandstone, silty; medium-grained, iron-stained.
	94.0	2.0	0.005	(unknown)
	153.0	3.0	0.005	(unknown)
12	202.0	1.0	0.005	Sandstone, silty, pebbly; medium-grained, poorly sorted, iron-stained.
	544.5	2.5	0.004	Clay
	565.0	6.0	0.004	Clay
	647.5	3.0	0.004	Sand
13	204.0	0.5	0.005	(unknown)

[a] Determined from gamma-ray log using adaptation of method presented by Scott and others (1960, p. 21-25). Grade considered anomalous if greater than or equal to 0.004 percent.

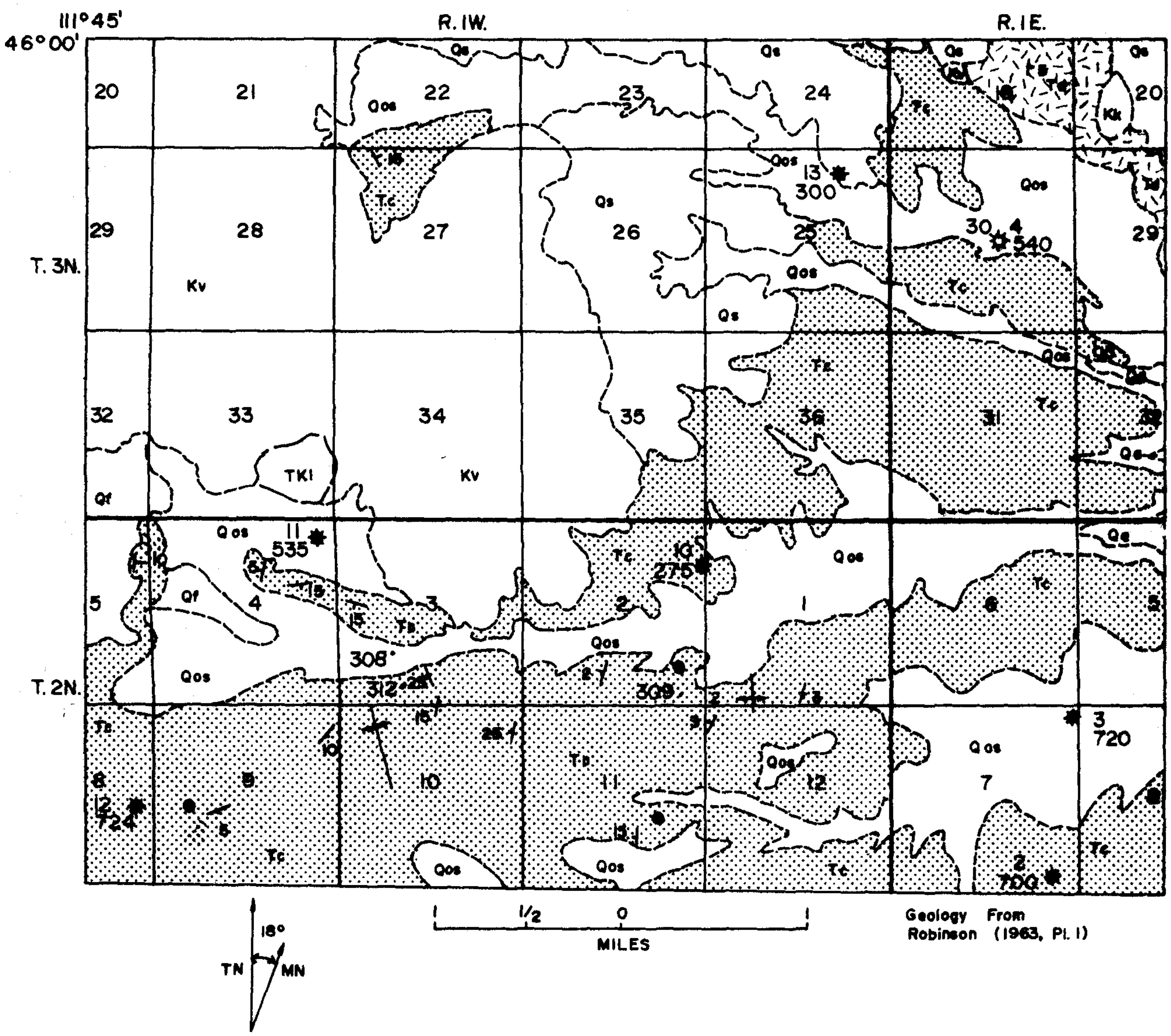


Figure I-1. Location of uranium exploration drill holes and study localities of part of the Three Forks basin. (See Pl. 2 for location of map area.)

EXPLANATION FOR FIGURE I-1

QUATERNARY

Pleistocene and Recent

- Qa — Young alluvium
- Qos — Old alluvium, subrounded gravel
- Qs — Eolian silt and sand
- Qf — Fan gravel, colluvial and alluvial

TERTIARY

Bozeman Group

- Oligocene: Td — Dunbar Creek Formation
- Eocene and Oligocene: Tc — Climbing Arrow Formation

Intrusive Rocks

- Upper Cretaceous and/or Lower Tertiary: TKl — Latite

CRETACEOUS

- Upper Cretaceous: Kl — Elkhorn Mountains volcanics
- Lower Cretaceous: Kk — Kootenai Formation

Contact, long dashed where approximately located, short dashed where indefinite

Syncline, dashed where approximately located

Anticline, dashed where approximately located

50 Strike and dip of beds

Horizontal beds

•312 Study locality, with locality number (App. A).

4/540 Uranium exploration drill hole, gamma-ray log not available. Upper number is hole number, lower is total depth in feet (Table I-1).

10/275 Uranium exploration drill hole, no anomalies on gamma-ray log. Upper number is hole number, lower is total depth in feet (Table I-1).

11/535 Uranium exploration drill hole, one or more anomalies on gamma-ray log (Table I-2). Upper number is hole number, lower is total depth in feet (Table I-1).

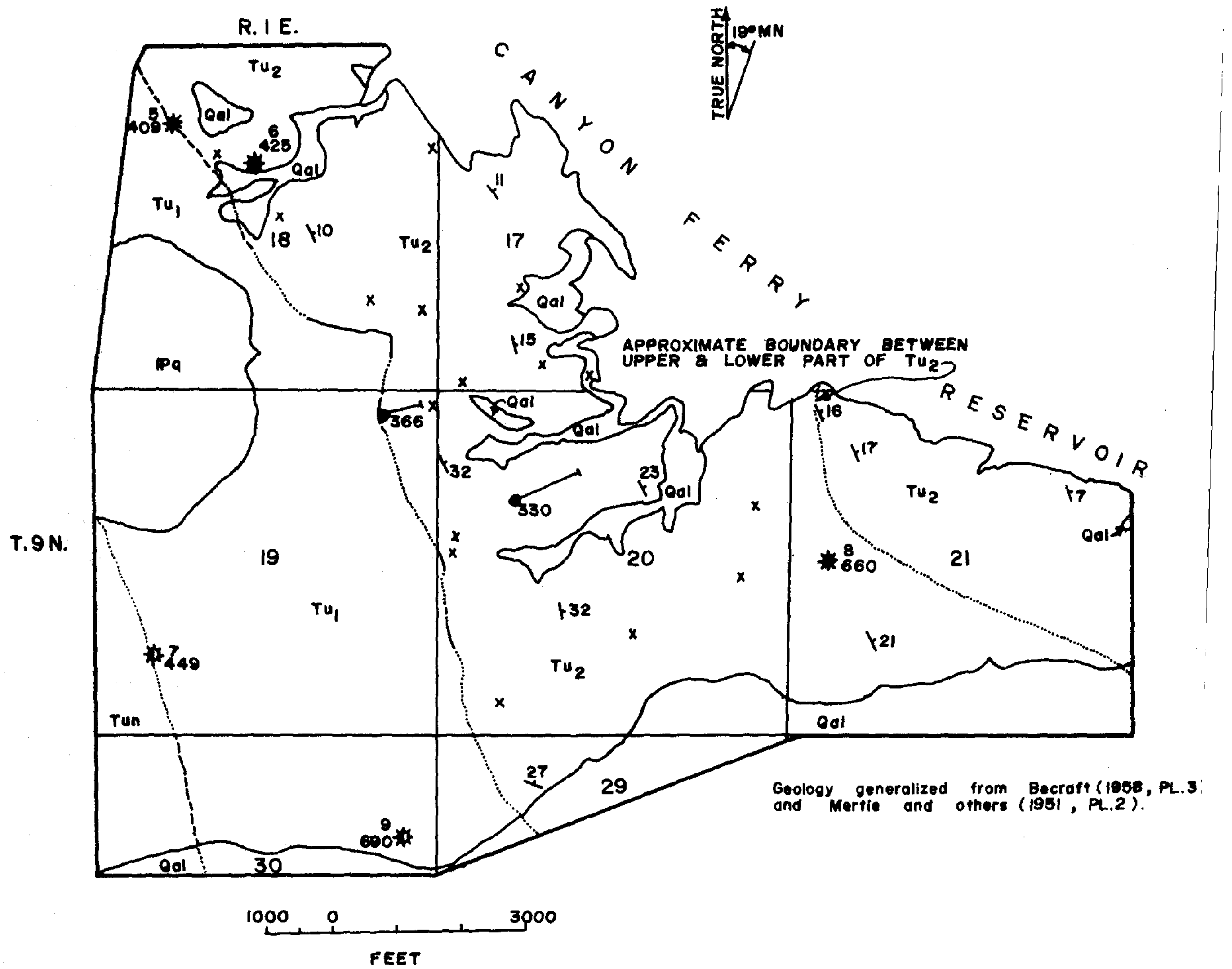


Figure I-2. Location of uranium exploration drill holes, surface radioactivity anomalies, and study localities of an area near Winston, Townsend basin. (See Pl. 2 for location of map area)

EXPLANATION FOR FIGURE I-2

Qal
Alluvium
} QUATERNARY

Oligocene {

Tu2
Unit 2. Thin-bedded tuff, including bentonite and thin beds of carbonaceous shale.

Tu1
Unit 1. Conglomerate, shale, and tuff, in places bentonitic

}

Tun
Tertiary undifferentiated
} TERTIARY

IPq
Quadrant formation undivided. Quartzite, in part interbedded with limestone, sandstone, and shale.
} PENNSYLVANIAN

27	Strike and dip of beds
X	Surface radioactivity anomaly
——— — — ······	Contact, dashed where approximately located, dotted where concealed.
—●	Study locality with locality number and line of section (App. A).
8 660	Uranium exploration drill hole, no anomalies on gamma-ray log. Upper number is hole number, lower is total depth in feet (Table I-1).
5 490	Uranium exploration drill hole, one or more anomalies on gamma-ray log (Table I-3). Upper number is hole number, lower is total depth in feet (Table I-1).

TABLE I-3. SUBSURFACE RADIOACTIVITY ANOMALIES IN AN AREA NEAR WINSTON, TOWNSEND BASIN

Hole number	Radioactivity anomaly: Depth to top (ft)	Thickness (ft)	Grade (% eU_3O_8)[a]	Lithology
5	3	2.0	0.007	(unknown)
	9.5	1.5	0.007	(unknown)
	20.5	1.5	0.006	(unknown)
	24.5	2.0	0.008	(unknown)
	34.5	1.0	0.005	(unknown)
	39.0	4.0	0.006	Sandstone, pumiceous, pebbly; coarse grained.
	51.0	0.5	0.004	(unknown)
	62.5	1.0	0.004	(unknown)
	70.5	1.5	0.004	(unknown)
	81.5	2.0	0.008	(unknown)
	119.0	0.5	0.005	(unknown)
	136.5	1.0	0.005	(unknown)
	157.5	1.0	0.006	(unknown)
	216.5	1.0	0.005	(unknown)
6	49.0	1.5	0.004	(unknown)
	55.0	4.0	0.006	(unknown)
	65.5	3.0	0.005	(unknown)
	86.0	2.0	0.011	(unknown)
	94.5	1.5	0.008	(unknown)
	98.0	1.0	0.007	(unknown)
	174.5	1.5	0.011	(unknown)
	180.0	3.0	0.006	(unknown)
	188.0	1.0	0.012	(unknown)
	233.0	9.0	0.005	(unknown)
	261.0	21.5	0.004	Volcanic ash
8	259.0	1.5	0.010	(unknown)
	270.0	2.5	0.005	(unknown)
	591.0	1.0	0.007	(unknown)
	599.0	2.0	0.007	(unknown)
	607.0	1.5	0.004	(unknown)
	612.5	1.0	0.014	(unknown)
	615.0	1.5	0.008	(unknown)
	623.0	1.5	0.008	(unknown)
	625.5	1.0	0.005	(unknown)
	639.5	1.0	0.005	(unknown)
	645.5	1.0	0.004	(unknown)
	651.0	3.0	0.006	(unknown)

[a] Determined from gamma-ray log using adaptation of method presented by Scott and others (1960, p. 21-25). Grade considered anomalous if greater than or equal to 0.004 percent.

TABLE I-4. SUBSURFACE RADIOACTIVITY ANOMALIES IN PART OF THE UPPER RUBY RIVER BASIN

	Radioactivity Anomaly			
Hole number	Depth to top (ft)	Thickness (ft)	Grade (% eU_3O_8)[a]	Lithology
16	48	1.5	0.004	Clay cemented gravel
20	63	5.0	0.004	(unknown)
	79	6.0	0.005	(unknown)
21	265	2.0	0.010	Silty sandstone
23	19	1.0	0.004	Volcanic ash

[a] Determined from gamma-ray log using adaptation of method presented by Scott and others (1960, p. 21-25). Grade considered anomalous if greater than or equal to 0.004 percent.

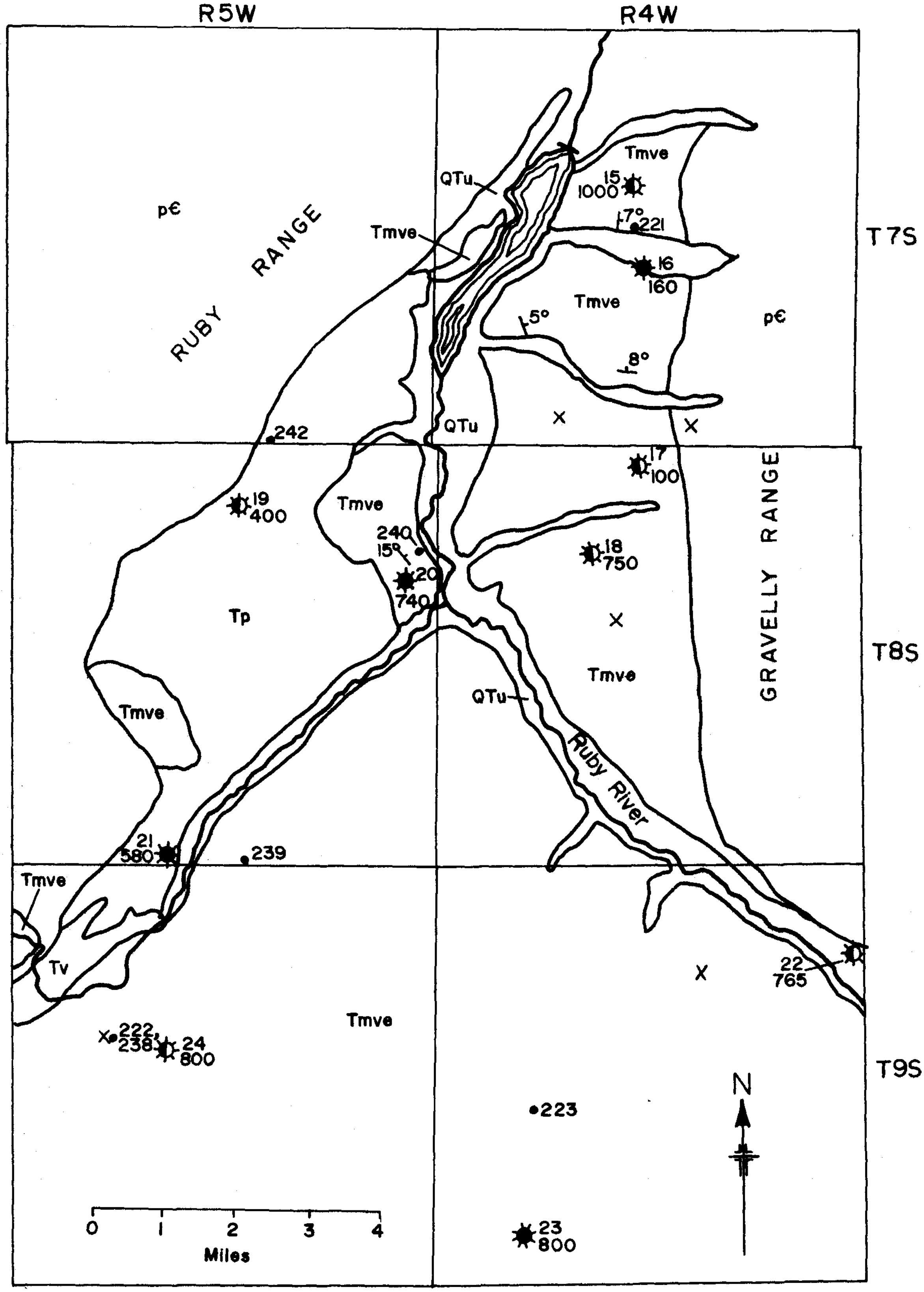


Figure I-3. Location map of uranium exploration drill holes, surface radioactivity anomalies, and study localities of part of the Upper Ruby River basin. (See Pl. 2 for location of map area.)

EXPLANATION FOR FIGURE I-3

Post-Early Pliocene - Recent	QTu	Alluvium and hot springs deposits
	Tv	Volcanics
Early Miocene - Early Pliocene	Tmve	"Madison Valley equivalent"
Oligocene - Early Miocene	Tp	Passamari Formation
Precambrian	P€	Pre-Beltian gneisses and schists

—— Contact

50 Strike and dip of beds

X Surface radioactivity anomaly

● 312 Study locality, with locality number (App. A).

10 / 275 Uranium exploration drill hole, no anomalies on gamma-ray log. Upper number is hole number, lower is total depth in feet (Table I-1).

11 / 535 Uranium exploration drill hole, one or more anomalies on gamma-ray log (Table I-4). Upper number is hole number, lower is total depth in feet (Table I-1).

APPENDIX J

URANIUM OCCURRENCES DESCRIBED IN PUBLISHED AND OPEN-FILED REPORTS

APPENDIX J. URANIUM OCCURRENCES DESCRIBED IN PUBLISHED AND OPEN-FILED REPORTS

Identification no.	Location	Reference	Number of occurrences
1	Secs. 17, 18, 20, 21, 28, and 34, T. 9 N., R. 1 E.; Broadwater County	Becraft, 1958, p. 152-159, Pl. 3	21
2	On east-west section line between secs. 1 and 2 and secs. 11 and 12, T. 2 N., R. 1 W.; Jefferson County	Becraft, 1958, p. 162-163, Fig. 19	2
3	Secs. 2 and 10, T. 2 N., R. 1 W.; Jefferson County[a]	Pruitt, 1955b	1
4	Sec. 22, T. 2 N., R. 5 W.; Jefferson County	Moen and Hetland, 1953	1
5	Secs. 1, 2, and 3, T. 3 N., R. 1 W.; Jefferson County	Becraft, 1958, p. 161-162, Fig. 18	4
6	Sec. 31, T. 3 N., R. 1 W.; Jefferson County	Jarrard, 1955	1
7	Secs. 28 and 29, T. 11 N., R. 2 W.; Lewis and Clark County	Becraft, 1958, p. 160-161, Fig. 17	4
8	Sec. 17, T. 9 S., R. 5 W.; Madison County	Jarrard and VanAlstine, 1954	1
9	Sec. 18, T. 10 S., R. 13 W.; Beaverhead County[a]	Pruitt, 1955a	1

[a] Location provided by authors of the present report; location given in cited reference is in correct.

APPENDIX K

RESULTS OF URANIUM DISEQUILIBRIUM STUDIES

APPENDIX K

RESULTS OF URANIUM DISEQUILIBRIUM STUDIES

The equivalent uranium (eU) and chemical uranium (cU) values from 37 selected rock samples were plotted on Figure K-1 in order to ascertain which of the samples, if any, were in disequilibrium. For the purposes of this report, a sample is considered to be in disequilibrium if it plots clearly outside of the 99 percent confidence envelope of analytical precision. A sample is considered to be in possible disequilibrium if it plots on the edge or barely outside of the 99 percent confidence envelope. Table K-1 shows the distribution of the selected rock samples by basin and by degree of disequilibrium.

Of the 37 samples 6 are in disequilibrium and 7 are in possible disequilibrium. All 6 samples in disequilibrium and 3 samples in possible disequilibrium exhibit eU values that are higher than their respective cU values. Of these 9 samples 5 are from the western part of the Three Forks basin, and 1 each of the remaining 4 samples is from the Townsend, Helena, Upper Ruby River, and Horse Prairie basins, respectively.

The other 4 samples, of the 7 that are in possible disequilibrium, exhibit eU values which are lower than their respective cU values. Of these 4 samples 3 are from the western part of the Three Forks basin and 1 is from the Clarkston basin.

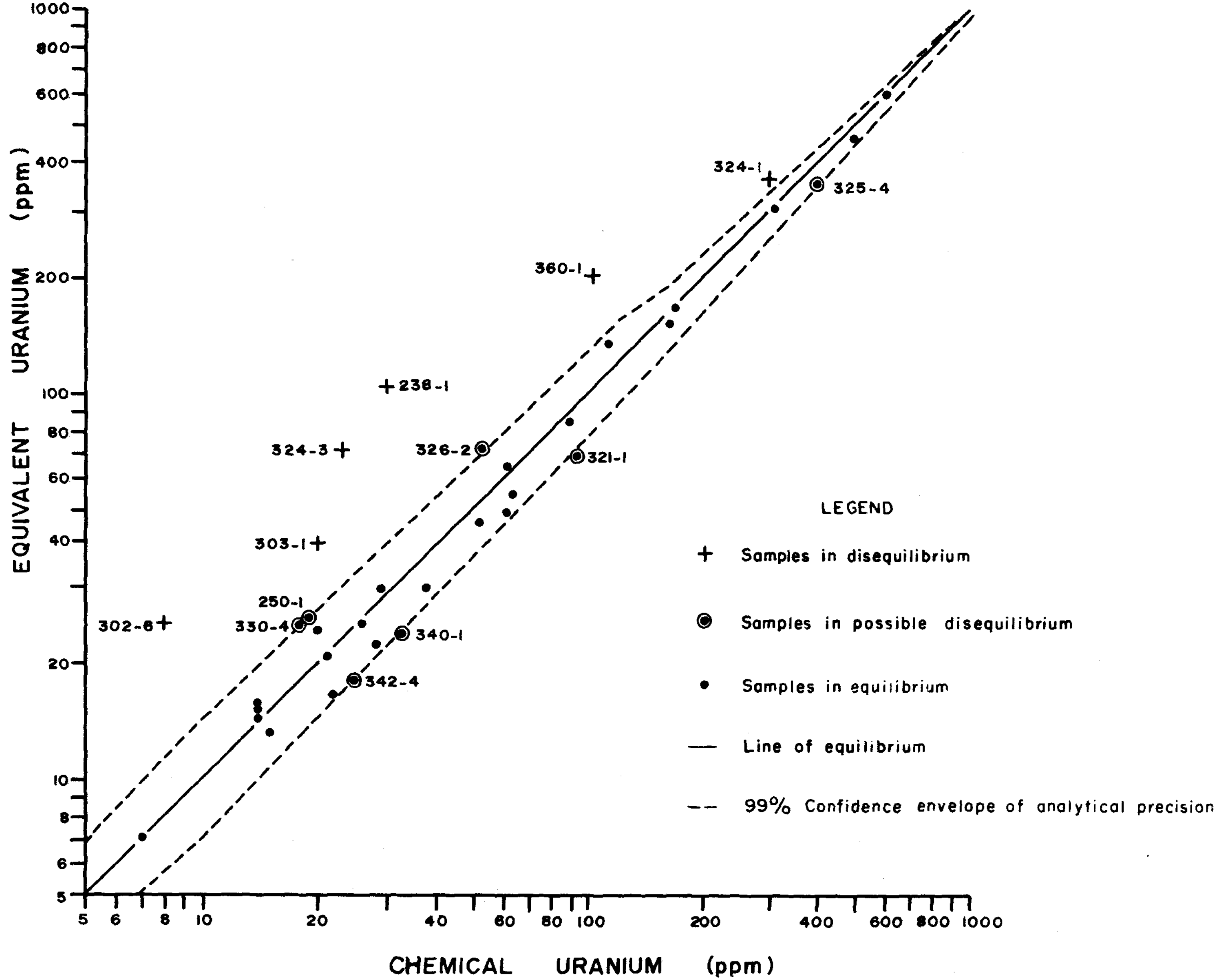


Figure K-1. Plot of chemical uranium versus equivalent uranium for selected samples from southwestern Montana.

TABLE K-1. DISTRIBUTION OF SAMPLES ANALYZED FOR URANIUM DISEQUILIBRIUM, BY AREA AND DEGREE OF DISEQUILIBRIUM

Basin(s)	Number analyzed	Number in disequilibrium	Number in possible disequilibrium
Three Forks basin, western part	20	4	4
Three Forks basin, eastern part	1	0	0
Townsend and Clarkston basins	4	0	2
Helena basin	4	1	0
Smith River basin	2	0	0
Jefferson, Beaverhead, and Lower Ruby River basins	1	0	0
Upper Ruby River basin	2	1	0
Grasshopper Creek, Horse Prairie, Medicine Lodge Creek, and Big Sheep Creek basins	1	0	1
Big Hole River basin	2	0	0
Total number	37	6	7

EXPLANATION

(Stippled pattern indicates unit investigated in this study)

Quaternary

Qs — Quaternary sedimentary rocks undifferentiated

Unconsolidated to consolidated gravel, sand, silt, clay, and limestone. Includes some late Tertiary sedimentary rocks.

Tertiary

Miocene and Pliocene

Tpm — Miocene and Pliocene sedimentary rocks undifferentiated

Poorly to well consolidated siltstone, sandstone, conglomerate, claystone, and limestone with minor tuff, bentonite and lignite. Fine grained sedimentary rocks are predominantly tuffaceous

UNCONFORMITY

Eocene and Oligocene

Toe — Eocene and Oligocene sedimentary rocks undifferentiated

Poorly to well consolidated claystone, siltstone, and sandstone with minor tuff, conglomerate, limestone, and lignite. Fine grained sedimentary rocks are predominantly bentonitic.

Paleocene

UNCONFORMITY

Ts — Tertiary sedimentary rocks undifferentiated

Poorly to well consolidated siltstone, claystone, sandstone, and conglomerate with minor tuff, lignite, and limestone. Fine grained sedimentary rocks are predominantly tuffaceous or bentonitic. Includes some rocks of Quaternary age and possibly some rocks of Upper Cretaceous age.

Tv — Tertiary volcanic rocks undifferentiated

Latite, quartz latite, and andesite. Includes some rhyolite and basalt. May include some pre-Tertiary volcanic rocks. (Ross and others, 1955)

Ti — Tertiary intrusive rocks

Alkalic syenite, leucite-rich, and other alkalic varieties. Includes some quartz diorite, monzonite, and similar rock. (Ross and others, 1955)

TKb — Boulder batholith and broadly related stocks

Quartz monzonite, includes diorite, aplite, and other rocks. (Ross and others, 1955)

Cretaceous throuth Younger Precambrian

TKc — Beaverhead Formation

Well consolidated conglomerate with minor sandstone, siltstone, and limestone. Includes Sphinx Conglomerate.

Kp€u — Cretaceous through Upper Precambrian rocks undifferentiated

Sedimentary, igneous, and metamorphic rocks. Includes Belt Supergroup.

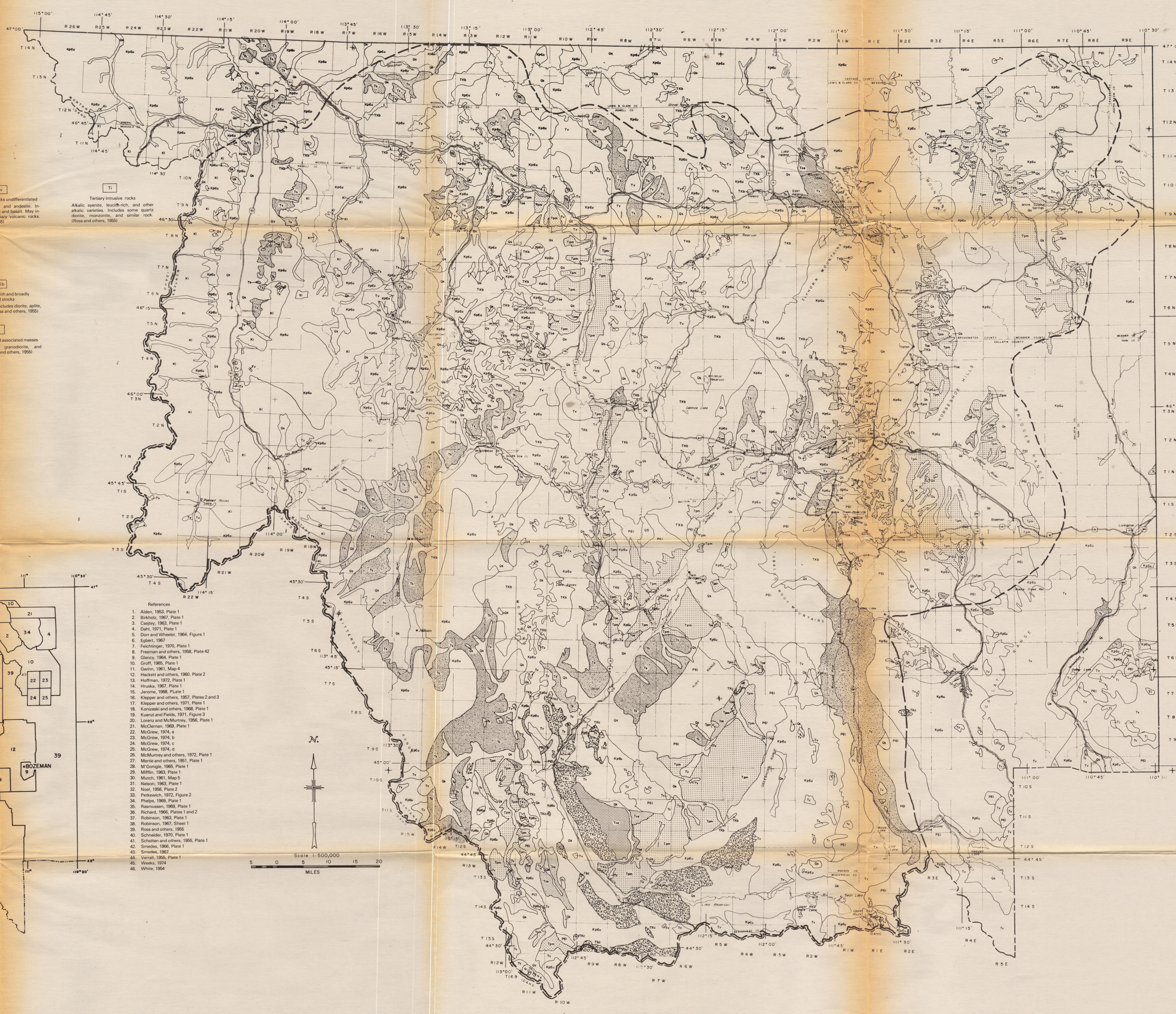
Ki — Idaho batholith and associated masses

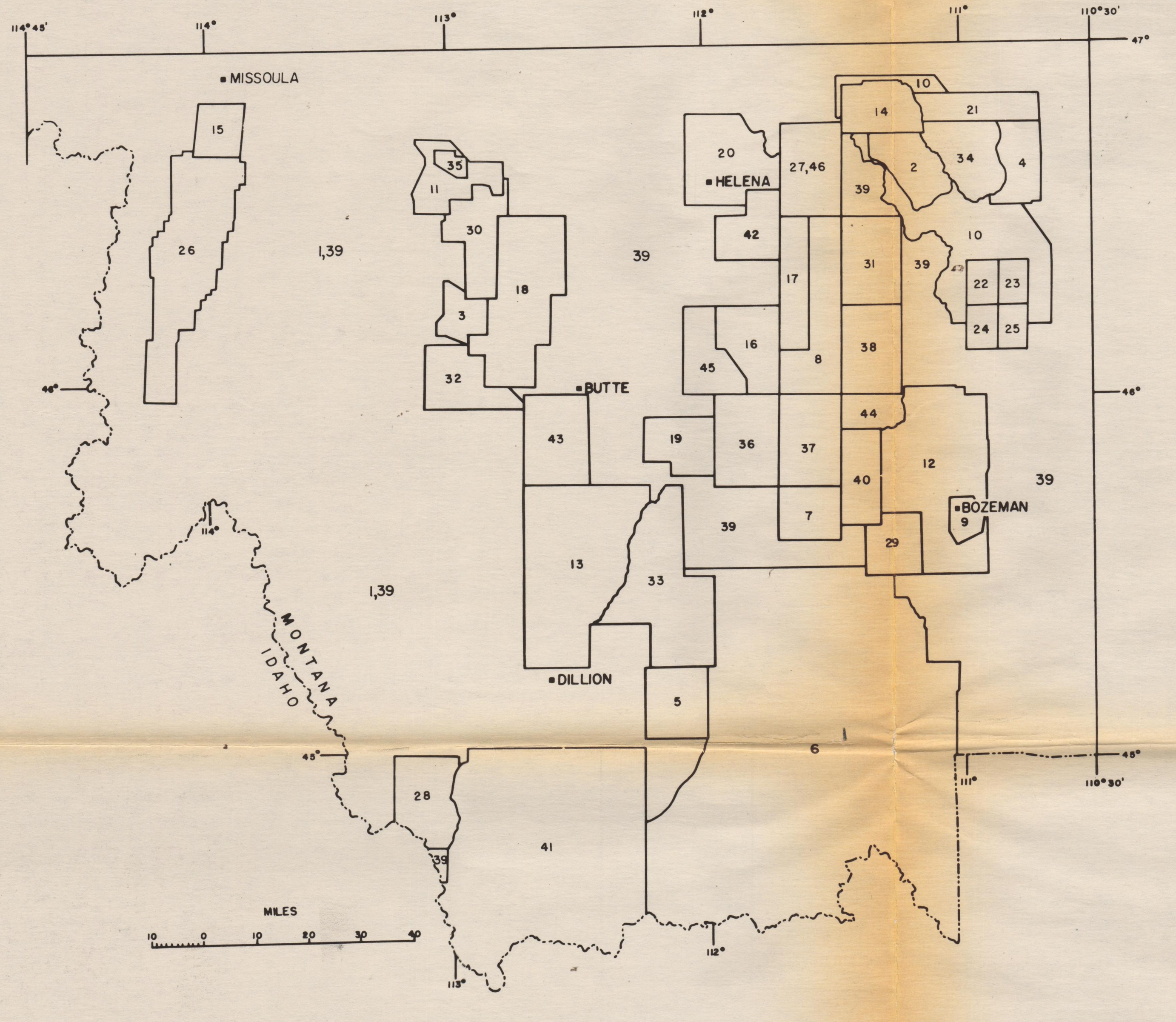
Quartz monzonite, granodiorite, and similar rocks. (Ross and others, 1955)

Older Precambrian

P€l — Older Precambrian gneiss, schist, and related rocks

Gneiss, schist, and related rocks. Includes marble and quartzite.





MAP SHOWING SOURCES OF GEOLOGIC DATA

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14. Hruska, 1967, Plate 1
15. Jerome, 1968, PLate 1
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19. Kuenzi and Fields, 1971, Figure 3
20. Lorenz and McMurtrey, 1956, Plate 1
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29. Mifflin, 1963, Plate 1
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31. Nelson, 1963, Plate 1
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33. Petkewich, 1972, Figure 2
34. Phelps, 1969, Plate 1
35. Rasmussen, 1969, Plate 1
36. Richard, 1966, Plates 1 and 2
37. Robinson, 1963, Plate 1
38. Robinson, 1967, Sheet 1
39. Ross and others, 1955
40. Schneider, 1970, Plate 1
41. Scholten and others, 1955, Plate 1
42. Smedes, 1966, Plate 1
43. Smedes, 1967
44. Verrall, 1955, Plate 1
45. Weeks, 1974
46. White, 1954

PLATE I. GENERALIZED GEOLOGIC MAP OF SOUTHWESTERN MONTANA.

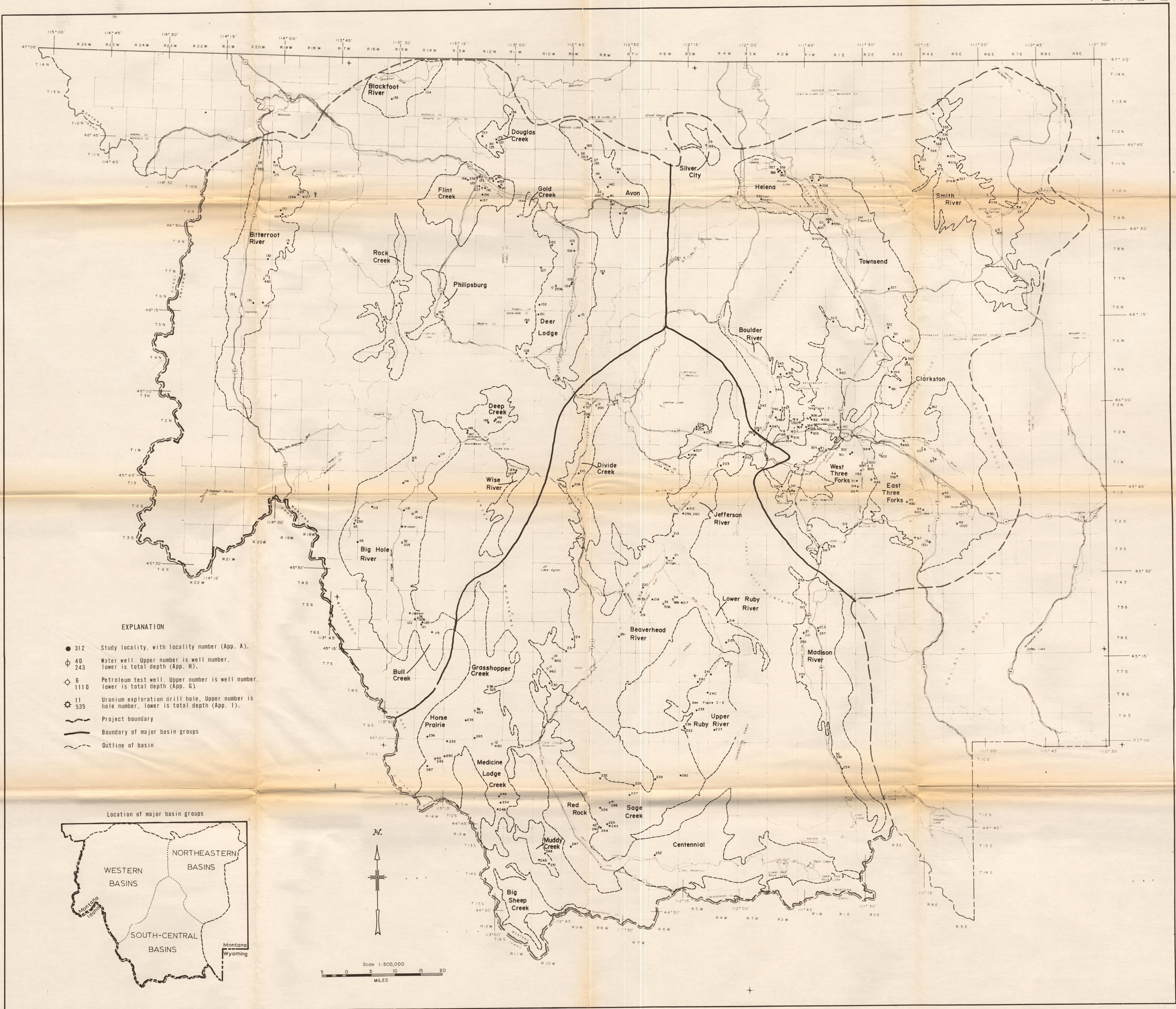

PLATE 2. OUTLINES OF BASINS AND LOCATION OF STUDY LOCALITIES, WELLS, AND DRILL HOLES, SOUTHWESTERN MONTANA.