GEOLOGY OF THE LOWER CRETACEOUS CUTBANK CONGLOMERATE IN NORTHWEST MONTANA

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

Alton V. Gallagher

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GEOLOGY OF THE LOWER CRETACEOUS CUTBANK CONGLOMERATE IN NORTHWEST MONTANA

By

Alton V. Gallagher

A THESIS

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GEOLOGY OF THE LOWER CRETACEOUS

CUTBANK CONGLOMERATE

IN NORTHWEST MONTANA

Alton V. Gallagher

ABSTRACT

The continental Cutbank conglomerate is the base of the lower member of the Cretaceous Kootenai formation in northwest Montana. It overlies unconformably strata of the marine Jurassic Ellis Group. It is overlain by the Cutbank Sand, a salt and pepper sandstone, which also forms the matrix and interbeds in the conglomerate. It is highly lenticular and frequently cross-bedded. The conglomerate consists of black and tan chert and white and black to purplish-black quartzite pebbles with minor amounts of shale and fossil fragments.

An isopach map of the Cutbank phase and a structure contour map on the base of the Cutbank phase were constructed using information from twenty-two wells in the area.

Samples were collected for laboratory study in the Disturbed Belt and in the Sawtooth Range west to the Lewis Overthrust Fault.

The conclusions which have been reached as a result of this investigation are summarized below:

(1) The isopach map in conjunction with lithologic evidence strongly suggest that the Cutbank phase in the Disturbed Belt is a deltaic-type deposit.

(2) Fossil and shale fragments in the conglomerate indicate that at least part of the sediments forming the conglomerate are later than Precambrian.

(3) The mineral suite found in the conglomerate is as follows: pyrite, limonite, hematite, siderite, leucoxene, tourmaline, barite, zircon, cassiterite, magnetite, calcite, kaolinite, chert and quartz. Underlined minerals are detrital.

(4) Oriented samples are highly suggestive of a southwesterly source area for the gravels forming the conglomerate and this suggests that the material may have come from the area of the Coeur D'Alene Mountains.

CONTENTS

FIGURES

INTRODUCTION

The Cutbank phase is the base of the lower member of the Cretaceous Kootenai formation in northwest Montana. The Cutbank phase is a continental deposit and unconformably overlies the marine Jurassic Ellis Group. The basal part of the Cutbank phase is a chert-quartz conglomerate and will be the primary concern of this investigation. This research was directed toward learning the origin of this conglomerate. The area covered in this study is shown in Figure 1.

The Cutbank Sand from the Cut Bank and Kevin areas was first recognized and described by Bartram (1935). Feray and Sloss (1948), made an examination of thin sections of core samples in the Cut Bank Oil Field. Cobban (1955), has also done extensive work on the Mesozoic beds in this same area.

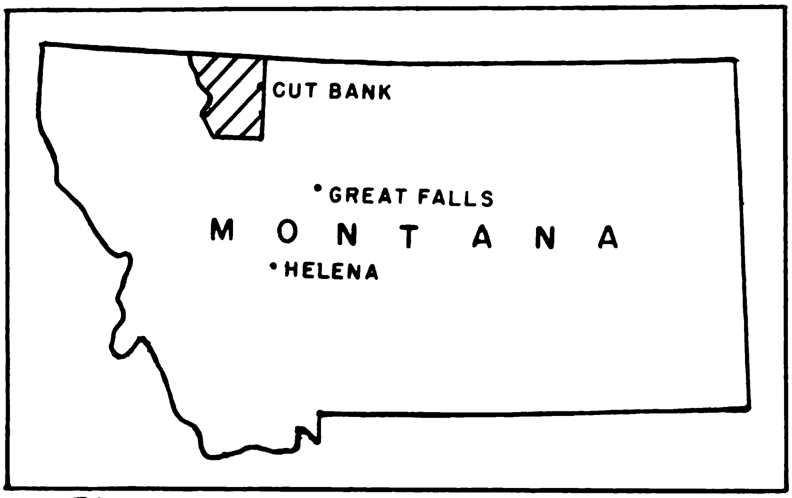
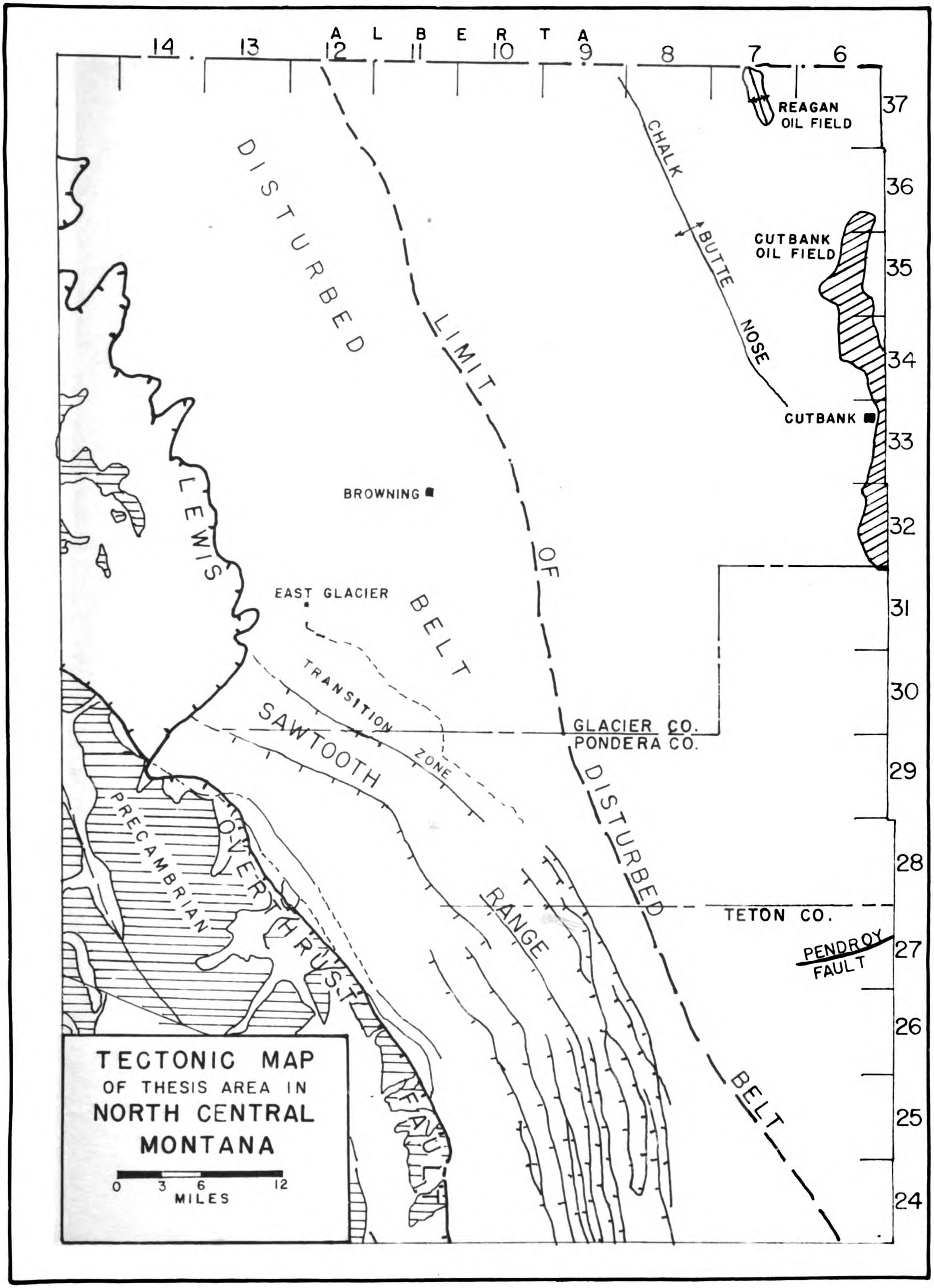


Figure 1.-Montana Location Map

This study has been divided into a surface and a subsurface investigation. The surface phase was restricted to the northern part of the Sawtooth Range. This area is bounded on the north and west by the Lewis Overthrust. The eastern boundary of the surface phase is formed by what the writer prefers to call the eastern boundary of the Transition Zone separating the Disturbed Belt from the Front Ranges (Fig. 2). The subsurface part is bounded on the north by the International Boundary between Canada and the United States. The eastern boundary falls approximately along a line drawn from the Canadian border south along R6W near the town of Cut Bank. The southern limit of the area is T27N.

The field work for this paper which consisted of studying outcrops of the conglomerate and collecting of samples for laboratory work was accomplished during July, August and early September of 1956. The subsurface investigation consisted of an examination of electric, radioactivity, core and sample logs.



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REAGAN OIL FIELD
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CUTBANK OIL FIELD
CUTBANK
DISTURBED BELT
LIMIT OF DISTURBED BELT
BROWNING
LEWIS
EAST GLACIER
TRANSITION ZONE
SAWTOOTH RANGE
GLACIER CO.
PONDERA CO.
PRECAMBRIAN
OVERTHRUST FAULT
TETON CO.
PENDROY FAULT
TECTONIC MAP OF THESIS AREA IN NORTH CENTRAL MONTANA
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MILES

FIGURE 2

STRATIGRAPHY

The general stratigraphic column of the study area is shown in Figure 3.

The Cretaceous Kootenai formation is underlain unconformably by the Jurassic Swift formation and to some extent in the eastern part of the study area by the Rierdon formation.

The Rierdon formation is a dark gray, calcareous, micaceous shale with thin layers of gray, dense, blocky limestone. The Swift formation consists of an upper thin-bedded, ripple-marked sandstone unit interspersed with thin micaceous shale films. The lower unit of the Swift formation is predominantly shale with a thin glauconitic sandstone at its base.

The overlying Kootenai formation is divided into two members. The lowest member has three phases which are from oldest to youngest, the Cutbank, Sunburst and Moulton. The Sunburst and Moulton phases are located by subsurface drilling in the eastern part of the study area. These beds do not crop out in the Disturbed Belt. The Cutbank phase crops out in the western part of the Disturbed Belt as well as numerous places in the Sawtooth Range.

STRATIGRAPHY IN NORTHWESTERN MONTANA

ERA	PERIOD	GROUP	FORMATION	MEMBER	PHASE
	Cret.		Willow Creek St. Mary River		
		Montana	Horsethief Bearpaw Two Medicine Virgelle Telegraph Cr.		
			Colorado	Upper Blackleaf	
			Kootenai	Upper	
				Lower	Moulton Sunburst Cutbank
	Jur.		Morrison		
		Ellis	Swift Rierdon Sawtooth		
	Miss.	Madison	Charles Mission Canyon Lodgepole		
	Dev.		Three Forks Potlatch		
			Duperow	Upper Lower	
			Souris River		
	Camb.		Devil's Glen Switchback sh. Steamboat ls. Pagoda ls. Dearborn ls. Damnation ls. Gordon sh. Flathead ss.		
		Missoula	Kintla		
		Siyeh	Sheppard dol. Purcell lava Upper Siyeh Spokane sh. Lower Siyeh		
		Ravalli	Grinnel sh. Appekunny Altyn ls.		

Figure 3

In the western part of the area the base of the Cutbank phase consists of a chert-quartz conglomerate averaging ten feet in thickness. A salt and pepper sandstone, which is absent in the extreme western part of the area thickens eastward to 130 feet and thins to forty feet in the vicinity of the town of Cut Bank, overlies the basal conglomerate. The conglomerate zone thins rapidly to the east and throughout most of the area it consists only of a few inches of basal conglomerate. The Cutbank phase is highly lenticular and cross-bedding is visible in most outcrops.

The Sunburst phase is from ten to ninety feet thick and consists of variegated mudstone, siltstone and white lenticular sandstones. Near the top of the Sunburst phase is a limestone bed up to eleven feet thick which contains fresh water fossils. This limestone weathers bright orange and tan. The Moulton phase consists of two units; an upper massive cross-bedded sandstone and variegated mudstone unit, and a lower lacustrine deposit consisting of dark gray shale with thin beds of limestone, siltstone and very fine-grained sandstone (Cobban, 1955).

The upper member of the Kootenai formation is composed of variegated mudstone, siltstone and greenish-gray sandstone. The sandstones are fine to coarse-grained, massive, cross-bedded and highly lenticular. Cobban states that, "In contrast to the sandstones of the lower member, those of the upper member contain more micas and other grains derived from freshly weathered igneous rocks." (Cobban, 1955).

The Kootenai formation is overlain by the Colorado formation which consists of a lower member composed of dark marine shale and considerable sandstone, siltstone, mudstone and bentonite and an upper member which is primarily a dark-gray marine shale.

The Colorado is in turn overlain by the Montana Group which from oldest to youngest is composed of the marine Telegraph Creek and Virgelle formations, the continental Two Medicine, marine Bearpaw and the brackish to marine Horsethief formations.

The St. Mary River and the Willow Creek formations overlie the Montana Group and are both non-marine in origin.

TECTONIC HISTORY

The area which is discussed in this paper forms the boundary between two major tectonic provinces, the Central Stable Platform on the east, and the Cordilleran Geosyncline on the west. The Stable Shelf Area is represented by a south-trending arch, which lies just to the east of the area covered by the Tectonic Map (Fig. 2). This arch extends from Great Falls, Montana north into Alberta and is composed of two major elements; the South Arch to the south of the area and the Kevin Sunburst Dome on the north which lies directly to the east of the Cutbank Field. The Cordilleran Geosyncline in north-central Montana and its general regional geologic history is best summarized by the following from Alpha.

> The Cordilleran Geosyncline of northern United States extended westward to the Pacific margin until the Nevadan orogeny in late Jurassic time. The Nevadan orogeny created a north-south uplift from southeastern California to northern Idaho and northward into British Columbia, separating the geosyncline into east and west troughs. In late Mesozoic and Cenozoic time in what is now western Montana the east trough became the site of an orogenic belt commonly known as the Cordilleran Genanticline. This geanticline is composed of large thrust sheets of sedimentary strata pushed eastward. The Front Ranges of the Rockies lie along the east margin of the Cordilleran Geosyncline.

The Disturbed Belt is essentially a tectonic transition zone between the two major provinces and is composed mainly of highly squeezed Mesozoic strata. On the west directly adjacent to the Sawtooth Range the rocks forming the Disturbed Belt appear as overturned drag folds, small anticlinal and synclinal structures and numerous small thrusts, which have undergone extreme compression from the southwest. The Cutbank conglomerate zone is one of the most competent beds in the Cretaceous phase. As such it is usually found in the Disturbed Belt as a prominent ridge. Eastward toward the margin of the Disturbed Belt, the folding and faulting become less intense and reverse faulting becomes dominant. On the Tectonic Map the intensely folded part of the Disturbed Belt has been designated the "Transition Zone."

SUBSURFACE CUTBANK OF THE DISTURBED BELT AND SHELF AREA

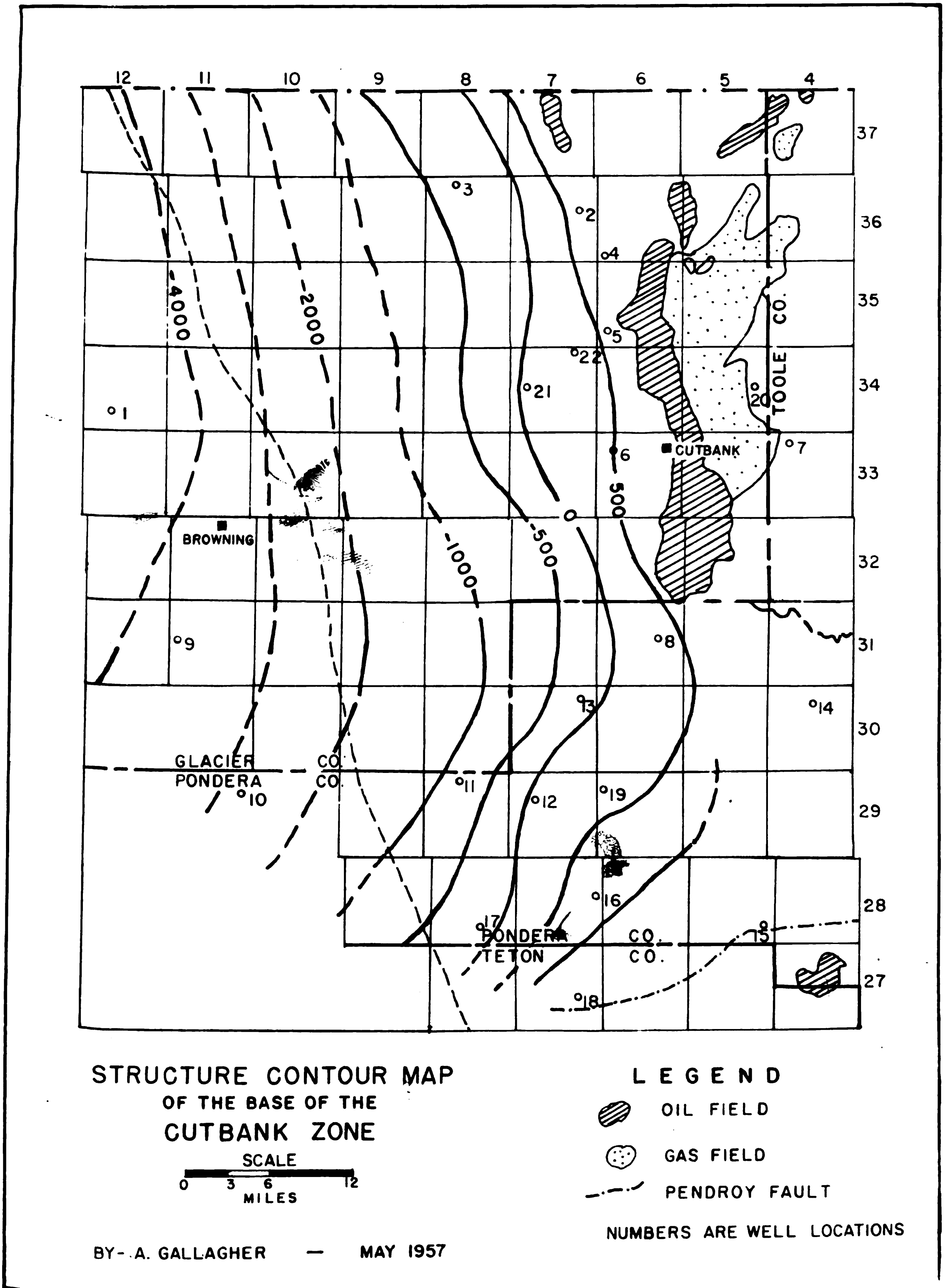
The object of studying the subsurface Cutbank phase was to determine by a critical examination of logs, core and sample descriptions whether the type of depositional environment could be determined and the direction from which the gravels forming the conglomerate of the Cutbank phase came. A structure contour map on the base and an isopach map of the Cutbank phase were constructed. The wells that were used in this study along with their map identification number and the type of material obtained from them are listed below.

Electric Log = E Radioactivity Log = R Sample Log = S

No.	Name	Location	Log	Samples	Core
1.	Carter-Phillips (Lucy Weaselhead No. 1)	Sec. 28 T34N R12W			X
2.	Carter Oil Co. (Indian Tribal No. 1)	Sec. 12 T36N R7W	E		
3.	Union Oil Co. (Tribal 534 No. 1)	Sec. 4 T36N R8W	E		
4.	Union Oil Co. (Union Tribal 422-1)	Sec. 31 T36N R5W	E		
5.	Wagner & O'Hanlon (Marceau No. 1	Sec. 30 T35N R6W	E		
6.	Union-Carter (Miller-Tribal)	Sec. 7 T33N R6W	ER	X	X

No.	Name	Location	Log	Sample	Core
7.	Skelly Oil Co. (H. U. Amidon No. 1)	Sec. 5 T33N R4W	E		
8.	Stanolind Oil Co. (Rutherford No. 1)	Sec. 14 T31N R6W	E	X	X
9.	Union Oil Co. (Morning Gun No. 1)	Sec. 18 T31N R11W	R	X	X
*10.	Union Oil Co. (Mittens No. 1)	Sec. 12 T29N R11W	R		
11.	Grant Brown Jr. (Brown-Deruwe No. 1)	Sec. 4 T30N R8W	E		
12.	Texas Co. (Kingsbury No. 1)	Sec. 8 T29N R7W	S	X	
13.	Texas Co. (Tribal 284 No. 1)	Sec. 11 T30N R7W	E	X	
14.	Chicago Corp. & Republic Natural Gas (Nelson No. 1)	Sec. 10 T30N R4W	E		
15.	Farmers Union (Mancornerl No. 1)	Sec. 25 T28N R5W	E		
16.	Northern Ordnance (Jannusch No. 1)	Sec. 13 T28N R7W	E		
17.	Northern Ordnance (Pitchairn No. 1)	Sec. 27 T28N R8W	E		
18.	Mule Creek Oil Co. (Rockport No. 1)	Sec. 23 T27N R7W	E		
19.	George R. Sharman (Ryan Estate No. 1)	Sec. 7 T29N R6W	E		
20.	Union Oil Co. (Dahlquist No. 12)	Sec. 13 T34N R5W	E		
21.	D. E. L. Byers (Tribal No. 1)	Sec. 17 T34N R7W	E		
22.	Carter Oil Co. (Carter No. 1 Coulee Tribal)	Sec. 2 T34N R7W	E		

* See text for discussion.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CUTBANK
BROWNING
GLACIER CO.
PONDERA CO.
PONDERA CO.
TETON CO.
STRUCTURE CONTOUR MAP
OF THE BASE OF THE
CUTBANK ZONE
SCALE
0 3 6 12
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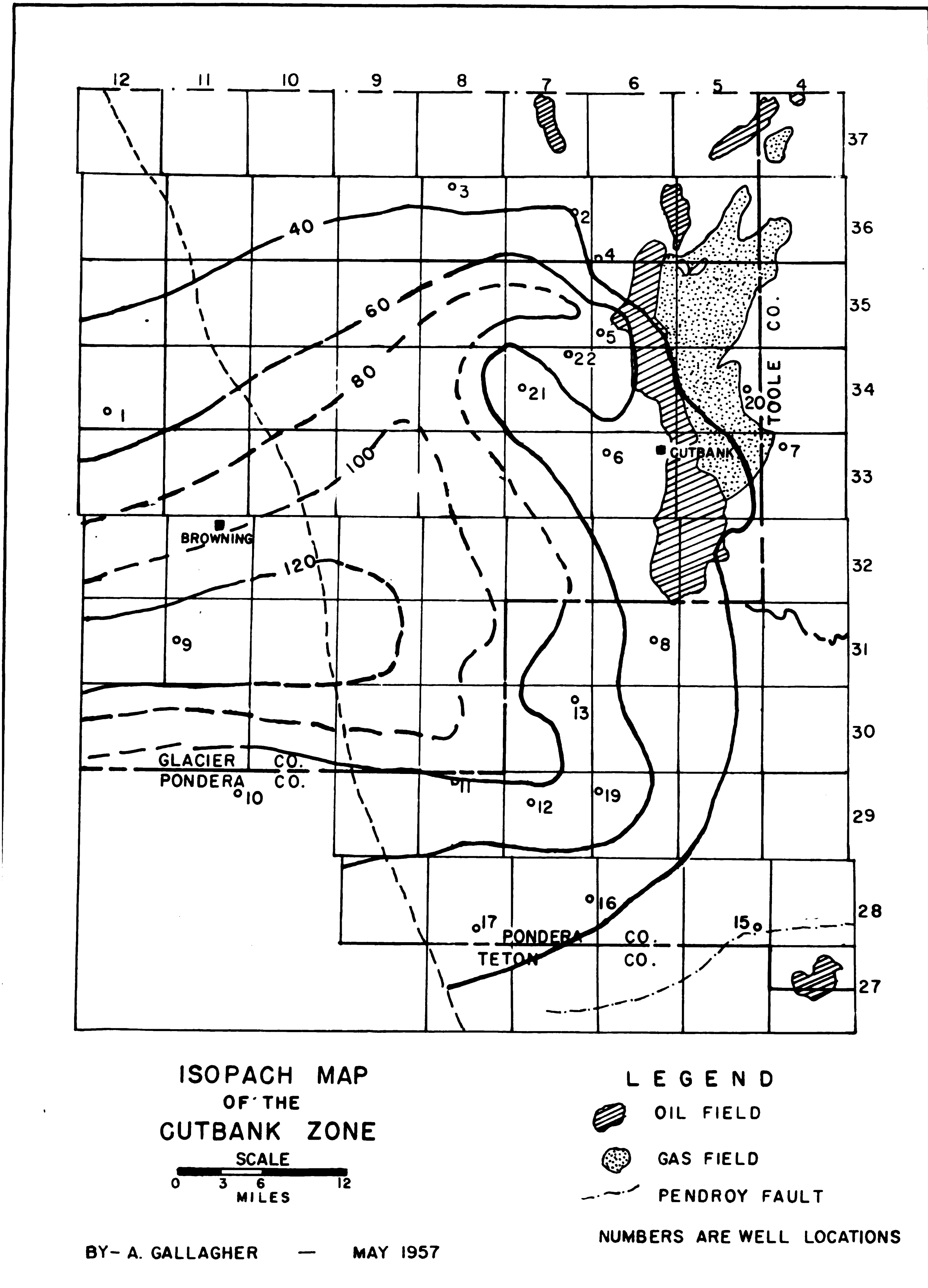
BY- A. GALLAGHER — MAY 1957
LEGEND
OIL FIELD
GAS FIELD
PENDROY FAULT
NUMBERS ARE WELL LOCATIONS

FIGURE 4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ISOPACH MAP
OF THE
CUTBANK ZONE
SCALE
0 3 6 12
MILES
LEGEND
OIL FIELD
GAS FIELD
PENDROY FAULT
NUMBERS ARE WELL LOCATIONS
BY- A. GALLAGHER — MAY 1957

FIGURE 5

In working with the well logs it was necessary to work with the entire Cutbank phase rather than the conglomerate zone itself.

Up to the time of this investigation published isopachs and structure contour maps of the Cretaceous have terminated at the eastern limit of the Disturbed Belt. The primary reason for this limitation was lack of control. Union Oil Company's, Morning Gun (well no. 9) and Mittens Well (well no. 10) were completed in late 1955. It can readily be seen from the isopach map (Fig. 5) that these two wells, particularly well number 9, occupy important positions for control purposes. Since these two wells are within the Disturbed Belt a word of explanation is in order to justify their use as valid control points.

The complex faulting characteristic of the Disturbed Belt extends from the surface to a depth of approximately 6510 feet. Upper Colorado shale in the faulted zone was repeated several times. There is a possibility that some lower Montana Group rocks were also involved. Between the depth of 6510 feet and 9550 feet where the well "bottoms" in the Mississippian Misson Canyon formation, the column appears as an undisturbed sequence. Since the Cutbank phase occurs at a depth of 8335 feet it was felt that the information pertaining to the Morning Gun well could be utilized with a good degree of certainty. A further check on the Morning Gun was made by comparing the computed apparent dip measured at the base of the Cutbank phase between wells 9, 11 and 16. These wells are roughly in line with each other as can be readily seen from Figure 5. The apparent dip between wells 11 and 16 is 1°24' and between wells 9 and 11 is 1°25'. The close correspondence between the dips supports the premise that the Cutbank phase is undisturbed in well 9.

Well 10 (Mittens) lies even farther to the west than well 9 and is approximately midway between the Front Range and the east edge of the "Transition Zone". It is roughly one half mile east of the base of Little Plume Peak (Fig. 6). This well "bottomed" in Kootenai formation at 7500 feet. There is no way of knowing whether or not the well ended in a thrust plate or in the underlying normal undisturbed sequence. In this well the Kootenai formation is repeated five times and the Cutbank phase is repeated twice. The Cutbank sediments in the two thrusts are in both instances overlain by Kootenai formation and underlain by Ellis Group sediments. As this is the usual relationship found in the field and in surrounding wells it is considered that the thicknesses represented are true values. The Cutbank phase is 64 feet thick in the upper thrust plate and 60 feet thick in the lower. As there is no way of knowing the original geographic location of the thicknesses represented in the thrusts they were not used in the construction of the isopach or structure contour maps. However, even though the depths in this well and the thicknesses in the thrust plates have no significance by themselves, they can help to support the overall picture.

The structure contour map fairly well outlines the southward extension of the Alberta Trough, which has been thoroughly discussed in the existing literature (Alpha, 1955).

The isopach map of the Cutbank phase shows the rapid decrease in thickness to the east near the town of Cut Bank. There is a more rapid decrease in thickness toward the north and south. This decrease in thickness does not appear to have been structurally controlled except possibly in a minor way in the northeast part of the area. An examination of the map indicates that the sediments forming the Cutbank phase came from approximately S65°- 85°W.

FIELD STUDY OF THE CUTBANK CONGLOMERATE

The Cutbank conglomerate crops out in scattered localities just west of the east margin of the Transition Zone. In the Badger Creek area (Fig. 6) the conglomerate forms several small ridges across the Transition Zone to the base of the Sawtooth Range where it is overidden by Mississippian and Devonian sediments. In the vicinity of South Fork Creek samples 20 and 21 were collected from the fartherest east outcrop of the conglomerate. Samples 12 and 14 taken from the south side of Little Plume Peak are from the most westerly outcrops in the Badger Creek area. Samples from the Lee Creek exposure represent the next major line of outcrop. The intervening area consists mainly of Paleozoic and small amounts of Jurassic strata. Outcrops one mile south of Elkcalf Mountain on the Continental Divide and in the vicinity of Kip Creek are the last good exposures of the conglomerate before the Sawtooth Range is terminated by the Lewis Overthrust Fault.

STRATIGRAPHY

The conglomerate unconformably overlies marine sediments of the Jurassic Ellis Group. The writer believes it to lie on the Upper Swift formation described by Cobban (1945). Within the Upper Swift of the Little Plume and Badger Creek

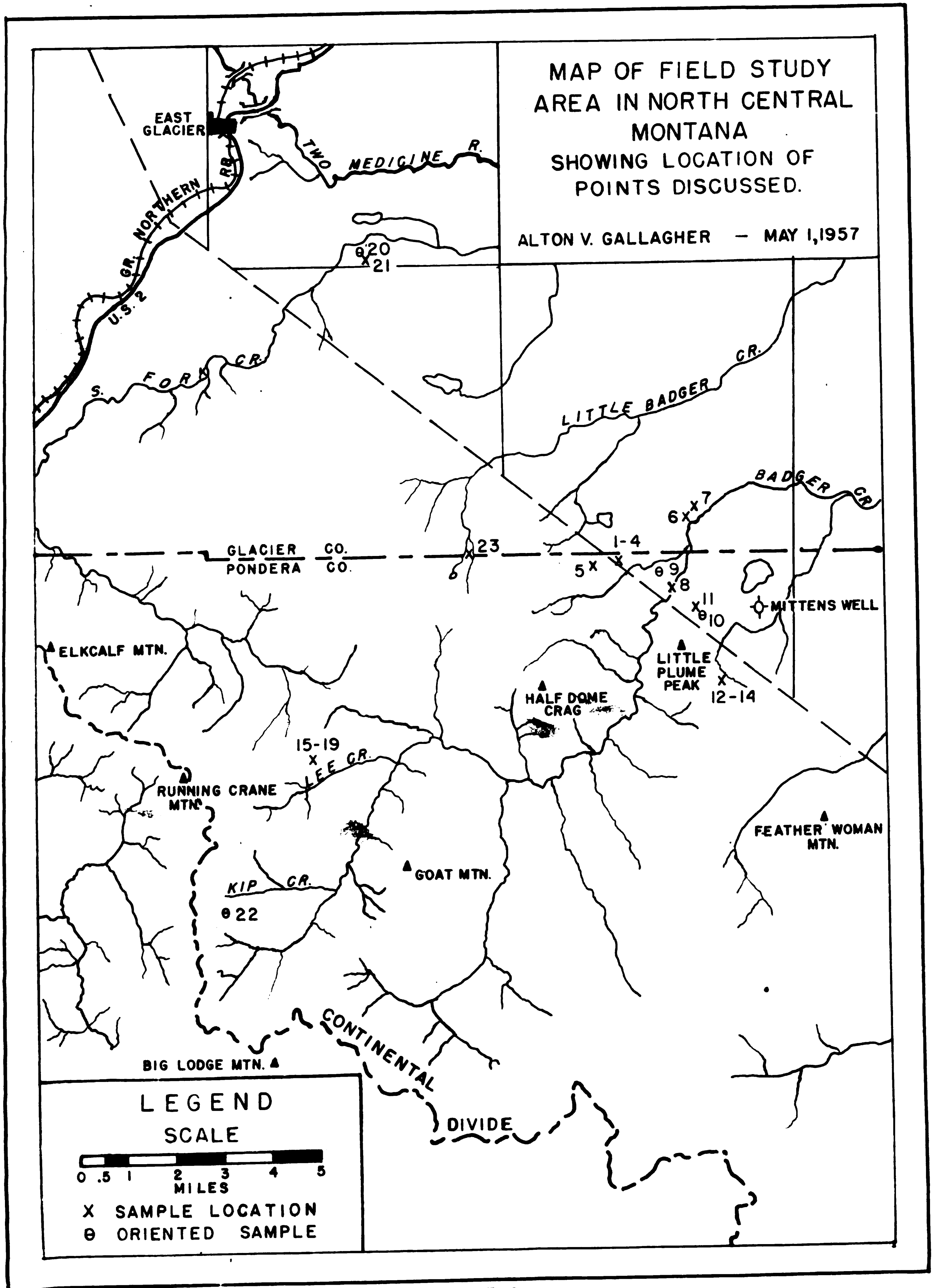
MAP OF FIELD STUDY AREA IN NORTH CENTRAL MONTANA SHOWING LOCATION OF POINTS DISCUSSED.
ALTON V. GALLAGHER — MAY 1, 1957
EAST GLACIER
TWO MEDICINE R.
GR. NORTHERN RR.
U.S. 2
S. FORK CR.
LITTLE BADGER CR.
BADGER CR.
GLACIER CO.
PONDERA CO.
MITTENS WELL
ELKCALF MTN.
LITTLE PLUME PEAK
HALF DOME CRAG
RUNNING CRANE MTN.
LEE CR.
KIP CR.
GOAT MTN.
FEATHER WOMAN MTN.
BIG LODGE MTN.
CONTINENTAL DIVIDE
LEGEND
SCALE
0 .5 1 2 3 4 5
MILES
X SAMPLE LOCATION
θ ORIENTED SAMPLE

FIGURE 6

areas numerous outcrops of a brown-stained sandstone ledge containing worm(?) burrows or trails were seen. This supports the premise that the underlying sandstone ledge is the Swift formation. In most small exposures of the conglomerate and the underlying Jurassic formations, the conglomerate appears to overlie conformably the Jurassic, however slight angular discordance was noted at several large outcrops.

In all localities in which the conglomerate was observed it is overlain by the gray salt and pepper sandstone characteristic of the Cutbank phase. At the Lee Creek, Little Plume and Kip Creek outcrops the Cutbank phase is overlain by a very persistent limestone bed which is from three to fifteen feet thick. In the Lee Creek and Kip Creek areas the limestone bed is separated from the conglomerate by ten to fifteen feet of sandstone. In the Morning Gun well this same limestone is separated from the Cutbank phase by seventy-five feet of the Sunburst sandstone. In well 6 the limestone bed is eighty-five feet above the top of the Cutbank phase and it is seventy feet above in well 13. This is possibly the same limestone which Cobban describes as occurring east of Great Falls. As this limestone is an excellent horizon marker in the Sawtooth Range it is felt that it is worthy of description. On fresh exposure the lower part of the limestone bed appears dense, dark black, finely crystalline and fossiliferous. This comprises approximately two-thirds of the bed in most outcrops. A fresh exposure of the upper part of the bed appears light gray, fairly dense and non-fossiliferous. On the weathered surface the lower part is dark gray and vuggy with calcite stringers and fossils weathering out in relief, the upper part is orange to buff. The line separating this lower black limestone from the light gray top of the bed is very sharp.

At the time the samples from all areas were taken, the lithology and any other data that might have some value was recorded. It should be kept in mind while observing this map (Fig. 6) that sample locations are geographic only. For example, samples 6 and 7 are farthest east geographically, however they are in a thrust which overlies the thrusts from which samples 8 through 10 were taken, thus their true geographic relationship is west of samples 8 through 10.

Difficulty was experienced in obtaining good samples. Nevertheless oriented samples were taken from exposures where there was absolutely no question as to the correct orientation of the main body of the conglomerate lens and to avoid taking any samples from foreset beds.

LITHOLOGY

The Cutbank conglomerate consists of chert and quartz pebbles in a matrix of light gray salt and pepper sandstone.

Black, tan, white and very minor amounts of blue and green chert pebbles comprise from 70 to 90 percent of the clastics. The remainder of the fragments, with two exceptions, consist of pure white and black to purplish-black quartzite pebbles. The fragments vary in size from less than an eight inch to more than seven inches in diameter. All of the cobbles over five inches in diameter were composed of white quartzite. The average size of the pebbles decreases from bottom to top of the conglomerate zone. The conglomerate is so well cemented that it fractures across the grains rather than around them. The salt and pepper sandstone that forms the matrix is generally light gray although near the top of the section it is tan at many places. The sandstone consists of colorless to tan quartz and black and tan chert grains.

The purplish-black to black quartzite pebbles are found only in samples which were taken from near the Continental Divide, namely the Lee and Kip Creek areas. These quartzite pebbles occur only in the top two feet of the conglomerate zone.

Kaolinite in small varying amounts occurs in all samples as part of the cementing material. It is found in considerably larger amounts where the conglomerate is more quartzitic.

The conglomerate is slightly fossiliferous from two to three feet above the base in the Lee Creek section; identification of the fragments was impossible. This is the only area in which fossils were observed.

On the Continental Divide, about one mile south of Elk Calf Mountain, several shale fragments were observed in a series of small thrusts of the conglomerate. The largest of these measured five by three by one-half inches. These shale fragments occurred in the middle of a lens in the lower half of the conglomerate zone.

The conglomerate is exposed in lenses varying from four inches to over six feet in thickness, and from ten feet or more in length.

On the weathered surface the conglomerate characteristically is a dark reddish-brown color although occasionally some of the sandstone interbeds appear in their normal light gray or tan color. A fresh and weathered surface views of the conglomerate are shown in Figures 7 and 8.

Pyrite which is a fairly abundant heavy mineral in the basal foot of the conglomerate, is not visible macroscopically even with a good hand lens.

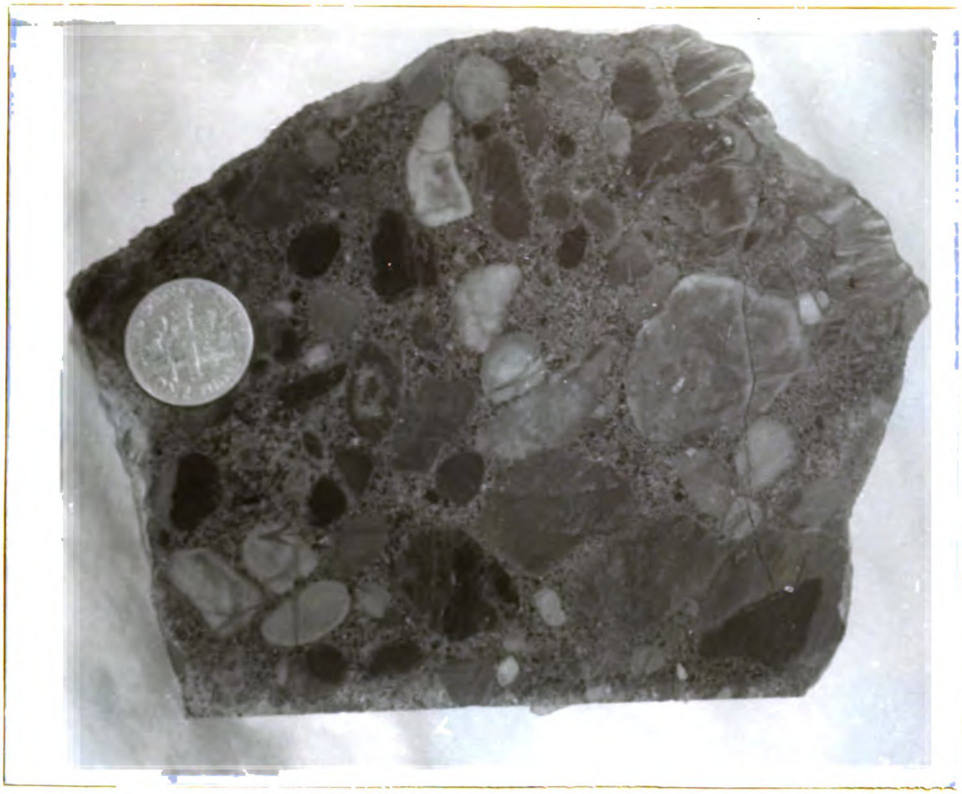

Figure 7.- Fresh sample of the Cutbank conglomerate.

Figure 8.- Weathered sample of the Cutbank conglomerate.

LABORATORY STUDY OF THE CUTBANK CONGLOMERATE

A laboratory study of the Cutbank conglomerate was made using the samples that were collected in the field. A heavy mineral analysis was run on the samples and two thin sections were made and studied. The oriented samples were studied to determine if there was any preferred orientation.

HEAVY MINERAL ANALYSIS

All attempts to disaggregate the samples in order that a size, shape and heavy mineral analysis could be run were futile . This was found to be primarily due to secondary enlargement of the quartz crystals. The size and shape analysis were abandoned and attention was turned to crushing the rock samples in a diamond mortar so that heavy mineral separations could be carried out. The crushed fragments were sieved repeatedly until they would pass through a thirty-five mesh screen. The standard heavy mineral separate procedure presented by Krumbein and Pettijohn (1938), was then used. Two heavy mineral separates were made from each sample in order to provide a check against possible error. The heavy minerals from the two separates after being weighed were then combined into one sample. Part of the heavy minerals were mounted on slides and part were used for the determination of refractive indices.

The heavy mineral analysis did not prove to be significant; the heavy minerals varied from .032 to .081 percent. With an average percentage present in all samples of .065. There seems to be no apparent pattern of the distribution of the heavy minerals and it was therefore concluded that heavy mineral determinations were of little value in the study of the Cutbank conglomerate.

Actual percentage counts of the heavy minerals found in each slide were not made for three reasons: (1) the amount of heavy minerals was insufficient and too erratic, even when samples were located in close proximity to one another; (2) fracturing as a result of crushing the conglomerate had occurred to some extent; (3) samples from the sections on Lee and Badger Creeks were examined closely and the erratic distribution was not found to vary laterally to any appreciable extent.

A composite mineral suite covering the average ten foot thickness of the conglomerate was made. The most common heavy minerals were, pyrite, limonite, hematite, siderite, leucoxene , tourmaline, barite, zircon, cassiterite and magnetite. Minerals identified in minor amounts were, andradite, green hornblende and a green iron silicate mineral possibly greenalite.

Pyrite is present almost to the exclusion of all other minerals in the first foot of the conglomerate, but decreases considerably in the second foot and is very rare three feet above the base of the conglomerate. It does not reappear until the top foot of the conglomerate section where it is found in small amounts. The pyrite always appears to show varying degrees of alteration to limonite.

Limonite is abundant in the lower foot of the conglomerate and is dominant throughout the section. It always surrounds the pyrite and hematite grains.

Hematite is present in small amounts throughout the section and is unusually abundant from two to four feet and from seven to nine feet above the base of the section.

Magnetite and siderite are both found in small amounts throughout the section.

Leucoxene is common in all except the middle part of the ten-foot section of the conglomerate where it is scarce.

Tourmaline is found throughout the section in varying amounts. The variety indicolite was noted from three to five feet and from seven to ten feet above the base of the section. Tourmaline increases in abundance in the upper foot of the typical ten foot conglomerate zone.

Barite was observed in varying small amounts throughout the section, but increases noticeably in the upper foot of the ten foot section.

Zircon is found in scattered grains throughout the section. Several euhedral crystals which showed little if

any rounding were observed notably in the five to six foot zone of the typical conglomerate section.

Cassiterite was noted only in the upper three feet of the section where it is scarce to common.

Andradite and greenalite were noted as one or two grains per slide throughout the conglomerate section. The andradite showed a notable increase in the top foot of the section. Hornblende was observed in only two instances in the upper foot of the section.

The light minerals found in the conglomerate are: quartz, chert, kaolinite and calcite.

THIN SECTION ANALYSIS

The thin section analysis was used to aid in determining which minerals in the conglomerate are detrital and which are authigenic. A very thorough study of thin sections from the Cutbank Sand was made by Sloss and Feray in 1948.

A study of the thin sections revealed that pyrite, limonite, siderite, hematite, calcite and kaolinite occur as cementing or void-filling materials. Most of the quartz grains exhibit secondary growth by the addition of silica in optical orientation with the original quartz grain. Many of the chert grains are cut by fractures which are filled with secondary silica. The hematite and pyrite show alteration of varying degrees to limonite.

On the basis of the thin section analysis, heavy mineral separates and also information obtained from Milner's, "Sedimentary Petrography," the heavy mineral suite was divided into detrital and authigenic constituents.

Detrital	Authigenic
Tourmaline	Pyrite
Zircon	Limonite
Cassiterite	Hematite
Andradite	Siderite
Leucoxene	Barite

ORIENTATION ANALYSIS

As was mentioned previously all attempts to disaggregate the samples proved futile. Thus a method was devised for obtaining the azimuths of elongation of the pebbles in the oriented samples of the conglomerate.

Each sample was first cut into 1/8 to 3/16 inch slabs. Out of seven original oriented samples only four were competent enough to withstand this operation. The maximum permissible thickness of the slabs is dependent upon the average size of the pebbles in the conglomerate. If the average size of the pebbles is around 1/2 inch in diameter, a 3/16 inch slab will give satisfactory results. If the pebbles average from 1/4 to 3/8 inch in diameter then an attempt should be made to cut the slabs to 1/8 inch or thinner. Care had to be taken in cutting the slabs to prevent too much pressure from being applied by the saw to the rock causing the saw to veer or the conglomerate to disintegrate. As each slab was being cut the width of the saw cut was measured. After each cut the slab was oreinted and so marked. The pebbles were then traced very carefully with India ink on clear tracing vellum. Each tracing was oriented and a north-south line was also placed on each tracing. The use of the tracing vellum permitted the superposition of the slabs, represented by the tracings, which gives a three-dimensional effect which is necessary to determine the true axis of elongation in each pebble. The azimuths of the axes were then plotted on polar coordinate paper to which had been added several closely spaced north-south lines which greatly aidedin orienting the tracings on the coordinate paper. Each pebble was numbered, the number being placed on the tracing and also on the polar coordinate paper next to the azimuth of the pebble. Thus if there is any variation from the bottom to the top of the sample it can readily be determined. The amount of material removed by the saw (usually 1/16 of an inch) must be given due consideration in determining the correct position of the long axis in each pebble.

Since this is, to my knowledge, a new method, the azimuths of the samples were carefully determined three times. The average error was found to be + or - two degrees. The histograms (Figs. 9 - 12) were constructed from these measurements.

According to Twenhofel (1948), ellipsoidal particles

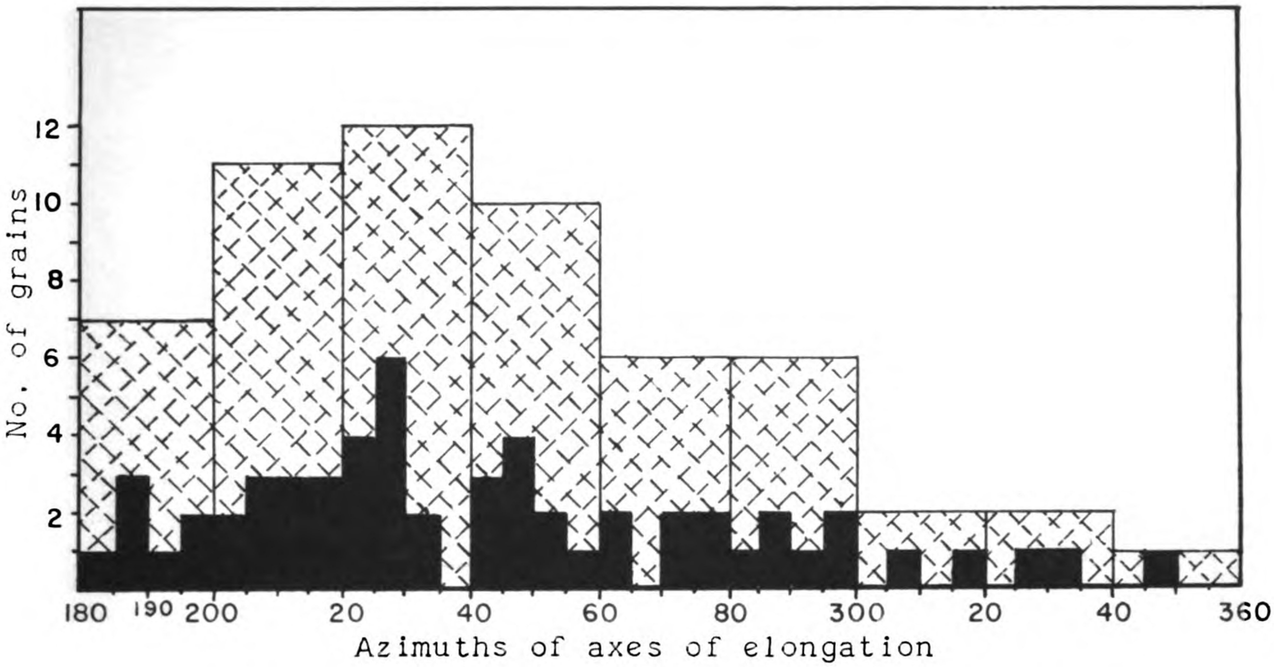

Figure 9.-Histogram of sample No. 10. The blackened area represents observed frequency count in 5° groups. The lined areas represent 20° frequency groups used in computing the mean and standard deviation.

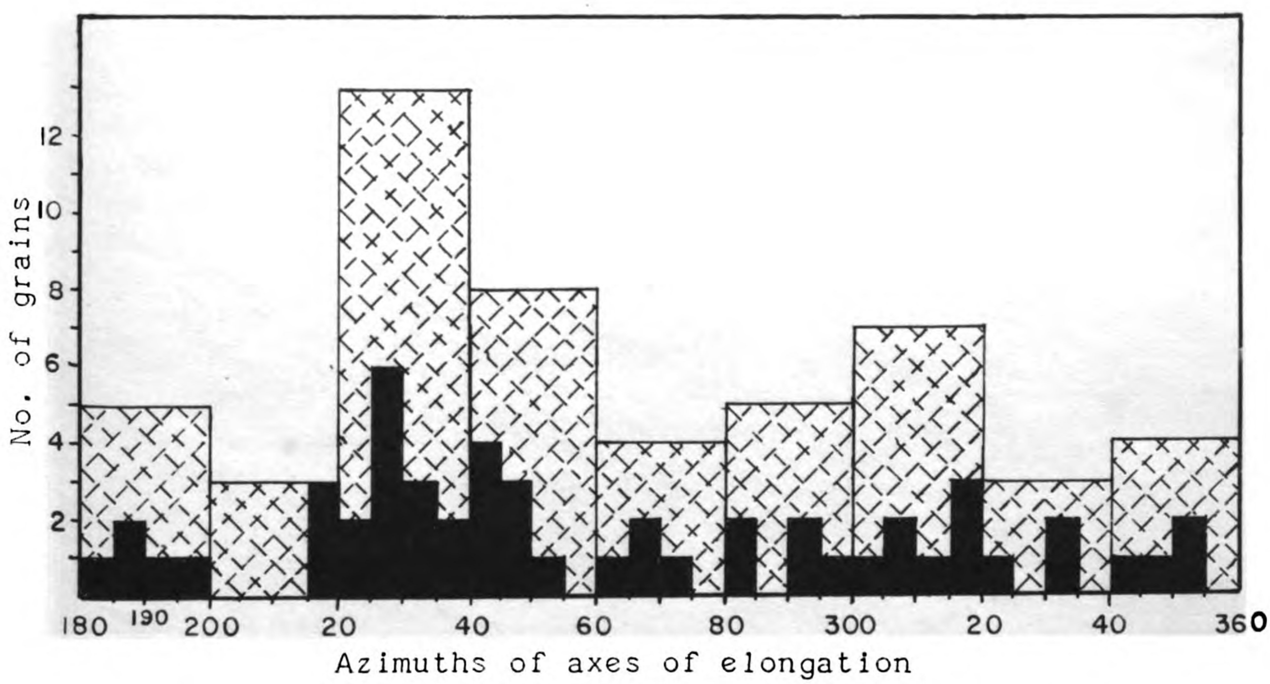

Figure 10.- Histogram of sample No. 9. The blackened area represents observed frequency count in 5° groups. The lined areas represent 20° frequency groups used in computing the mean and standard deviation.

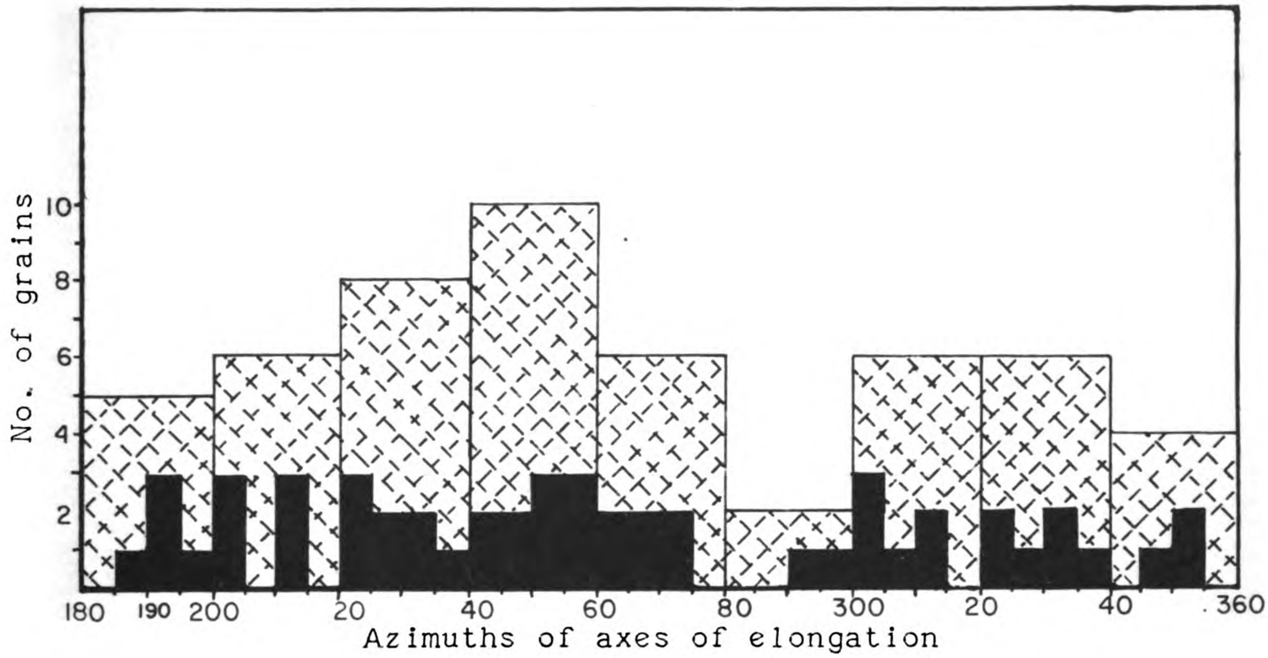

Figure 11.-Histogram of sample No. 20. The blackened area represents observed frequency count in 5° groups. The lined areas represent 20° frequency groups used in computing the mean and standard deviation.

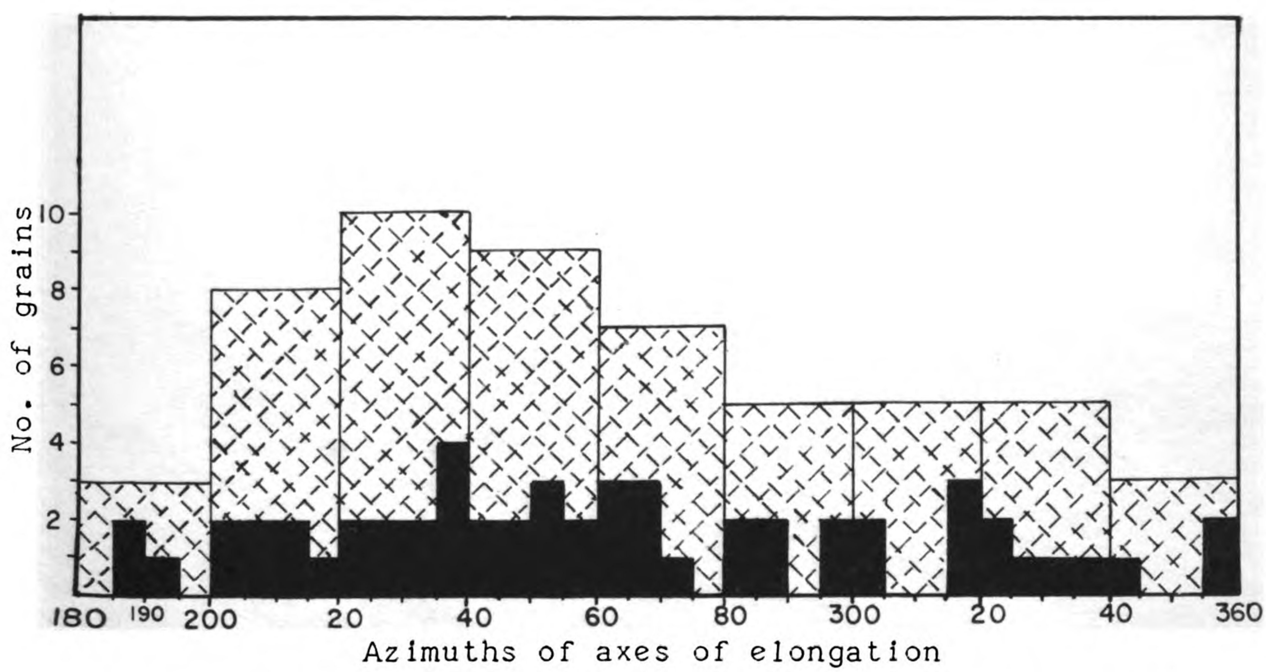

Figure 12.-Histogram of sample No. 22. The blackened area represents observed frequency count in 5° groups. The lined areas represent 20° frequency groups used in computing the mean and standard deviation.

tend to align themselves perpendicular to the current direction. Allowance for this was not made in the determination of the azimuths. This was not done because; (1) ellipsoidal pebbles were small in number, (2) the amount of matrix is small, which tends to reduce the alignment of pebbles perpendicular to the current, and (3) it was felt if this were true then a second high would appear in the histograms approximately 90° from the major high, if such highs were to appear.

After each of the histograms was completed the chi-square test was used to determine whether or not the fabric was isotropic. Using a 30° grouping all of the fabrics fell within the .05 sigificance level suggesting that the parent fabrics are anisotropic (Fairbairn).

The mean and the standard deviation were computed for each of the samples and are listed in the table below.

Sample	Mean	Standard Deviation
10	243.7°	40.0°
9	262.7°	51.6°
20	261.6°	44.8°
22	260.2°	48.6°

Sample ten consisted of pebbles which were not too closely packed and which averaged approximately 5/8 inch in diameter. Truly ellipsoidal pebbles were few.

Sample nine consisted of pebbles many of which were in juxtaposition and of which the average size range is 1/4 to

3/8 inch in diameter. Several of the pebbles in this sample were truly ellipsoidal, and all of these were oriented so that they fell between 310° and 355° with one exception which was aligned in the direction of 195°.

Sample 20 consists of pebbles which are in the size range from 1/2 to 5/8 inch diameter. The pebbles are not too closely packed, but there are more ellipsoidal fragments in this sample than in any other. Four pebbles in the 300° to 360° group have a definite ellipsoidal shape and several others in this same group are close to being ellipsoidal.

Sample 22 consists of fairly closely packed pebbles which have an average size range of 1/4 to 3/8 inch in diameter. This sample is highly quartzitic and contains few ellipsoidal particles.

It would appear from the histograms that the gravels that formed the Cutbank conglomerate came from somewhere to the southwest, probably in the range from S40°W to S80°W.

SUMMARY AND CONCLUSIONS

The main objective of this investigation was to learn something of the origin of the Cutbank conglomerate by means of a thorough study of its geology.

The field work, which consisted of examining numerous outcrops and samples of the Cutbank conglomerate indicated that this conglomerate contains materials other than its usual chert and quartz pebbles in a salt and pepper sandstone matrix. Fossil fragments, shale slabs and abundant black to purplish-black quartzite pebbles which have not been reported elsewhere in the conglomerate were found.

From various types of well logs a structure contour map on the base and an isopach map of the Cutbank phase were constructed. The writer believes that the Cutbank phase is a deltaic-type deposit laid down in a fresh water lake. This is inferred from data shown on the isopach map and also from the decrease in the size of the pebbles from bottom to top and from west to east.

Heavy mineral analyses were made of the mineral suite to determine if there was any uniform variation in the amount of heavy minerals present. The heavy mineral suite consists of; pyrite, limonite, hematite, siderite, leucoxene tourmaline, barite, zircon, cassiterite and magnetite.

Minor amounts of andradite, green hornblende and possibly greenalite were also observed. There is no appreciable lateral variability of the heavy minerals. A vertical variation of the heavy minerals does exist.

A method was devised for determining the orientation of the pebbles contained in the conglomerate. The azimuths proved highly suggestive of a S40°W to S80°W orientation. Though the number of pebbles per sample was small the close correspondence between individual samples cannot be overlooked.

The conclusions which have been reached as a result of this investigation are summarized below:

(1) The isopach map explains the rapid fluctuations in thickness over short distances, experienced in drilling through the Cutbank phase. The isopach map in conjunction with lithologic evidence strongly suggest that the Cutbank phase is a deltaic-type deposit in the Disturbed Belt area.

(2) The presence of fossil fragments in the conglomerate indicates that at least part if not all of the sediments forming the conglomerate are later than Precambrian. That part of the conglomerate which contained shale fragments cound indicate that some of the rocks forming the conglomerate are Mesozoic.

(3) Heavy mineral separates other than aiding in the determination of the mineral suite were of little value.

(4) The oriented samples are highly suggestive of a southwesterly source area for the gravels forming the conglomerate.

In Figure 13, the writer has plotted the suggested orientation on a regional map in order to show the possible source area. The source area would appear to be the southern half of the Coeur D'Alene Mountains. If this is true then it is possible that the Cutbank conglomerate represents the the first folding preceding the intrusion of the Idaho batholith (Anderson, 1948).

It is the writer's opinion that the Cutbank conglomerate is composed of lower Cambrian sediments interspersed with a small amount of Jurassic material in the lower half of the conglomerate zone and with some Precambrian Belt strata represented in the top two feet of the conglomerate section. This opinion is based entirely on a close examination of the literature in view of the material presented in this investigation.

An interesting sidelight that the study revealed concerns the fresh water limestone which overlies the Cutbank phase. As was pointed out previously, the Cutbank phase and the limestone are widely separated in the east part of the Disturbed Belt, whereas in the western part of the Sawtooth Range they are almost in contact with one another. From this it might be inferred that the western edge of the Sawtooth Range is not too distant from the western edge

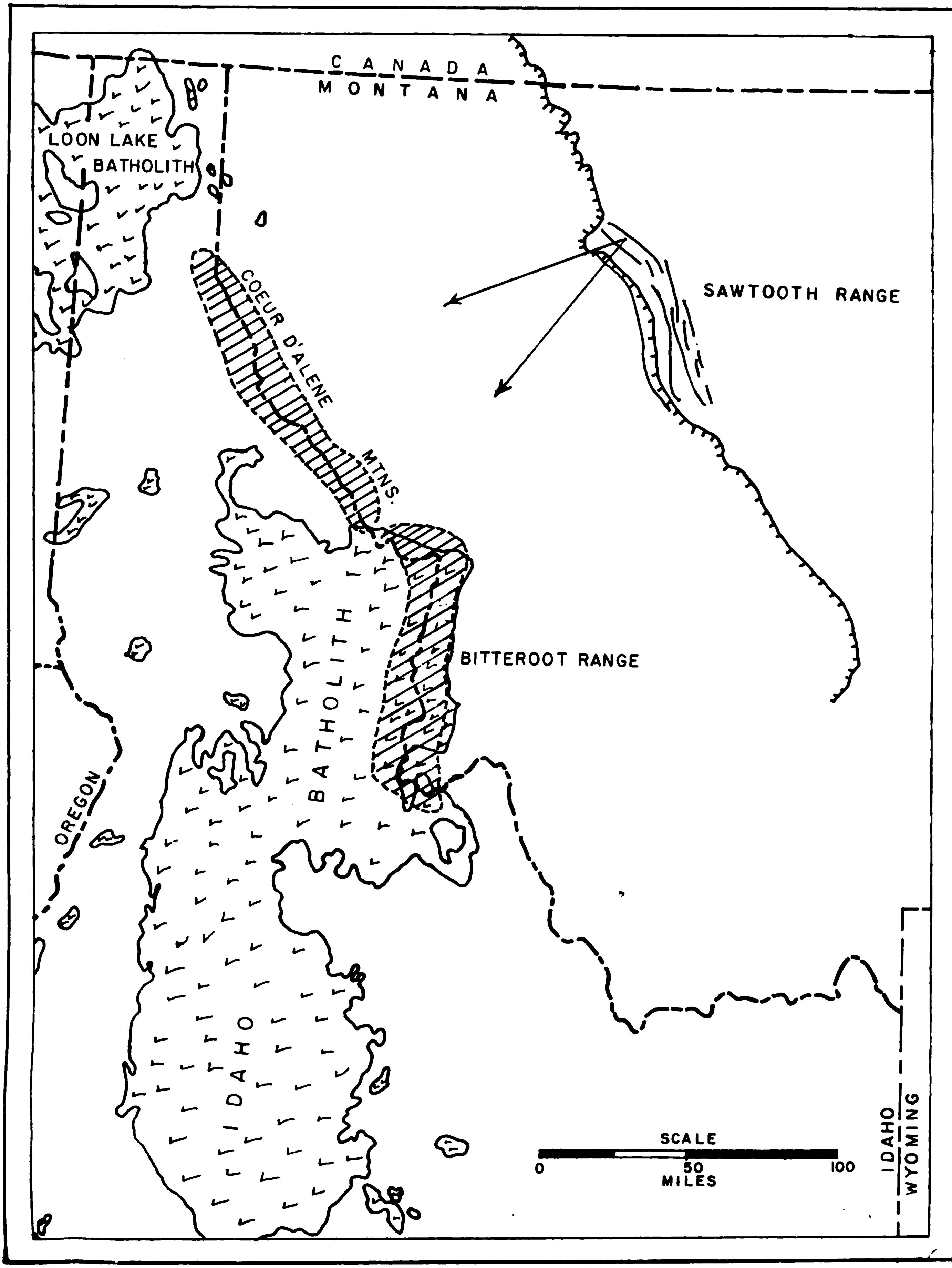

Figure 13.-Possible source areas of the Cutbank conglomerate.

of the shallow trough which existed at the beginning of deposition of the upper member of the Kootenai formation.

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