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A Petrographic Analysis of the Basal Member of the Kootenai Formation

Frank E. Coupal

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A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

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ILLUSTRATIONS

ABSTRACT

The basal member of the Kootenai formation in southwestern Montana is typically a fine- to medium-grained "salt and pepper" sandstone and chert-pebble conglomerate. The section between Delpine, Montana, and Melrose, Montana, generally thickens and markedly coarsens to the West.

A petrographic analysis of the top and base of the member shows locally abundant occurrences of epidote, fluorite, iron oxide, titanite, and less abundant occurrences of tourmaline, zircon, biotite, hornblende, pyrite, leucoxene, and other unindentified minerals. The distribution of heavy minerals fails to show any uniformity, either among the sections or between the top and bottom of the sections. The results fail to show a common source direction for the sediments of these six sections.

INTRODUCTION

Purpose. This report is the result of a petrographic analysis of the upper and lower portions of the basal member of the Kootenai formation, known as the Lower Cut Bank Sand. This member was chosen for study not only because of its importance as an oil reservoir, but because it represents the initial environment of deposition at the start of the Cretaceous Period. The member is also very widespread and its resistance to weathering causes it to form conspicuous outcrops. Thus its exposures offer excellent opportunities for an analysis such as this.

Problem. The following analysis represents a determination of the heavy minerals found in the basal sandstone of the Kootenai formation. The problems is to determine the concentrations of these minerals in each of the 6 sections that were sampled.

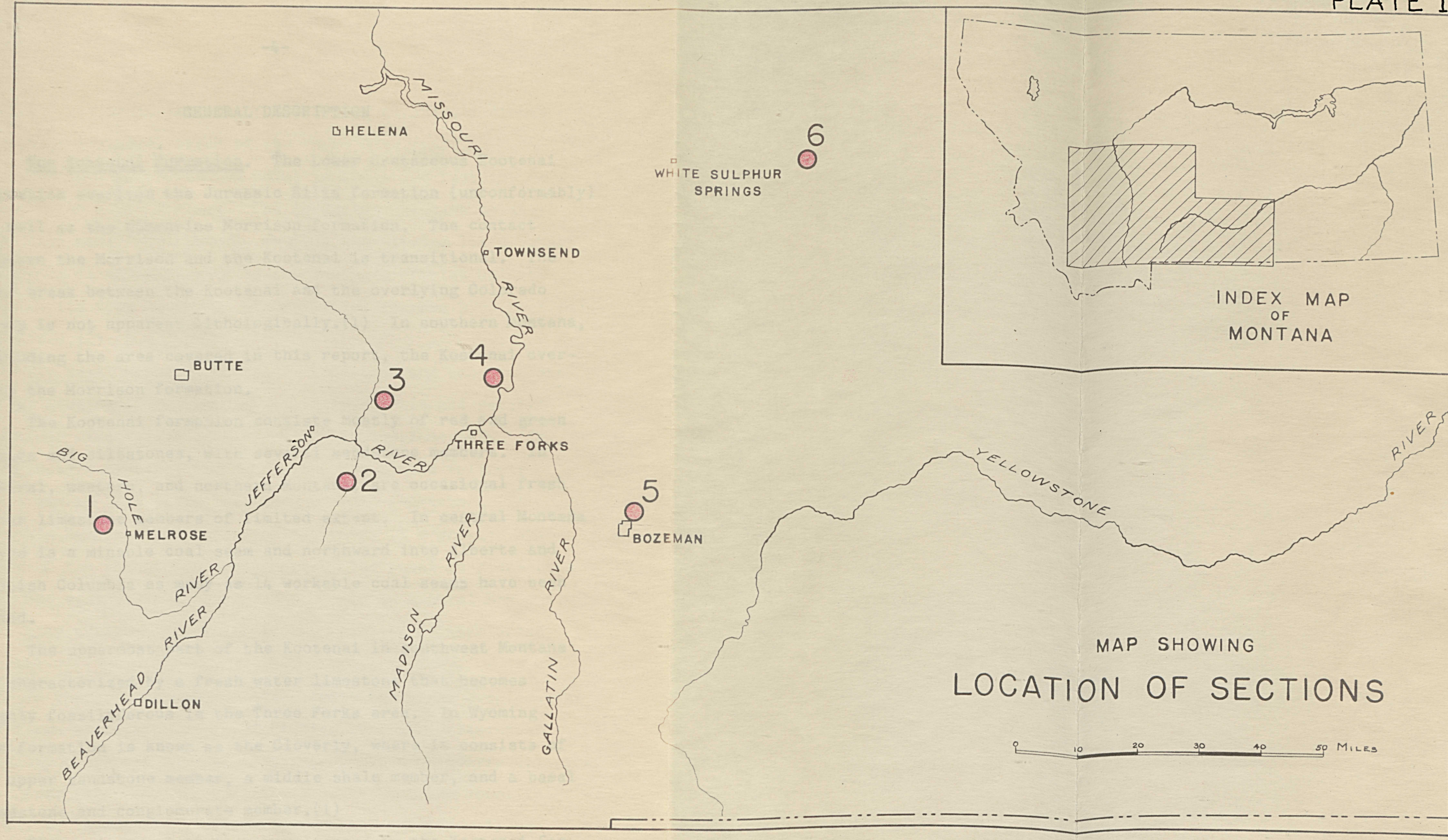
Areal Description. Six localities were sampled and their distribution forms a rough line from Melrose to Delpine (see map following page 3), a distance of about 125 miles. This region is semi-arid and in general, possesses a light cover of vegetation. Most of the outcrops are well exposed in moderately rugged terrain.

Acknowledgments. The author wishes to thank Professor McGlashan for the use of the facilities of the Mineral Dressing Department, where the samples were crushed and sized. Gratitude is also extended to Professor Robertson and Dr.

Blake for their guidance and criticisms.

Previous Work. In 1941 Dan Feray and Raymond B. Gallant, of the School of Mines, conducted a sedimentary and petrographic analysis of the entire formation, with special emphasis on the sands of the Cut Bank Oil Field of Montana. Their work involved the study of the sedimentary and lithologic characteristics of the Kootenai sediments by careful dissociation of the rocks with chemical methods. They separated the heavy minerals with acetylene tetrabromide (sp. gr. 2.96), identified them, and noted their place in the section.

PLATE I



HELENA
MISSOURI
RIVER
WHITE SULPHUR
SPRINGS
6
TOWNSEND
BUTTE
3
4
THREE FORKS
BIG
HOLE
JEFFERSON
RIVER
2
1
MELROSE
RIVER
5
BOZEMAN
MADISON
RIVER
GALLATIN
RIVER
BEAVERHEAD
RIVER
DILLON
YELLOWSTONE
RIVER
INDEX MAP
OF
MONTANA
MAP SHOWING
LOCATION OF SECTIONS
0
10
20
30
40
50 MILES

GENERAL DESCRIPTION

The Kootenai Formation. The Lower Cretaceous Kootenai formation overlies the Jurassic Ellis formation (unconformably) as well as the nonmarine Morrison formation. The contact between the Morrison and the Kootenai is transitional. The time break between the Kootenai and the overlying Colorado Group is not apparent lithologically.(1) In southern Montana, including the area covered in this report, the Kootenai overlies the Morrison formation.

The Kootenai formation consists mostly of red and green shales and siltstones, with several sandstone members. In central, western, and northern Montana, are occasional fresh water limestone members of limited extent. In central Montana there is a minable coal seam and northward into Alberta and British Columbia as many as 14 workable coal seams have been found.

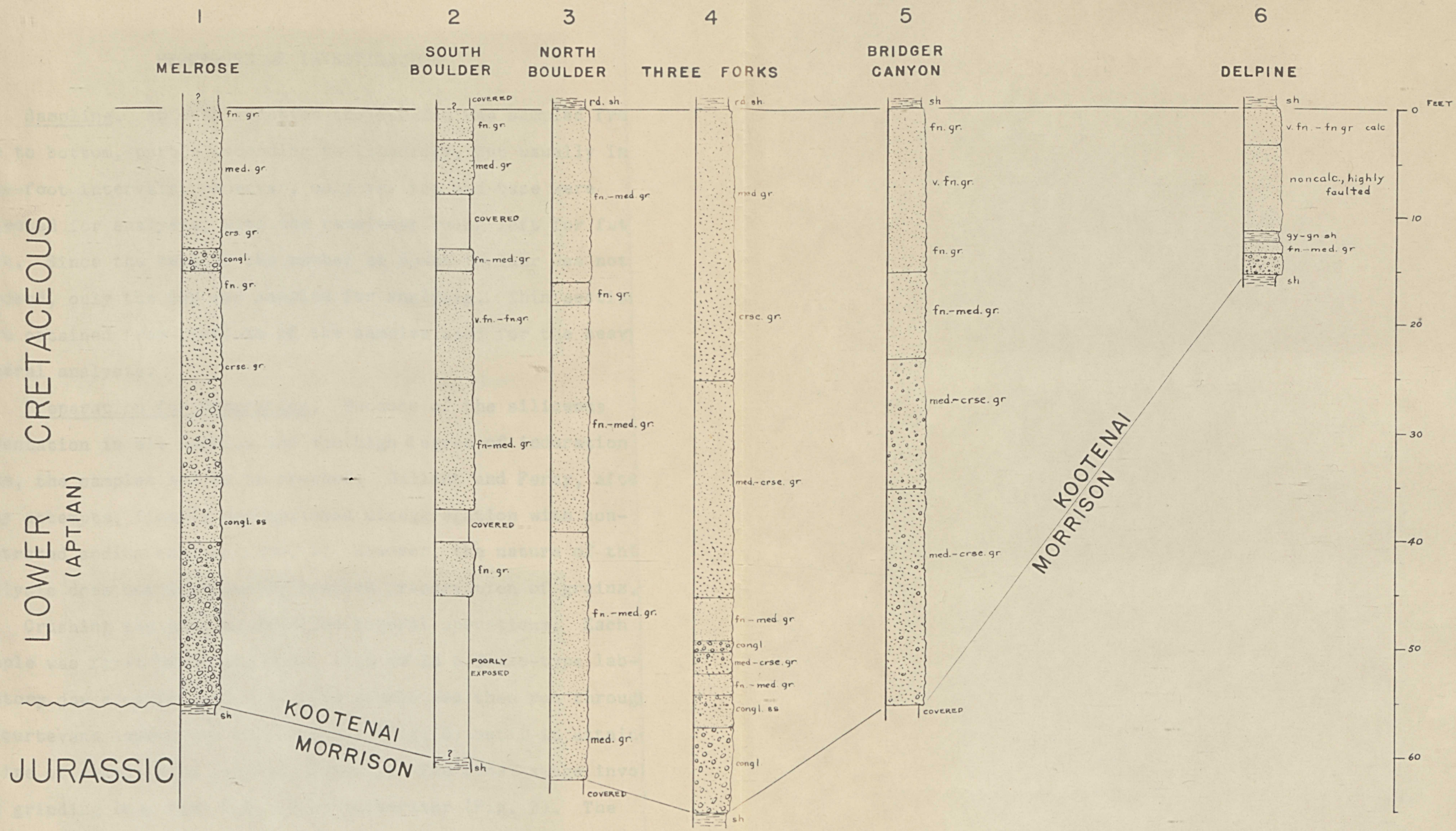
The uppermost part of the Kootenai in southwest Montana is characterized by a fresh water limestone that becomes highly fossiliferous in the Three Forks area. In Wyoming the formation is known as the Cloverly, where it consists of an upper sandstone member, a middle shale member, and a basal sandstone and conglomerate member.(1)

The environment that is represented by the Kootenai formation is essentially that of deposition of sediments into a large fresh water lake. The lenticular nature of many of the members in the West point to a river and stream type of deposition. The broad pattern of the coarse clastics indicate a northwest-southeast trend of the shore line.(1)

The Kootenai formation thins to about 250 feet in the vicinity of Saco, Montana. The formation thickens to about 1500 feet near Phillipsburg, Montana and attains its greatest thickness in southern Alberta and southern British Columbia. Here in its type locality, the formation reaches 9750 feet in thickness.(2)

The Basal Member. The basal sandstone and conglomerate of the Kootenai formation is typically a "salt and pepper" sandstone with interbedded chert-pebble conglomerates. In northwestern Montana, the sandstones are almost entirely chert and so lose their "salt and pepper" character. In southern Montana, and into Wyoming, there is a greater abundance of the lighter colored cherts. The basal conglomerates thin out eastward and pinch out entirely in central Montana. (1) They attain a thickness of 1000 feet in British Columbia.(2)

In the area studied in this report the basal conglomerate was found at both ends of the section, but the westernmost locality possesses a much greater proportion of coarse clastics. The chert fragments are dominantly black, but tan chert is abundant. A detailed description of each section will be found in the appendix and a stratigraphic cross section of the basal member follows page 5.



STRATIGRAPHIC CROSS SECTION
OF THE
BASAL MEMBER OF THE KOOTENAI FORMATION

HORIZONTAL SCALE: 1" = 20 MILES

PROCEDURE OF INVESTIGATION

Sampling. At each location the section was sampled from top to bottom, partly according to lithology, but usually in five-foot intervals. However, only the top and base were selected for analysis, with the remainder being left for future work. Since the base of the member at South Boulder was not exposed, only the top was sampled for analysis. Thin sections were obtained from portions of the samples used for the heavy mineral analysis.

Preparation for Separation. Because of the siliceous cementation in all samples and the high degree of induration of some, the samples had to be crushed. Gallant and Feray, after many attempts, finally accomplished disaggregation with concentrated sodium thio-sulfate.(1) However, the nature of this analysis does not necessarily require preservation of grains.

Crushing the samples involved several operations. Each sample was first broken to about -1.5 cm in a Blake-type laboratory jaw crusher (Fig. 1). The sample was then run through a sturtevant laboratory roll crusher (Fig. 2) until it attained a size of about -2 mm (approx. 8-mesh). The final stage involved grinding in a type U.S. Braun pulverizer (Fig. 3). The ground sample was screened on the tyler Ro-tap (Fig. 4) and the sized, or 100/150-mesh product was then ready for separation.

Separation of Heavy Minerals. Prior to separation, each

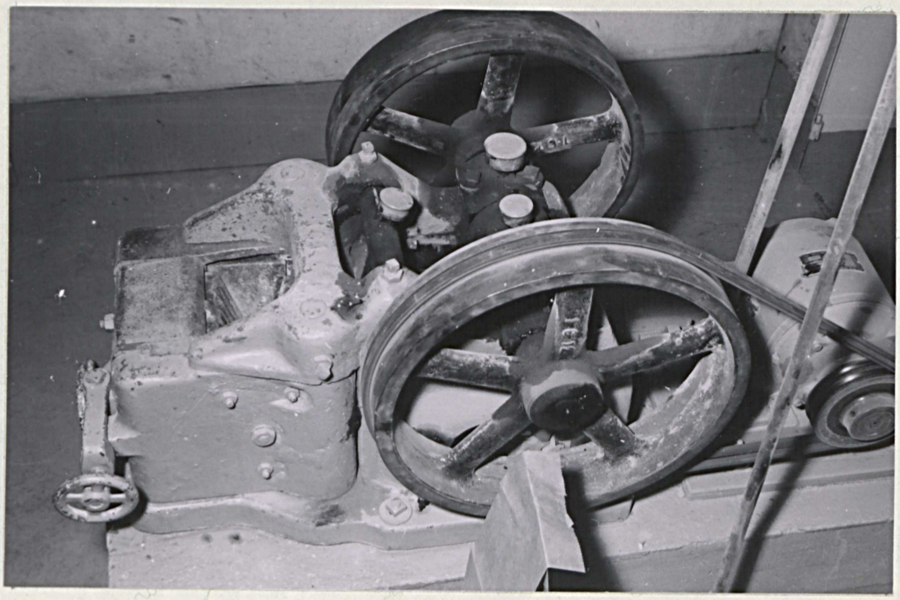


Fig. 1 Blake-type laboratory jaw crusher

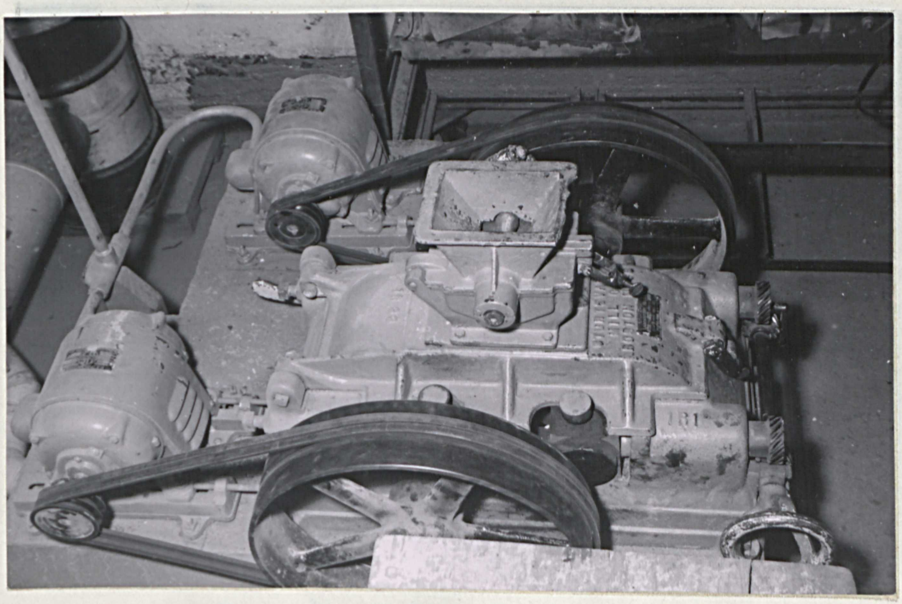


Fig. 2 Sturtevant laboratory roll crusher

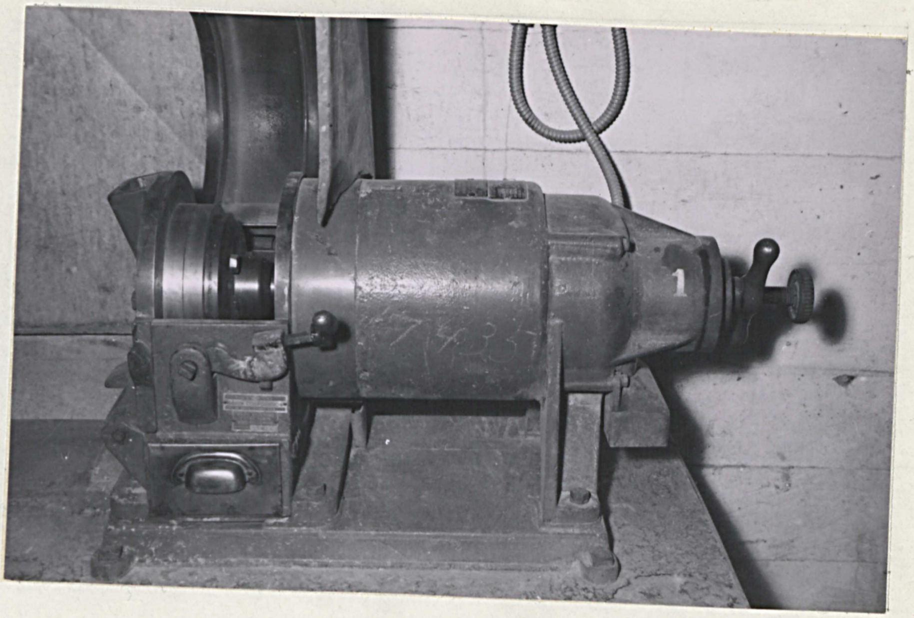


Fig. 3 Type U. A. Braun Pulverizer

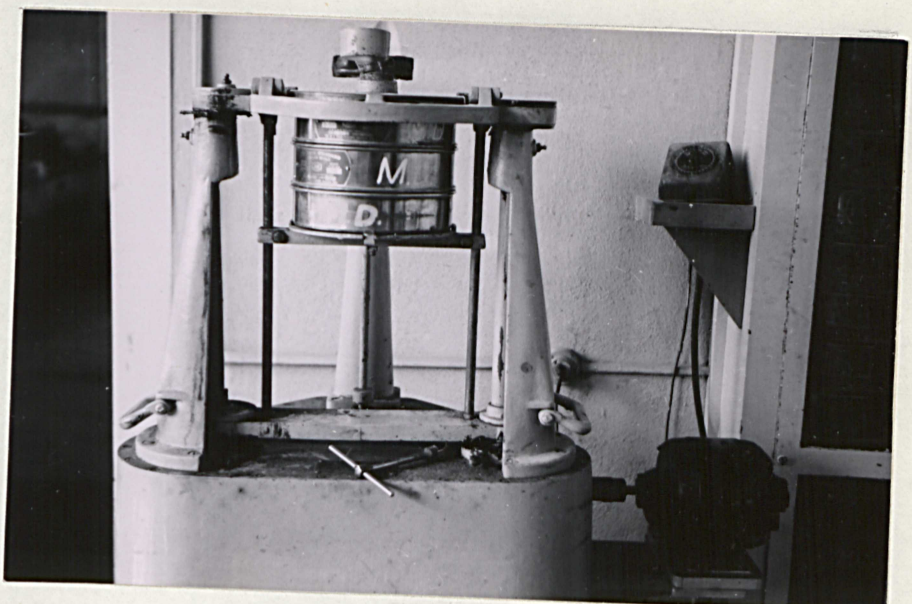


Fig. 4 Tyler Ro-tap

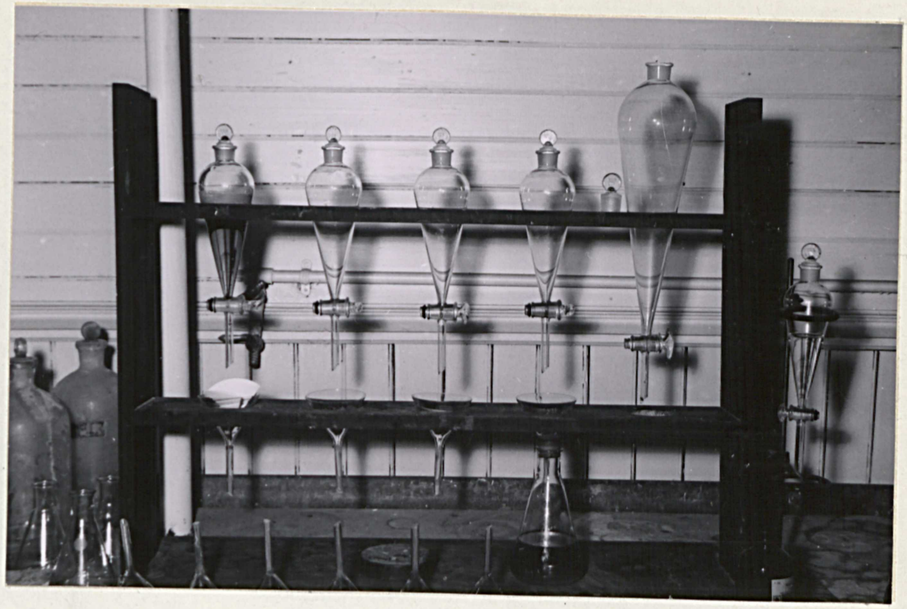


Fig. 5 Separatory Apparatus

sample was cleaned by successive washings and decantations in water. Partial coagulation resulted, which was found to be caused by the adhesion or cementation of grains to the pulverizer chips as they rusted upon drying. The laborious task of dissociating these particles was not attempted at this point. After the samples were cleaned and dried, they were weighed and separated with the separatory apparatus shown in Fig. 5. Bromoform (sp. gr. 2.88) was the separating medium. The dried heavy fraction was examined under the binocular microscope and it was immediately evident that much of the coagulated material had been brought down. However, the particles were easily broken apart by rubbing with the finger.

At this point the magnetic separation was made by repeated passes with a small, powerful horseshoe magnet. The magnetic portion was examined and was found to contain mostly pulverizer chips or flakes. Other particles were present in varying amounts, but no attempt was made to separate the magnetic minerals from the pulverizer flakes.

The samples were again run through the separatory process previously described in order to remove the light minerals brought down by the metal flakes. These products were dried and weighed. The results of the weighings and the percentage of the sample they represent are shown in Table I.

Analysis of Nonmagnetic Heavy Minerals. Several hundred grains of each sample were mounted in Canada balsam between a glass slide and a cover glass. Each slide was examined to determine what heavy minerals were present as well as the relative concentration of each mineral. The results of these analyses are shown beneath the detailed description of each section.

TABLE I

DISTRIBUTION OF NONMAGNETIC HEAVY MINERALS

Location		Sample Weight(gms.)	Nonmagnetic Heavy Minerals	
			Weight	Percentage
Melrose	Top	263.76	0.695	2.63x10
	Base	225.80	0.865	3.83x10
South Boulder	Top	128.29	0.045	0.35x10
North Boulder	Top	124.68	0.080	0.64x10
	Base	322.85	0.225	0.70x10
Three Forks	Top	29.64	0.025	0.86x10
	Base	263.93	0.210	0.80x10
Bridger Canyon	Top	105.62	0.495	4.69x10
	Base	53.26	0.030	0.56x10
Delpine	Top	224.57	0.585	2.60x10
	Base	284.83	0.225	0.79x10

DESCRIPTIONS OF THE HEAVY MINERALS OF THE BASAL KOOTENAI

Since the samples were crushed to 100/150 mesh, very few of the mineral grains survived without being broken. Therefore, all descriptions apply to fractured grains, except where noted otherwise. Photographs of the more common heavy minerals are shown on Plate III. Except where otherwise stated, all minerals possess indices of refraction that exceed that of balsam.

Fluorite. The fluorite grains are colorless with occasional tinges of purple, and are angular with prominent octahedral cleavage. The relief is moderate and the index of refraction is less than that of balsam. The distinguishing features of the fluorite are its isotropic character, perfect cleavage, and occasional purple tints.

Titanite. The titanite, or sphene grains are pale yellow to deep yellow and are very irregular in shape with rare suggestions of cleavage. The relief is very high and the birefringence is extreme. The interference colors are rarely discernible and because of intense reflection, only a white flash appears as the stage is rotated under crossed nicols. Extinction is often incomplete and interference figures are difficult to obtain; however, they suggest a biaxially positive mineral. The titanite grains are distinguished by their pale yellow color, high birefringence, and high relief.

Epidote. The grains identified as epidote vary in color from colorless to white to pale green. They are difficult to identify on the basis of their shape, because they vary from a finely granular fragment to a partially transluscent grain. Occasionally coarse crystals can be found attached to quartz grains (Plate III, D.). Often the grains show partial alteration to iron oxide. The relief is high and the birefringence is strong (several orders). Because of the granular appearance of the epidote, a good interference figure was not obtained. Extinction is parallel. The distinguishing feature of the epidote here observed is the pale green granular form it possesses.

Biotite. The biotite grains are pale tan to brown in color, pleochroic, and are flat with irregular outlines. The grains show moderate relief. Birefringence is masked by the color of the biotite, and the irregularity of the grains makes it necessary to estimate parallel extinction. The optic axis figure indicates a biaxially negative mineral. Biotite is characterized chiefly by its pleochrism, parallel extinction, and uniformly pale brown color (indicating its tabular shape).

Tourmaline. The tourmaline is pleochroic and varies from a pale tan and pale green to a very dark brown and blue. The grains are distinctly irregular and show conchoidal fracture in reflected light. Relief is fairly high. The birefringence is high, but the colors are partially or wholly subdued by the color of the mineral. Tourmaline gives a distinct uniaxially negative optic axis figure. The distinguishing features of the mineral are its strong pleochrism and its lack of any cleavage.

Zircon. The zircon grains are colorless and are one of the few minerals that were relatively unaffected by the crushing process. Several of the grains are well rounded, while others retain their prismatic shape (Plate III, A.). The fractured grains show no evidence of cleavage. Zircon shows very high relief and the birefringence is strong (several orders of color). Extinction is parallel. Interference figures show that the mineral is uniaxial and positive. Zircon is distinguished by its prismatic shape, high relief, and especially by its rounded shape in this analysis.

Hornblende. The grains identified as hornblende are deep to almost opaque and exhibit strong pleochrism. The grains show perfect cleavage and high relief. The color of the grains conceals the interference colors. Extinction occurs at 15-25^{o} and the interference figure shows the mineral to be biaxially negative. Hornblende is distinguished by its good cleavage, strong pleochrism, and its extinction angle.

Iron oxide. The iron oxide grains are reddish-yellow to dark brown and earthy. They are often found adhered to grains of quartz and other light minerals.

Leucoxene. The leucoxene grains are dull white to pale tan in color, earthy, and irregular in shape. They represent an alteration product of ilmenite.

Pyrite. The pyrite fragments are pale yellow and occasionally tarnished. They possess a metallic luster and exhibit conchoidal fracturing. Some is found imbedded in other grains.

Carbonates. The carbonate minerals are rare in the samples of this analysis so they were not identified further. These minerals are distinguished by their perfect rhombohedral cleavage and their extreme birefringence.

Unknown mineral A. This mineral is colorless to a translucent white. It varies from irregular to grains that show marked cleavage. The smaller cleavage angle is about 72°. Relief is high and the birefringence is moderate (first order blue and green). Extinction appears to be symmetrical in those grains that show cleavage. The mineral is uniaxial and positive.

Unknown mineral B. This mineral is bright green and irregular in shape. Its relief is very high and it possesses strong birefringence (several orders). Because it transmits so little light, an optic axis figure can not be obtained.

Unknown mineral C. This mineral is colorless and irregular in shape. Relief is very low and the index of refraction is slightly less than that of balsam. The mineral is isotropic.

Unknown mineral D. This opaque mineral is dark grey and slightly translucent at the edges. It is earthy to compact in texture.

Unknown mineral E. This mineral is bright yellow to dull orange in color and is earthy to granular.

Unknown mineral F. This abundant mineral is purple to black and compact when not broken. It breaks conchoidally showing a vitreous luster. These grains may include chromite, allanite, or other nearly opaque minerals.

Unknown mineral G. This mineral is deep red and compact. Many of the broken grains show a vitreous luster with little or no evidence of cleavage. Some of the grains are definitely not isotropic but their deep red color prevents further determination of their optical properties. These grains may include such minerals as garnet, spinel, rutile, and staurolite.

Unknown mineral H. This mineral, which occurs in only one sample, is silvery in color and possesses a metallic luster. It has an amorphous texture.

CONCLUSION

The occurrences and concentrations of the nonmagnetic heavy minerals are listed under the detailed description of each section. The nonopaque minerals include fluorite, epidote, titanite, tourmaline, zircon, biotite, hornblende, and a few unidentified minerals. The opaque minerals include iron oxide, leucoxene, pyrite, and several unidentified minerals. The unknown minerals are described in the previous section.

The distribution of the minerals is shown on Plate VI. The nonopaque minerals of the Melrose section are conspicuous by their absence. Their scarcity is probably due to the fact that they simply represent a much smaller proportion of the sediments. The Delpine section possesses a relatively high concentration of nonopaque minerals. The unusually high concentration of fluorite at Delpine suggests postdepositional mineralization, but at the same time, the section is relatively very low in iron oxides. Although the rock is now highly faulted and almost friable, the photomicrograph (Plate IV, J.) showing the fracture reveals split quartz grains. The section was at one time much more highly indurated than at present. Subsequent deformation and alteration may have been accompanied by some mineralization.

A high concentration of titanite occurs at the top of North Boulder, and the top of South Boulder contains the only significant quantity of tourmaline. Epidote is found in relatively large quantities at the tops of North Boulder and Delpine. The latter section also contains the only important occurrence of biotite. Zircon is found in a relatively high concentration at the top of South Boulder. The iron oxide content generally is much higher in the basal portions of the sections.

The distribution of the heavy minerals fails to show any uniformity with respect to sections, and no consistent relationship exists between tops and bottoms of sections. The irregular pattern of mineral occurrences fails to show any evidence of a common source direction of the sediments comprising the six sections.

APPENDIX

DETAILED DESCRIPTIONS OF SECTIONS

MELROSE

Location: Sec. 29, T. 2 S., R. 9 W.

Description. The Melrose section is well exposed about 4 miles west of Melrose, Montana, in an area of intense folding. The member contains several small quartz veins. The beds here strike N. 25° W. and dip 65° E. and are the east flank of a sharp asymmetrical fold.

The top of the member grades gradually into a fine-grained greenish-grey quartzite. The top 13 feet is dark, brownish-grey medium-grained slightly cherty quartzite, coarsening downward, and underlain by 2 feet of coarse chert-pebble conglomerate. The sequence is repeated in 10 feet of fine- to medium-grained "salt and pepper" quartzite and 9 feet of coarse chert-pebble conglomerate. The sequence is repeated for a third time in 6 feet of medium- to coarse-grained "salt and pepper" quartzite which coarsens into 15 feet of brownish-grey quartzite and chert-pebble conglomerate. The entire member is about 55 feet thick, 26 feet of which is conglomerate. The pebbles of the conglomerates are occasionally as much as 3 inches in diameter. The entire section is highly indurated and noncalcareous. Below is a condensation of the analysis of the Melrose section.

SAMPLE DATA

	Top	Base
Wt. of sample	263.76 gms.	225.80 gms.
Wt. of nonmagnetic heavy minerals.	0.695 gms.	0.865 gms.

DISTRIBUTION OF HEAVY MINERALS
(per cent of 200 grains)

Nonopaque Minerals

TOP		BASE	
1. Epidote	1.5%	1. Fluorite.	tr.
2. Tourmaline.	tr.	2. Biotite	tr.
Total	1.5%	3. Epidote	tr.
		Total	1.5%

Opaque Minerals

TOP		BASE	
1. Unknown D.	82.5%	1. Iron oxide.	44.5%
2. Unknown E.	9.5	2. Unknown E	43.0
3. Iron oxide	4.0	3. Unknown D	6.0
4. Leucoxene.	2.0	4. Unknown G	3.5
5. Pyrite	tr.	5. Leucoxene	1.5
Total	98.0%	Total	98.5%

SOUTH BOULDER

Location: NW¼ Sec. 10, T. 1 S., R. 3 W.

<u>Description</u>. The section at South Boulder is fairly well exposed and is located on the west side of the road 6 miles south of Jefferson Island. The formations here strike N. 65° W. and dip about 40° N. The upper portion of the basal Kootenai is well exposed, but much of the remainder is covered.

The top 3 feet is light-grey to tan fine-grained slightly cherty sandstone, followed by 5 feet of medium-grained slightly argillaceous "salt and pepper" sandstone. Below 5 feet of covered formation is 2 feet of fine- to medium-grained "salt and pepper" sandstone. Underlying this is about 10 feet of very fine- to fine-grained "salt and pepper" sandstone, which contains about 2 feet of moderately calcareous sandstone. The next 12 feet is fine- to medium-grained somewhat argillaceous "salt and pepper" sandstone. After 3 feet of covered formation, 5 feet of fine-grained slightly cherty argillaceous sandstone was exposed, followed by about 20 feet of poorly exposed formation. The base is covered and no evidence of a basal conglomerate was found in the area. Since the lower contact could not be found, the member is estimated to be from 60 to 65 feet thick. Except for the small known calcereous zone, the remainder of the sampled section is non-calcareous. Below is a condensation of the analysis of the South Boulder section.

SAMPLE DATA

	Top	Base
Wt. of sample	128.29 gms.	
Wt. of nonmagnetic heavy minerals	0.045 gms.	None

DISTRIBUTION OF HEAVY MINERALS
(per cent of 200 grains)

TOP		BASE
Nonopaque Minerals		
1. Zircon.	11.0%	Not sampled
2. Fluorite.	7.0	
3. Tourmaline.	6.5	
4. Titanite.	tr.	
5. Unknown B	tr.	
6. Hornblende.	tr.	
Total	25.0%	
Opaque Minerals		
1. Leucoxene	24.0%	
2. Iron oxide.	24.5	
3. Unknown E	14.5	
4. Unknown D	5.5	
5. Unknown F	4.5	
6. Unknown G	3.0	
7. Pyrite	tr.	
Total	73.0%	

NORTH BOULDER

Location: W½ Sec. 3, T. 2 N., R. 2 E.

Description. This section is about 8 miles east of Whitehall. Here the formations strike due North and dip 60° E. The basal member here is generally well indurated, in part cross-bedded, and wholly noncalcareous.

Specifically, the section is relatively uniform. It consists of light grey to light tan, fine- to medium-grained "salt and pepper" sandstone, slightly coarser toward the base. No evidence of a basal conglomerate was found. The section here is 62 feet thick. On the following page is a condensation of the analysis of the North Boulder section.

SAMPLE DATA

	Top	Base
Wt. of sample	124.68 gms.	322.85 gms.
Wt. of nonmagnetic heavy minerals.	0.080 gms.	0.225 gms.

DISTRIBUTION OF HEAVY MINERALS
(per cent of 200 grains)

TOP | BASE

Nonopaque Minerals

TOP		BASE	
1. Epidote	47.0%	1. Fluorite	tr.
2. Titanite.	23.5		
3. Carbonates.	3.5		
4. Hornblende.	3.0		
5. Fluorite.	2.0		
6. Unknown B	1.0		
7. Zircon.	1.0		
8. Tourmaline.	tr.		
Total	81.0%		

Opaque Minerals

TOP		BASE	
1. Pyrite.	7.5%	1. Iron oxide.	78.0%
2. Unknown F	7.5	2. Unknown D	11.0
3. Leucoxene	2.0	3. Leucoxene	10.0
4. Iron oxides	1.0	Total	99.0%
5. Unknown G	tr.		
Total	18.0%		

THREE FORKS

Location: NW$\frac{1}{4}$ Sec. 15, T. 3 N., R. 2 E.

Description. The section near Three Forks is in the range of hills 7 miles north of the town, in the area of the Lombard Overthrust. The basal member here strikes N. 25° E., and is slightly overturned. The beds dip 95° W. and form the east limb of an isoclinical fold. The section sampled is intensely slickensided, moderately indurated, in part well bedded, and noncalcareous.

The top 45 feet is a grey to tan medium- to coarse-grained "salt and pepper" sandstone, coarsening downward. This overlies 4 feet of light brown fine- to medium-grained sandstone, also coarsening downward to 1 foot of chert-pebble conglomerate that appears to move across the general bedding planes. The conglomerate is underlain by 2 feet of medium- to coarse-grained conglomeratic "salt and pepper" sandstone and 2 feet of reddish-grey fine- to medium-grained sandstone. Below this is 3 feet of chert-pebble conglomerate grading downward to a medium-grained "salt and pepper" sandstone, which contains a thin (few inches) lens of fine-grained laminated sandstone. The bottom 8 feet is a chert-pebble conglomerate. The total thickness is 65 feet. Below is a condensation of the analysis of the Three Forks section.

SAMPLE DATA

	Top	Base
Wt. of sample	29.64 gms.	263.93 gms.
Wt. of nonmagnetic heavy minerals.	0.025 gms.	0.210 gms.

DISTRIBUTION OF HEAVY MINERALS
(per cent of 200 grains)

Nonopaque Minerals

TOP		BASE	
1. Epidote	17.0%	1. Titanite.	1.5%
2. Titanite.	3.5	2. Fluorite.	1.0
3. Unknown A	3.0	3. Unknown A	1.0
4. Fluorite.	2.0	4. Unknown C	tr.
5. Carbonates.	tr.	Total	3.5%
6. Hornblende.	tr.		
Total	25.5%		

Opaque Minerals

TOP		BASE	
1. Iron oxide.	36.5%	1. Iron oxide	71.0%
2. Unknown G	16.5	2. Leucoxene.	13.5
3. Leucoxene	12.0	3. Pyrite.	5.0
4. Unknown F	3.0	4. Unknown D.	2.5
5. Pyrite.	2.5	5. Unknown G.	2.0
6. Unknown H	1.0	6. Unknown F.	tr.
Total	71.5%	Total	94.0%

BRIDGER CANYON

Location: Sec. 28, T. 1 S., R. 6 E.

Description. The Bridger Canyon section is about 6 miles northeast of Bozeman, Montana. The area here is highly faulted, but the basal member of the Kootenai appears to be relatively undisturbed. The formation strikes N. 10 E. and dips 140 W. In general the member is moderately indurated and massive with occasional bedding. The entire section is noncalcareous. The top 15 feet consists of light grey to light tan fine-grained silty sandstone. The next 8 feet is light grey fine- to medium-grained cross-bedded "salt and pepper" sandstone. Underlying this is 12 feet of poorly sorted chert-pebble conglomerate. The lower 20 feet is a light grey to greyish-brown medium- to coarse-grained "salt and pepper" sandstone, which is conglomerate in part. The section at Bridger Canyon is 55 feet thick. On the following page is a condensation of the analysis of the Bridger Canyon section.

SAMPLE DATA

	Top	Base
Wt. of sample	105.62 gms.	53.26 gms.
Wt. of nonmagnetic heavy minerals.	0.495 gms.	0.030 gms.

DISTRIBUTION OF HEAVY MINERALS
(per cent of 200 grains)

Nonopaque Minerals

TOP		BASE	
1. Titanite	1.5%	1. Unknown A	78.5%
2. Epidote.	1.0	2. Carbonates.	2.0
3. Hornblende	tr.	3. Fluorite.	2.0
4. Fluorite	tr.	4. Zircon.	tr.
Total	2.5%	5. Hornblende.	tr.
		Total	82.5%

Opaque Minerals

TOP		BASE	
1. Iron oxide.	91.5%	1. Leucoxene	10.0%
2. Leucoxene..	4.0	2. Iron oxide.	3.0
3. Unknown G	1.0	3. Unknown F	2.5
4. Unknown F	tr.	4. Unknown D	1.0
Total	96.5%	Total	16.5%

DELPINE

Location: Sec. 14, T. 9 N., R. 10 E.

Description. The Kootenai outcrop at Delpine is about 27 miles east of White Sulfur Springs, about 300 yards north of Highway 6. The formation strikes N. 20 W., and dips 115 W. Here the basal member is highly faulted, which may account for its small thickness. The section is generally only moderately indurated and almost friable in part. The member is somewhat argillaceous and thoroughly coursed with tiny clay filled fractures. Several well-defined, though thin, fault zones are evident, especially near the base.

The top 11 feet is a light grey very fine- to fine-grained "salt and pepper" sandstone, slightly calcareous in part and coarsening at the base. The next foot is a soft greenish-grey shale, and below this is one foot of fine- to medium-grained slightly conglomeratic "salt and pepper" sandstone. The basal 2 feet consists of a conglomeratic sandstone coarsening to a poorly sorted chert-pebble conglomerate. The entire section is only 15 feet thick. Below is a condensation of the analysis of the Delpine section.

SAMPLE DATA

Wt. of sample	224.57 gms.	284.83 gms.
Wt. of nonmagnetic heavy minerals	0.585 gms.	0.225 gms.

DISTRIBUTION OF HEAVY MINERALS
(per cent of 200 grains)

Nonopaque Minerals

TOP		BASE	
1. Epidote	64.0%	1. Fluorite	39.0%
2. Fluorite	8.5	2. Epidote	10.0
3. Titanite	5.0	3. Biotite	8.5
4. Carbonates	2.0	4. Titanite	6.5
5. Biotite	1.0	5. Hornblende	3.0
6. Hornblende	tr.		
Total	80.5%	Total	67.0%

Opaque Minerals

TOP		BASE	
1. Unknown F	5.5%	1. Unknown F	14.0%
2. Unknown D	4.5	2. Iron oxide	10.0
3. Leucoxene	3.5	3. Leucoxene	4.5
4. Iron oxide	2.5	4. Pyrite	3.5
5. Pyrite	1.5	5 Unknown G	tr.
6. Unknown G	tr.	6. Unknown D	tr.
Total	17.5%	Total	32.0%

		MELROSE	SOUTH BOULDER	NORTH BOULDER	THREE FORKS	BRIDGER CANYON	DELPINE
TOURMALINE	Top	tr.	6.5%	tr.	-	-	-
	Base	-	*	-	-	-	-
ZIRCON	Top	-	11.0%	1.0%	-	-	-
	Base	-	*	-	-	tr.	-
EPIDOTE	Top	1.5%	-	47.0%	17.0%	1.0%	64.0%
	Base	tr.	*	-	-	-	10.0%
TITANITE	Top	-	tr.	23.5%	3.5%	1.5%	5.0%
	Base	-	*	-	1.5%	-	6.5%
LEUCOXENE	Top	2.0%	24.5%	2.0%	12.0%	4.0%	3.5%
	Base	1.5%	*	10.0%	13.5%	10.0%	4.5%
FLUORITE	Top	-	7.0%	2.0%	2.0%	tr.	8.5%
	Base	tr.	*	tr.	1.0%	2.0%	39.0%
BIOTITE	Top	-	-	-	-	-	1.0%
	Base	tr.	*	-	-	-	8.5%
HORNBLENDE	Top	-	tr.	3.0%	tr.	tr.	tr.
	Base	-	*	-	-	tr.	3.0%
PYRITE	Top	tr.	tr.	7.5%	2.5%	-	1.5%
	Base	-	*	-	5.0%	-	3.5%
IRON OXIDE	Top	4.0%	21.5%	1.0%	36.5%	91.5%	2.5%
	Base	44.5%	*	78.0%	71.0%	3.0%	10.0%

* Not sampled

TABLE II. DISTRIBUTION OF THE MORE ABUNDANT HEAVY MINERALS

PLATE III

Heavy Minerals of the Basal Kootenai
(Plane polarized light)

A. Zircon(z) from the top of the South Boulder section. (x100)

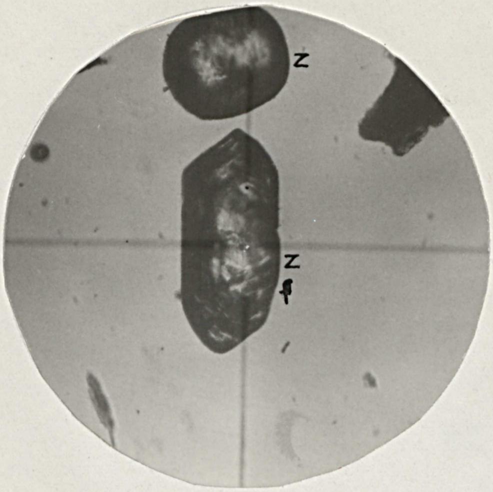
B. Unknown A. from the base of the Bridger Canyon section. (x100)

C. Epidote(e) and fluorite(f) from the top of the Delpine section. (x100)

D. Epidote on quartz(e) and titanite(t) from the top of the North Boulder section. (x100)

E. Hornblende(h) and biotite(b) from the base of the Delpine section. (x100)

F. Fluorite(f) from the base of the Delpine section. (x100)



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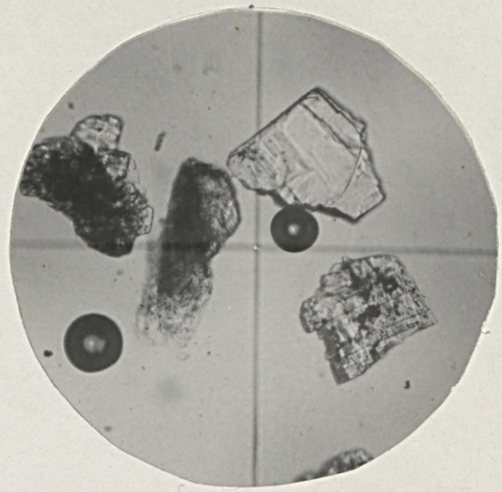

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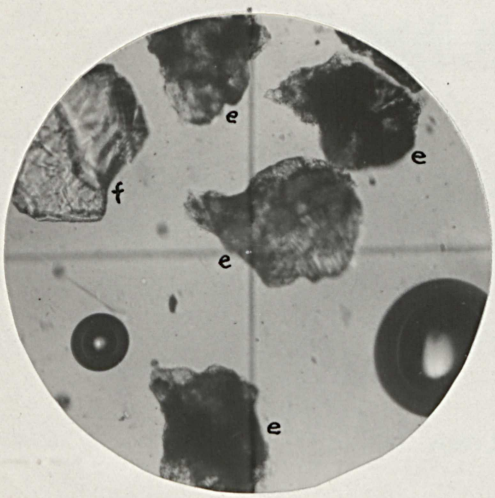

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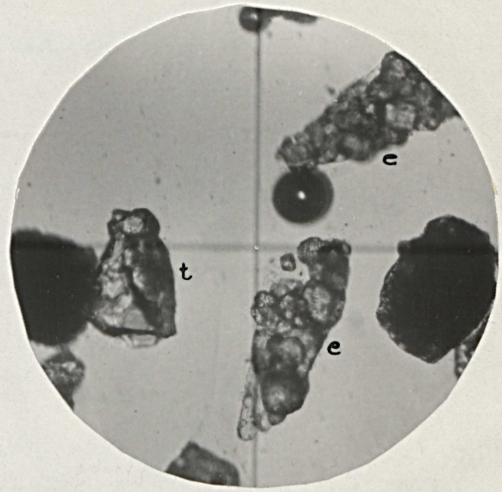

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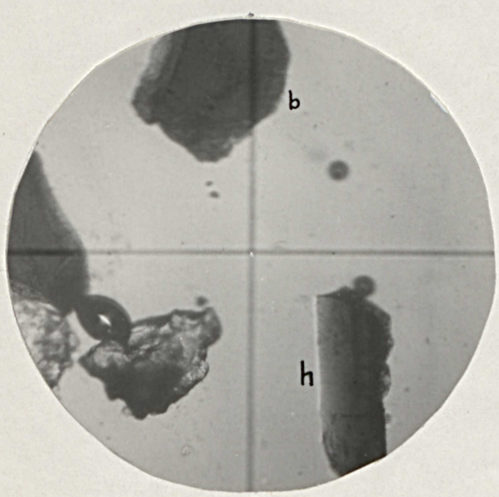

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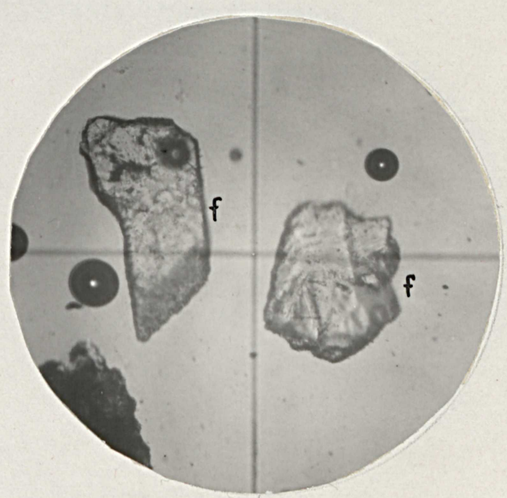


F.

Heavy Minerals of the Basal Kootenai

PLATE IV

Photomicrographs of the Basal Kootenai
(Crossed-Nicols)

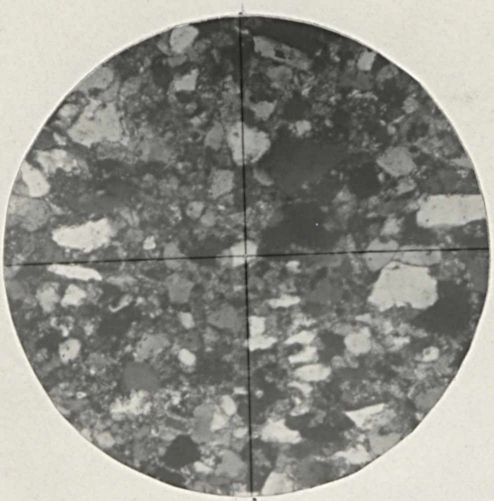
A. Top of the Melrose section- fine-grained quartzite. (x65)

B. Base of the Melrose section- coarse chert-and-quartzite-pebble conglomerate. (x17.5)

C. Top of the South Boulder section- fine-grained slightly cherty sandstone. (x65)

D. Top of the North Boulder section- fine- to medium-grained cherty sandstone. (x65)

E. Base of the North Boulder section- medium-grained "salt and pepper" sandstone. (x65)



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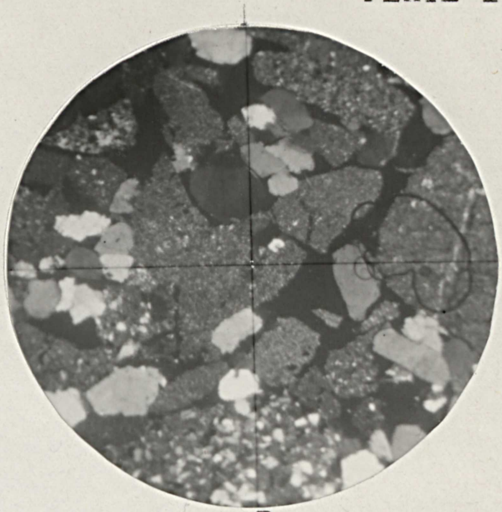

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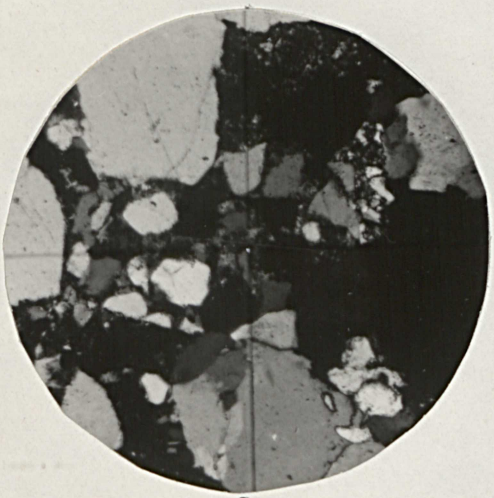
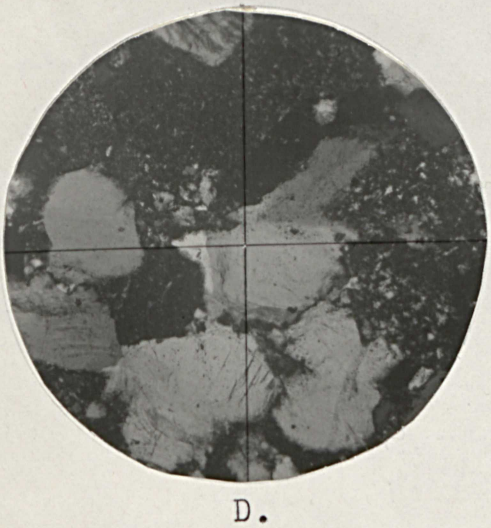


C.

No basal
sample taken



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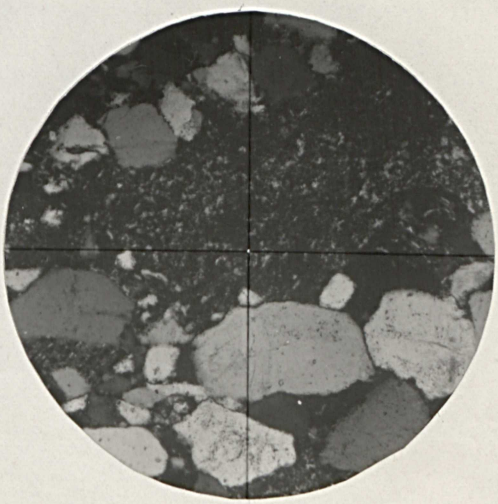


E.

Photomicrographs of the Basal Kootenai

PLATE V

Photomicrographs of the Basal Kootenai
(Crossed-Nicols)

F. Top of the Three Forks section- fine- to medium-grained "salt and pepper" sandstone. (x65)

G. Base of the Three Forks section- chert-pebble conglomerate. (x17.5)

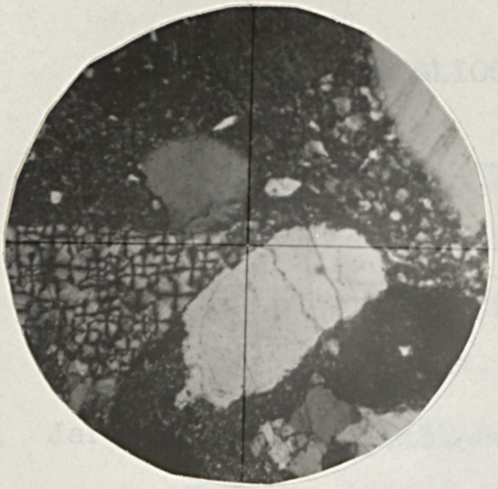
H. Top of the Bridger Canyon section- fine-grained slightly cherty sandstone. (x65)

I. Base of the Bridger Canyon section- medium- to coarse-grained "salt and pepper" sandstone. (x65)

J. Top of the Delpine section- very fine-grained sandstone showing fracture cutting quartz grain. (x65)

K. Base of the Delpine section- chert-pebble conglomerate. (x17.5)

PLATE V



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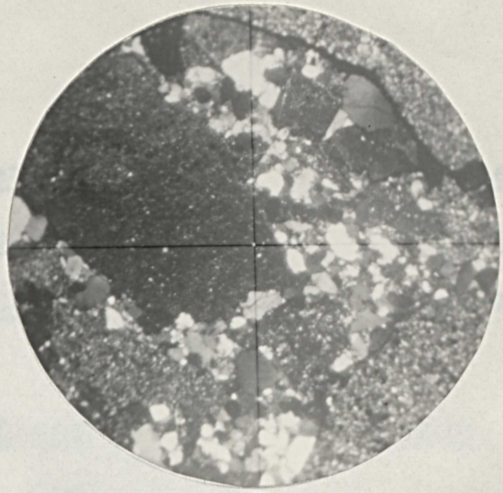

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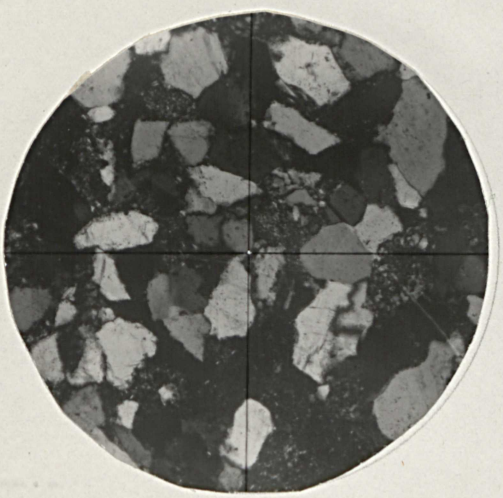

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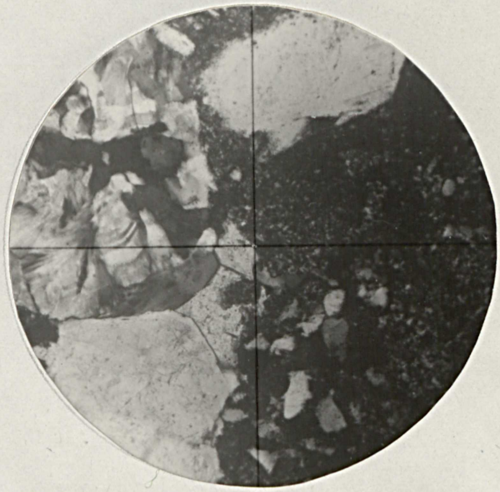
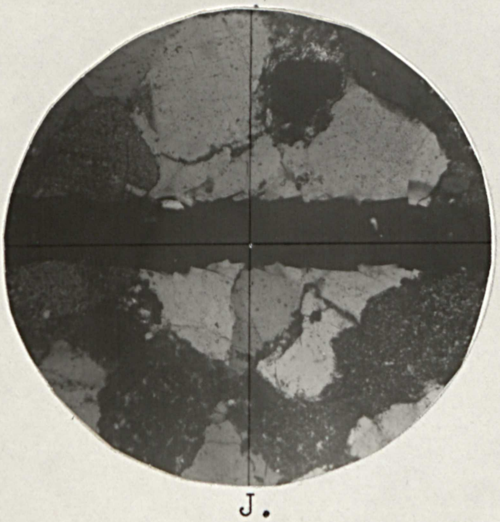


I.



J.

K.

Photomicrographs of the Basal Kootenai

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