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Geology of the southwestern part of the Stryker quadrangle northwestern Montana

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GEOLOGY OF THE SOUTHWESTERN PART OF THE STRYKER QUADRANGLE, NORTHWESTERN MONTANA

by

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ABSTRACT

The southwestern part of the Stryker Quadrangle is in the northern Salish Mountains. It consists of about 250 square miles and is bounded on the northeast by the Rocky Mountain Trench. A minimum thickness of 12,000 feet of Precambrian Belt sedimentary rocks is exposed. The lowest outcropping lithologic unit is the Ravalli Group, which consists mostly of purplish argillites and quartzites. Rocks mapped as Ravalli in the southwestern part of the area are argillites, whereas in the northwest rocks included in the Ravalli have in addition beds of well rounded, coarse grained quartzite. Overlying the Ravalli Group is the calcareous Piegan Group. The boundary between these two groups is gradational. The unnamed greenish-gray argillitic basal unit of the Piegan Group was mapped separately from the overlying gray limestone unit, which was referred to the Siyeh Formation and is the highest Belt unit exposed in the area. Quaternary glacial and alluvial sediments blanket the region.

Structural features of the area trend northwesterly and consist of symmetrical and asymmetrical folds, longitudinal high-angle thrust faults which dip southwest, and longitudinal normal faults. Beds are overturned to the east in the asymmetrical fold located in the southwest corner of the area. Longitudinal normal faults occur on the southwestern side of

the Rocky Mountain Trench.

Supermature sand of the sandy argillites high in the Ravalli Group may have been derived from high energy sources such as beaches or dunes. This sand was sporadically deposited in a shallow mud flat environment. Composite quartz sand grains, themselves composed of cemented rounded grains, indicate a pre-Ravalli sedimentary source rock.

INTRODUCTION

LOCATION AND ACCESSIBILITY

The mapped area consists of a triangular portion of the south half of the Stryker 30-minute quadrangle. This quadrangle is in the northern part of the Salish Mountains northwest of Whitefish, Montana, and southwest of Eureka, Montana (fig. 1). The Canadian border forms its northern boundary, and the 115th meridian marks the eastern boundary. The portion of the Stryker quadrangle mapped in this investigation lies north of latitude 48°30', south of 48°45', and south of U. S. Highway 93. This includes most of the southwest Stryker 15-minute quadrangle and the southwest corner of the southeast Stryker 15-minute quadrangle. The total area mapped is approximately 260 square miles.

Access to the area is made possible by U. S. Highway 93. Departing southward from Highway 93 are both county and Forest Service roads that give general access to most of the area. Logging roads provide further access and excellent exposures throughout the quadrangle; Forest Service trails are valuable for ridge traverses and remote areas. The county and Forest Service improved light duty roads are usually impassable from late fall to early spring because of snow.

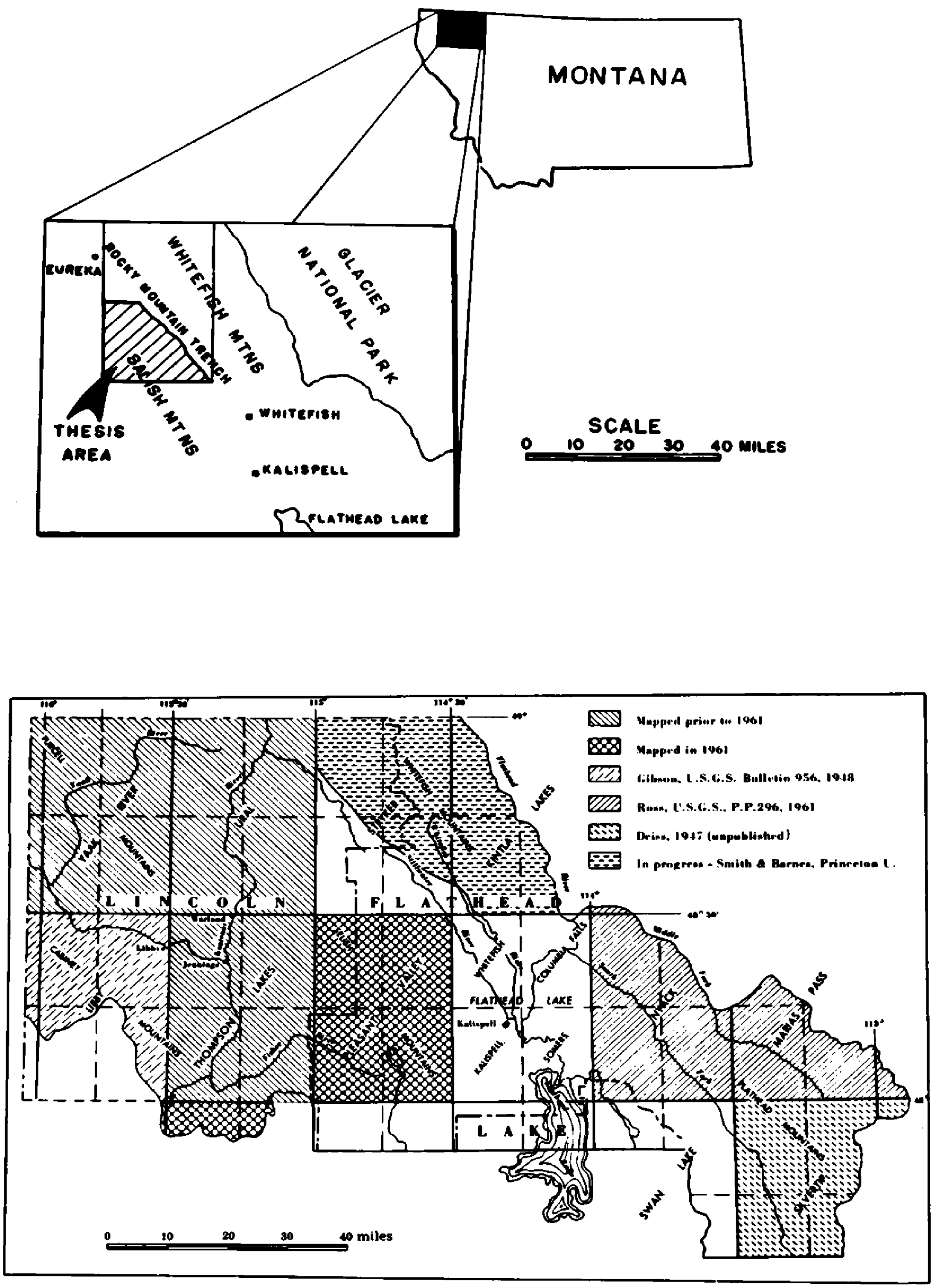

Figure 1. Index map showing location of map area. Lower map taken from Montana Bureau of Mines and Geology Bulletin No. 24.

The Basin Creek-Sunday Creek road runs from the north-east side to the southwest corner of the area and provides a good cross section of the geology. The Martin Creek road serves a similar function in the southeast corner of the mapped area.

Both the Lincoln County-Flathead County boundary and the Kootenai National Forest and Flathead National Forest boundaries are in the area of investigation.

PREVIOUS WORK

Previous work in the SW and SE 15-minute Stryker quadrangles consist of regional reconnaissance mapping in Flathead-Lincoln Counties by G. S. Lambert and associates for the compilation of the state Geologic Map of Montana (1955). North of U. S. Highway 93 in both quadrangles, the geology has been mapped by William Barnes and Alan Smith, Princeton University graduate students, and will be published by the Montana Bureau of Mines and Geology. A study of the glacial geology made by W. C. Alden (1953) is primarily confined to the valleys in the mapped area. Another regional study is that of R. A. Daly (1912) in which he mapped the geology along the 49th parallel from the Cascade Mountains to the Great Plains.

Under the direction of W. M. Johns of the Bureau of Mines and Geology, a geologic reconnaissance project has been underway since 1958. The four 30-minute quadrangles that have been completed under this project are: Yaak River (Johns, 1959), Thompson Lakes (Johns, 1960), Ural (Johns, 1961), and Pleasant Valley (Johns, 1962). The NW 15-minute Thompson Lakes quadrangle was mapped by L. P. Beer (Johns, 1960) in 1959. A. Sheldon (1961, unpublished master's thesis, Montana State College) mapped the NW 15-minute Ural quadrangle and D. Sommers (Johns, 1961) mapped the NE 15-minute Ural quadrangle.

F. W. Hall (1962, unpublished master's thesis, Montana State University) mapped the NW 15-minute Pleasant Valley quadrangle directly south of the SW 15-minute Stryker quadrangle, and F. V. Latuszynski (1962, unpublished master's thesis, Montana State University) mapped the SW 15-minute Pleasant Valley quadrangle, both in 1961.

PRESENT STUDY

This investigation is part of the Kootenai-Flathead mineral survey, a program jointly sponsored by the Pacific Power and Light Company and the Great Northern Railway Company and under the direction of the Montana Bureau of Mines and Geology. The purpose of the project is to make a geologic reconnaissance of the Kootenai-Flathead area and assist in the location and development of mineral resources. The present study area is one of the final areas to be mapped under this six-year project (June, 1958, to June, 1964).

Between June and October of 1962, a total of 78 days were spent mapping, plus an additional two days in November, 1962. Most of the traverses were made by foot, partly because of poor transportation. Due to the scarcity of outcrops in the map area, no regular distribution of traverses was possible. In most cases traverse directions were determined by the availability of outcrops, since much of the area is covered with glacial till.

Aerial photographs (1:20,000 scale) taken in 1954 and 1955 by the U. S. Department of Agriculture Commodity Stabilization Service were used for planning traverses, and locating and interpreting geologic data. Field data were plotted directly on U. S. Forest Service planimetric maps (2 inches to the mile) and later transferred to a one inch to the mile U. S. Forest Service planimetric map for this report. Topographic control for making cross sections was obtained from the 30-minute Stryker quadrangle, Department of the Interior, U. S. Geological Survey (edition of 1916).

Laboratory work included a sedimentary petrographic study of the various Beltian rock types and stereographic plot of joints. Rock types selected for study represent the geologic section in various parts of the area. X-ray diffraction analyses were also made on some of the samples to determine the types of minerals.

ACKNOWLEDGEMENTS

The writer gratefully acknowledges the financial support of the Montana Bureau of Mines and Geology and permission to use the data collected while employed by the Bureau for this thesis.

The writer is indebted to a number of people who assisted with this investigation in various ways. Special thanks are due Mr. and Mrs. Earl Scott, Mr. Buck Calvert, members of the Ant Flat Ranger Station, and the Montana Stillwater Ranger Station for invaluable assistance. Many fruitful discussions were held with Mr. Willis M. Johns of the Bureau and with Alan Smith and William Barnes of Princeton University.

Professors Donald Winston, Robert Weidman, and Reuben Diettert of Montana State University provided valuable assistance and constructive criticism in the preparation of this thesis. Thanks are also due to Rod McKay and Dwight Maxwell, graduate students of Montana State University, for their help.

PHYSIOGRAPHY

TOPOGRAPHY AND DRAINAGE

The map area is in the Salish Mountains of the Northern Rocky Mountain Physiographic Province (Fenneman, 1931). The trend of these mountains is north to northwest, the same as most of the mountain ranges in northwestern Montana. The Rocky Mountain Trench, described by Daly (1912, p. 26), borders the Salish Mountains to the north and northeast. It forms a large topographic depression (fig. 2) that extends from the Laird River in Canada to the Flathead Valley in Montana, a distance of over 800 miles.

Figure 2. View from ledge of Basal Piegan approximately 300 feet above valley floor looking southeast along Rocky Mountain Trench.

The topography is in either a mature or late mature stage of development and is primarily the result of pre-glacial erosion by streams (Alden, 1953) that cut deeply into the existing uplifted mountains. The canyons of this area were slightly modified by glacial erosion and deposition of glacial debris by the Flathead Glacier during the Pleistocene. The present topography has been formed by recent fluvial modification of the glacial topography.

Elk Divide continues northward from Hall's (1962) area, but branches into two segments approximately one mile north of the Stryker-Pleasant Valley quadrangle border. The westernmost of these branches forms the drainage divide between the Tobacco River and Stillwater River. The easternmost branch forms the southern edge of the trench and contains some of the highest elevations of the area.

The lowest elevation in the map area is about 3,000 feet on the northern boundary of the area east of Murphy Lake. The highest elevation is 6,080 feet in the southwest corner of the area on the flank of Davis Mountain. Relief over most of the area is 800 to 1,000 feet; however, that between Davis Mountain and Fortine Creek is more than 2,000 feet.

Streams west of the major drainage divide flow into the Tobacco River, which is a tributary of the Kootenai River. The principal stream is Fortine Creek, which originates just south of the map area. Two major tributary streams are Swamp Creek and Edna Creek.

The eastern part of the area is drained to the east by the Stillwater River system, which begins in the Whitefish Range north of the map area and flows south into the Flathead drainage. Most of the Stillwater stream channels are in the Rocky Mountain Trench and flow through an interconnected series of lakes. Chief tributaries are Sunday Creek and Martin Creek, both of which are perennial streams.

Drainage patterns in the western and southern parts of the area are dendritic. On the northeast, adjacent to, and within the trench, stream patterns are structurally controlled. Examples of this are: Martin Creek along the Martin Creek thrust; Stillwater River in the trench; and Cripple Creek south of Dickey Lake.

CLIMATE AND VEGETATION

Precipitation and temperature records are not available for the map area. However, records have been obtained from the U. S. Weather Bureau at the Kalispell County Airport. Local residents report higher snowfall in the trench area than in the Kalispell area, with drifting snow common along the highway.

Mean annual precipitation reported for the Kalispell area for the period between 1921 to 1950 is 16.38 inches. For a 30-year period, the mean annual temperature is 43.2°F. The highest temperature recorded in the last 40 years is 104°F in 1960 and the lowest is -38°F in 1950. Over an eleven-year period, the seasonal snowfall averaged 68.3 inches.

The area is covered with both deciduous and evergreen trees; the deciduous trees grow along the valley bottoms, and the evergreens are confined mainly to the smooth mountain slopes. Native grasses such as timothy, quack grass, and fescue flourish on the fertile soil produced on the Pleistocene glacial sediments. Sedges and rushes occur around the lakes and rivers throughout the Rocky Mountain Trench. Lichens and mosses form lush growths on the striated glacial surfaces.

GLACIATION

Both erosional and depositional effects of Pleistocene glaciation exist throughout the map area. According to Alden (1953) a tongue of ice moved southward from Canada towards the map area during the Late Pleistocene. As this tongue moved southward, it increased in size by additions of ice from surrounding valley glaciers. The enlarged tongue grew until it became a large ice sheet that covered much of northwestern Montana, including the map area. Alden (1953, p. 115) refers to this glacier as the Flathead Glacier.

Glacial erosional effects in the area consist of striations, flutes, polish, and grooves. Glacial striations (fig. 3) commonly occur on ridges, along Fortine Creek, and along the Rocky Mountain Trench. They indicate directions of ice movement that range from S. 10° E. on the west to S. 35° E.

on the east (fig. 5). Most of these striated surfaces are also polished. Glacial grooves occur along Highway 93 near Stryker. Drumloidal flutings (Alden, 1953) are found along the Rocky Mountain Trench (fig. 4). These low mounds are covered with striations parallel to their long axes.

Figure 3. Glacial striations on surface of vertical beds of the Ravalli Group east of Fortine Creek. View southeast along direction that glacier moved.

Depositional features include glacial drift, moraines, drumlins, erratics, and lacustrine silts. The glacial drift (fig. 6) consists of unconsolidated pebbles, sand, and silt, that is locally stratified. In an outcrop along Fortine Creek, there is 30 feet of stratified till containing boulders up to 2 feet in diameter. Some of the beds are well sorted gravels, probably stream-deposited, outwash gravels (fig. 7).

Drumlins trending S. 35° E. are found in the northwest corner of the area and along the Rocky Mountain Trench (fig. 5). Several of these drumlins appear to have cores composed of Beltian rocks, which dip to the southeast, opposite to the regional structure. In fact they may be large transported blocks in the glacial drift. Large erratics are found sitting on, and in the drift south of Olney in the eastern part of the area. Lake silts are less common than the drift. They are best exposed east and south of Dickey Lake and north of Olney, and are up to 25 feet thick.

Figure 4. Stoss side of a drumloidal flute carved in the Grinnell Formation on the floor of the Rocky Mountain Trench.

An interesting aspect of the glaciation is the direction of movement of the ice sheet over the map area. A generalized

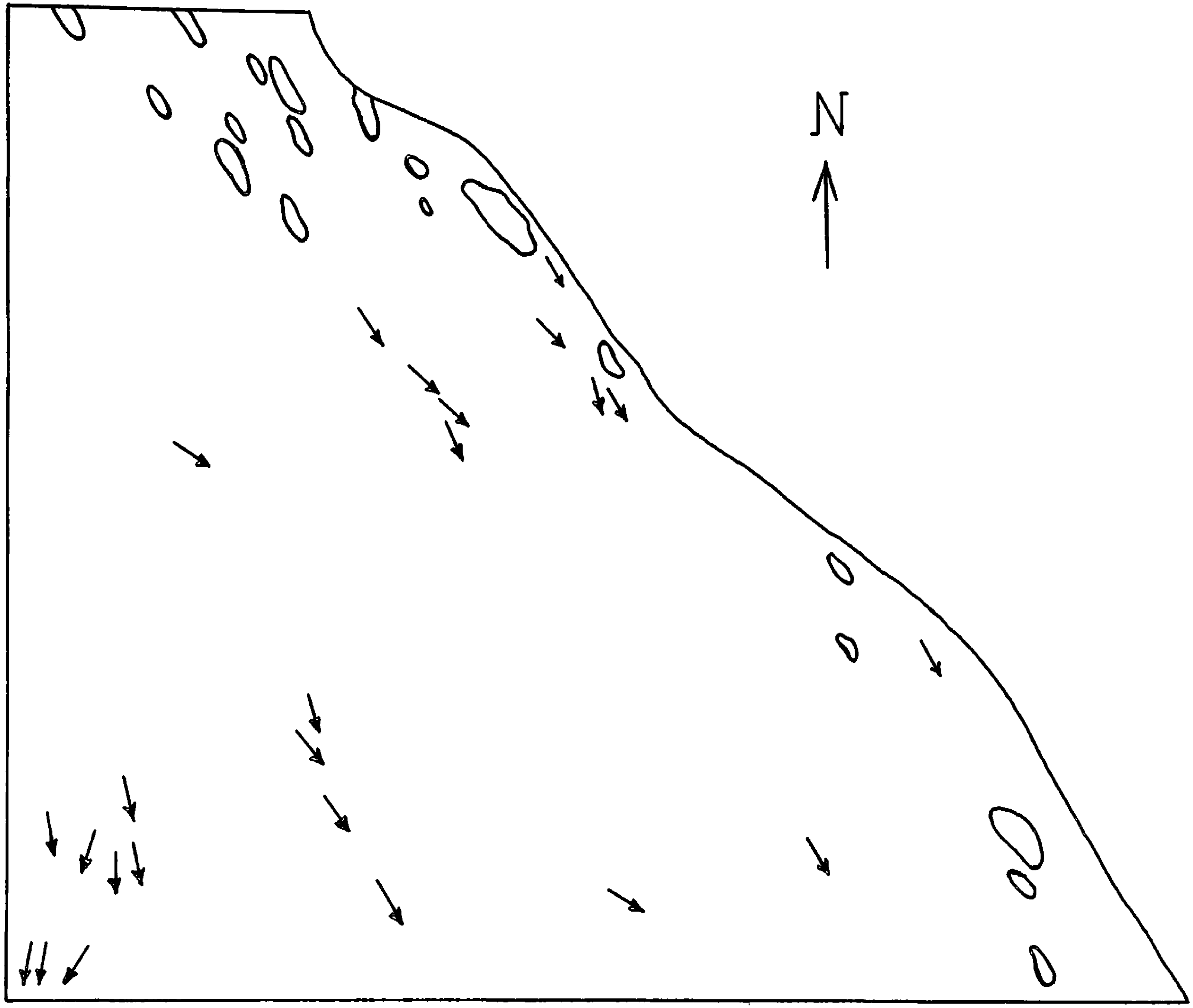

Figure 5. Map showing generalized glacial movement in the map area. Arrows indicate the direction of glacial striae and oblong circles represent drumlins.

Figure 6. Unconsolidated glacial drift exposed along Fortine Creek. Note hat for scale.

Figure 7. Sorted, stratified glacial stream deposits along Fortine Creek.

direction of movement can be depicted for the ice sheet by using the glacial striations (fig. 5) and the trends of the drumlins and drumloidal flutings. According to Alden (1953), the initial glacier moved down the Rocky Mountain Trench until it reached the vicinity of Rexford, where the ice lobe divided. One lobe extended down the Kootenai River Valley, and the other continued down the Rocky Mountain Trench toward the map area. South of Eureka where the trench is six to seven miles wide, drumlins and drumloidal flutings indicate a southeast direction of ice movement.

However, south of the Trego area, where the trench narrows abruptly to two miles, the glacier was forced to split into parts. One lobe continued down the trench, another up the Fortine Creek drainage, and still more ice moved southward over the mountain mass. With added ice and debris from the Whitefish Range, plus continual additions from the parent ice tongue, the entire area was soon inundated by the glacier. Striations are found on the highest peaks, and glacial drift fills the highest canyons.

In the Twin Meadows area, T. 32 N., R. 26 W., striations are found on the valley floor and high on the flank of Davis Mountain, which indicates a minimum thickness of 2,100 feet for the ice sheet.

As the Flathead Glacier began to recede, it left recessional moraines. In the map area, one of these moraines between Stryker and Dickey Lake divides the Kootenai River drainage from the Stillwater drainage. A lobe of the Flathead Glacier and this moraine probably dammed a lake that extended over much of the Fortine and Swamp Creek drainages, where thick sequences of lacustrine silts are exposed in roadcuts along the creeks.

STRATIGRAPHY

GEOLOGIC SETTING

Mountain ranges and broad intermontane valleys characterize northwestern Montana. Their general trend is N. 25° W. (McMannis, 1959). Underlying most of the region is a thick sequence of Precambrian sedimentary rocks called the Belt Supergroup (American Commission on Stratigraphic Nomenclature, 1961). These rocks are composed of argillites, quartzites, and carbonates. Paleozoic rocks overlie the Belt Supergroup at scattered localities in northwestern Montana, but most of these have been removed by erosion. The intermontane valleys contain Quaternary glacial and stream deposits.

Fold axes and faults parallel the northwest trend of the mountains of this region. The folds range from gently to tightly folded, and the faults are both normal and reverse. The Rocky Mountain Trench forms the northeastern boundary of the map area. This feature has been traced from the Laird River in Canada, to Kalispell in the Flathead Valley (Eardley, 1951). Both normal and reverse faulting have been postulated as the cause of the trench (Daly, 1912; Evans, 1932).

PRECAMBRIAN (BELT SUPERGROUP)

Sedimentary rocks exposed in the map area are part of the Precambrian Belt Supergroup and have a thickness of more than 12,000 feet. For this investigation, the Belt sedimentary rocks were divided into two groups, the Ravalli Group below and the Piegan Group above (fig. 8). This division corresponds to the work of Fenton and Fenton (1937, pp. 1880-1900), Johns (1959-62), Sheldon (1961), and Hall (1962). Neither the Prichard Formation below the Ravalli Group nor the upper strata of the Piegan Group are exposed in the map area. Therefore, the base of the Ravalli Group and the top of the Siyeh Formation (middle Piegan Group) could not be delimited and the total thickness of these units could not be determined. Unconsolidated glacial sediments are widely distributed over the area.

The boundaries between the Beltian formations in the map area are transitional. Faults and glacial cover in the Rocky Mountain Trench make it difficult to place oneself stratigraphically in any one of these interbedded transition zones. A more detailed study may justify a further subdivision of the Grinnell Formation of the Ravalli Group into members similar to those described by Fenton and Fenton (1937).

Before discussing the Beltian stratigraphy, it appears advisable to define several terms that are used in the following pages. In order to standardize the lithic descriptions of the rock units, classifications proposed by Folk are used throughout. These classifications appear in the appendix or their original descriptions have been cited.

The term argillite (Twenhofel, 1936-1937) is defined as

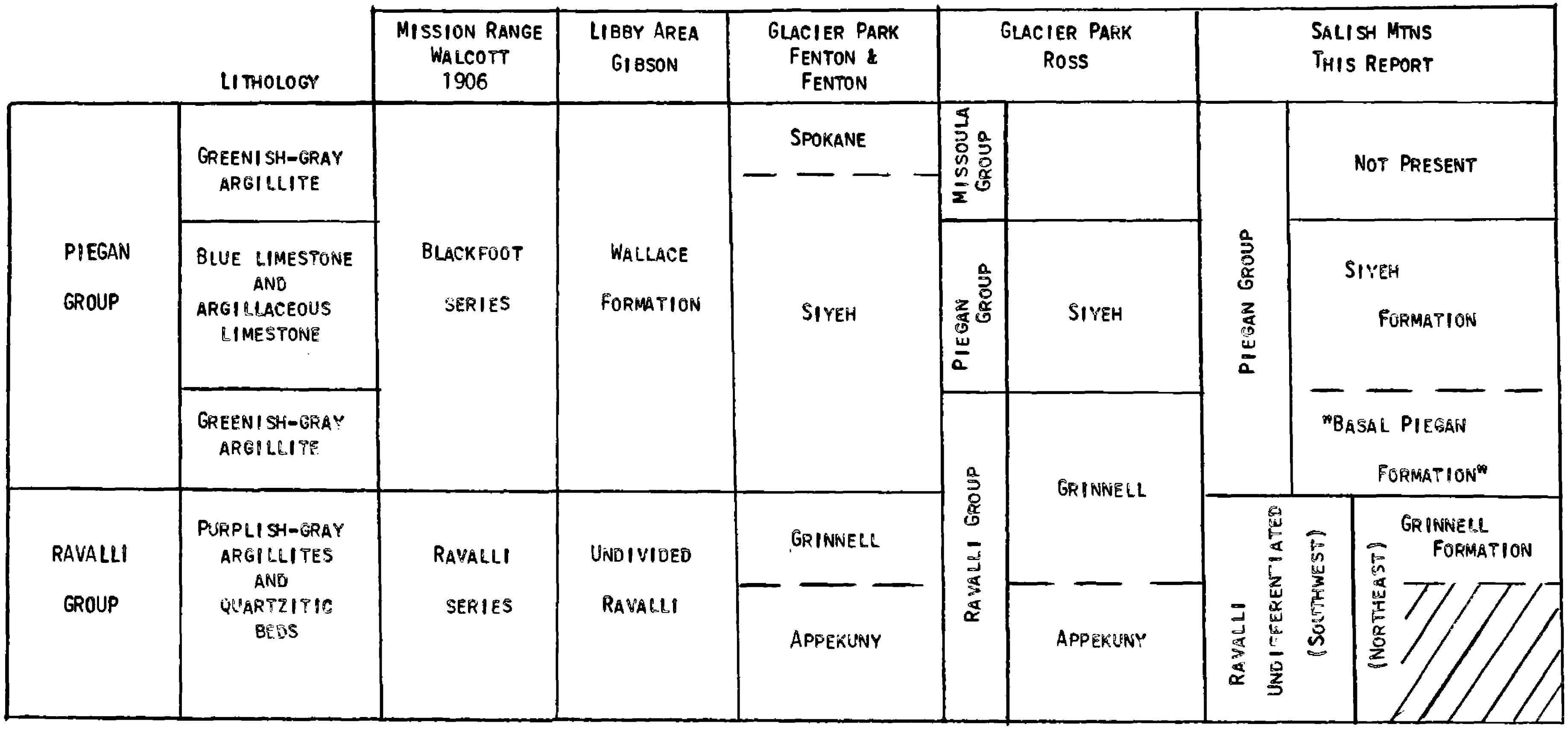

Figure 8. Diagram of historical development of Belt nomenclature. Horizontal lines are not necessarily isochronous.

> . . . a rock derived either from siltstone, claystone, or shale, that has undergone a somewhat higher degree of induration than is present in those rocks. Argillite holds an intermediate position between the rocks named and slate. . . .

Megascopically, the term argillite was used in describing rock units during the field mapping. However, under the microscope, enough of the original mineralogy and structures are present to justify the use of Folk's classification of clastic sediments (1954, pp. 345-351). This classification is presented in diagram form in Appendix I.

The grain size scale used is the Wentworth scale (Wentworth, 1922). Powers roundness images (Powers, 1953) were used to determine roundness of sand grains. Rock colors were standardized in the field and lab by using The Geological Society of America Rock Color Chart (Goddard, et al., 1951). McKee and Weir's (1953) terminology for describing stratification in rock units was followed in field descriptions (Appendix II).

The term "boundary" is preferred over the word "contact" in describing the relationships between the lithologic units of the Belt. Boundary is defined in the American College Dictionary as "something that indicates bounds or limits." The meaning of this term is closer in describing the transitional units of the Belt than the word contact, defined as "state or fact of touching; a touching or meeting of bodies." Although two units are meeting, no exact contact can be drawn.

Ravalli Group

The name "Ravalli" was used initially by C. D. Walcott (1906, p. 20) for a unit of 8,255 feet of purple, greenish, and gray siliceous arenaceous beds along Jocko Creek, about one mile southeast of Ravalli, Montana. Calkins, in mapping the Purcell, Cabinet, and Bitteroot Mountains (1907, p. 38) used the term Ravalli Group to designate an undivided sequence of rocks that corresponded to the previously named Burke Formation, Revett Quartzite, and the St. Regis Formation of the Coeur d'Alene district. Calkins was unable to differentiate these units and therefore used Ravalli Group to designate the sedimentary rocks between the Prichard Formation and the Wallace Formation (Piegan Group in this report).

In the Libby and Trout Creek quadrangles, Gibson et al. (1941, p. 368) continued to use the term Ravalli Group undifferentiated. This same usage has been continued in the quadrangles mapped for the Kootenai-Flathead project by Johns (1959-62), Sheldon (1961), and Hall (1962). The sedimentary rocks of the Ravalli Group in the southwest corner of the present map area could not be differentiated into the formations recognized in the Coeur d'Alene district. Therefore, these rocks are referred to in this report as the Ravalli Group undifferentiated. Hall (1962, p. 28) suggests that future workers may be able to subdivide the Ravalli Group into three mappable units in the NW Pleasant Valley quadrangle.

Along the northeastern boundary of the Salish Mountains in the Rocky Mountain Trench, the Ravalli Group differs lithologically from that of the southwest corner (Gilmour, 1963). Because of this difference, the two areas are described separately.

SW Stryker Quadrangle. Ravalli rocks crop out along Fortine Creek in the southwest part of the SW Stryker quadrangle. In the nearly 30 square miles of Ravalli rocks mapped in this area, the Ravalli section is not complete. The base of the Ravalli Group is not exposed, and because of faulting, the middle part of the group is missing. Bedrock is commonly obscurred by glacial deposits and vegetation. The uppermost Ravalli is well exposed along Fortine Creek road and Twin Meadows road, where beds are vertical (fig. 3).

On the southeast flank of Davis Mountain, the quartzites of the Ravalli Group form resistant ledges. This is characteristic of Ravalli quartzites over much of northwestern Montana (Sheldon, 1961, p. 16; Hall, 1962, pp. 27-28; Johns, 1959-62). The resistant ledges are on the antidip slope of the northwestward plunging Elk Mountain anticline (Plate 1). This slope should contain the contact between Hall's (1962, p. 28) lower and middle Ravalli Group. But because both of these units are highly quartzitic and generally cover the underlying slopes with talus, and because of the thick vegetation cover, the Ravalli could not be subdivided into units.

Megascopically, the Ravalli Group consists of interbedded argillites, sandy argillites, and quartzites. These rocks vary from different shades of gray to greenish-gray and purplish-gray. The quartzites tend to be gray and the argillites are commonly greenish- or purplish-gray. Stratification (Appendix II) also varies in the Ravalli Group. Generally, the quartzites are thin- to thick-bedded and the argillites are laminated to thin-bedded. The stratification of laminated and very thin-bedded argillites is emphasized by the alternation of purplish with greenish beds or laminae. This is especially characteristic of the uppermost 3,000 to 4,000 feet of the Ravalli.

In thin section, the upper Ravalli sediments east of Fortine Creek road consist of about 70 percent silt and 30 percent clay. A small percent of very fine sand occurs in the basal parts of microscopically graded laminae. These graded laminae pass upward into medium silt. Using Folk's (1961) terminology, the textural name for these sediments is very fine sandy mudstone. Included in these graded laminae are scattered rounded intraformational pebbles of clay-sized material, similar in general appearance to the clays between the graded laminae. In thin section, these pebbles along with mica flakes and a few quartz grains appear to be imbricated, and indicate a southeastward direction of the transporting medium, possibly offshore currents. However, interpretation is tenuous, because of the limited number of thin sections available for examination.

The total size range of these sediments is from clay to 0.21mm (fine sand). They are poorly sorted immature mudstones (Folk, 1961; Appendix I). The grains are bimodal; one mode is clay, the other is medium silt.

Small sand filled tunnels that occur throughout the clay and silt of sample 7-62-1 are probably evidence of burrowing organisms. Grains of sand from graded laminae may have been dragged into the burrows, completely filling them. These burrows are irregular in shape and range in diameter from 1mm to 8mm. Recent structures similar to these have been described by Moore and Scruton (1957).

Quartz, which comprises more than 90 percent of the sand and silt grains, is mostly common quartz (Folk, 1961) and occurs as single grains or as parts of rare composite grains. Extinction is straight to slightly undulose (Folk, 1961). Scattered stretched metamorphic grains comprise less than two percent, occur in most of the thin sections.

Some of the subangular composite grains contain well rounded grains of quartz (fig. 9). These grains indicate that the composite grains were derived from a pre-Ravalli sedimentary rock in which well rounded quartz grains had been cemented by quartz. Subsequent erosion of the sedimentary rock produced the subangular composite grains deposited in the Ravalli.

Feldspar, mainly plagioclase, comprises less than 5 percent of the sand and silt. Although evidence is not conclusive, the distribution of clay minerals around the feldspar grains suggests that the feldspar was altered in place. Quartz grains surrounding the feldspar are in point contact with other quartz grains without clay particles in between them. But between the feldspar grains and quartz grains, there is a coating of clay. Some of the mica flakes found in the sand and silt fractions are probably detrital.

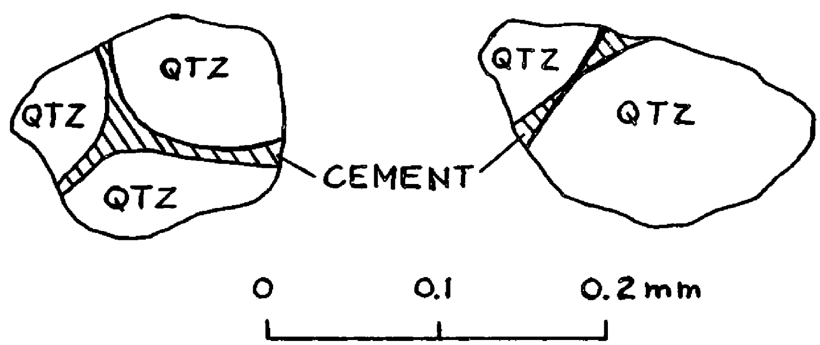

Figure 9. Composite quartz grains with rounded particles cemented by quartz.

For the rocks in the southwest part of the SW Stryker quadrangle the writer prefers to use Ravalli Group undifferentiated as adopted by Calkins (1907). Although in a future detailed stratigraphic study of this area, one may be able to discern a three-fold division of the Ravalli Group, the writer did not identify such a division. Since the environment of deposition for much of this section appears to have been uniform, the rocks are rather homogeneous and the Ravalli Group designation is best suited for this area. This is in accord with Johns (1959-62), Gibson, *et al.* (1941), Sheldon

(1961), and Hall (1962) who have mapped west and south of the map area.

<u>Rocky Mountain Trench Area</u>. The upper Ravalli Group along the northeastern boundary of the Salish Mountains differs lithologically from that of the southwest corner of the SW Stryker quadrangle. Only the upper 1,500 feet of the Ravalli Group is found in the trench south of Highway 93. In both areas the Ravalli Group is overlain by a series of greenish-gray, dolomitic argillites. The true thickness of the upper Ravalli is difficult to determine because of the large number of small faults, poor accessibility, and thick vegetation. Except in the northern part of the trench near the town of Stryker, the boundary between the Ravalli Group and the Piegan Group is a fault contact.

Rocks of the Ravalli Group exposed in the trench area are lithologically similar to the Grinnell Formation of the Livingston Range. The Grinnell "argillite" was named by B. Willis (1902, pp. 322-323) for 1,800 feet of red, sandy argillite on Mount Grinnell in Glacier National Park. Fenton and Fenton (1937, pp. 1887-1890) also used the Grinnell terminology. W. Barnes and A. Smith have used the Glacier National Park terminology for the Ravalli Group in their recent study of the Whitefish Range. On the other hand, Ross (1959) includes greenish-gray, calcareous argillite above the reddish, sandy argillite in the Grinnell Formation (fig. 8), and restricts the Siyeh Formation to the blue-gray, molar tooth limestone. Because the boundary between the reddish argillite and the greenish, dolomitic argillite is more easily mapped than the boundary between the green, calcareous argillite and the limestone, the term Grinnell Formation is applied in this report in the same manner as by Fenton and Fenton (1937).

Although some geologists claim that there is a sharp lithologic contact between the Grinnell Formation and the "Basal Piegan Formation" throughout northwestern Montana, the writer has not found this true in the Rocky Mountain Trench of the map area. The transition zone consists of interbeds of red and green argillite and is well exposed on the south flank of Stryker Peak in the Whitefish Range. This relationship was pointed out to the writer by A. Smith who mapped in the Whitefish Range. The same relationship is evident traversing the trench. In the small hills in the trench, it is common to pass vertically through several sequences of greenish-gray and purplish-gray argillite in a vertical distance of 300 feet. A large part of the Rocky Mountain Trench in the map area is composed of this transition zone. For convenience of mapping, all of the purplish-gray argillite is included in the Grinnell Formation except for the uppermost interval of that color, which is dolomitic. This uppermost argillite overlies nearly 200 feet of greenish-gray dolomitic argillite, and is therefore included in the "Basal Piegan

Formation."

The Grinnell Formation is composed of argillite and sandy argillite with stringers of sandstone. The argillite is purplish-gray except in the boundary zone between the Ravalli Group and the overlying Piegan Group where some beds are greenish-gray. The sandstone is commonly white but may appear purplish or greenish, depending on the argillite content. These sandstone stringers are commonly cross-bedded and contain intraformational clay pebbles. Most of the sand layers are 1 to 6 centimeters thick; however, some attain a thickness of 20 centimeters.

Two distinct textures are represented in the Grinnell. One is a bimodal sediment composed of clayey silt and varying amounts of medium sand, and the other is a unimodal medium sand. The bimodal sediments contain from 10 to 70 percent sand and from 30 to 90 percent clayey silt, which itself is composed of 70 percent silt and 30 percent clay.

Sand grains range from 0.06mm to 1.10mm with a mean size of 0.40mm (medium sand). These grains are subround to round and thus indicate a high energy source such as dunes or beaches but not rivers. According to Kuenen (1952) little or no rounding of sand particles is accomplished by rivers. Solitary rounded sand grains commonly occur along bedding planes within the silts and clays. The layered silts have a mean size of 0.03mm (coarse silt) and are angular to subangular. The textural name of these sediments is immature coarse silty medium sandstone to immature medium sandy mudstone.

The unimodal sands have a mean size of 0.40mm. They form well sorted, subround to round, supermature medium sandstone. The supermature sands occur as interbeds in the silt and clay. Flat pebbles of clay and silt, probably derived from the underlying beds, occur in the sand layers.

The mineral composition of the sand and silt grains averages 90 percent quartz and 10 percent feldspar. Common quartz comprises over 80 percent and stretched metamorphic quartz grains comprise less than 5 percent of the total sediment. Both orthoclase and plagioclase are present. The mean size of the rounded feldspar grains is less than that of the neighboring quartz grains. Quartz overgrowths usually cement the supermature sand layers. Less common is calcite and secondary dolomite cement.

From the foregoing description of the bimodal and unimodal sediments, the similarities are marked. The sand grains have a mean size of 0.40mm and are subround to round in both textural types. Although the sand content varies in the bimodal sediment, the silt to clay ratio is constant. The silt-clay component probably represents the material that was continuously deposited over much of the area whereas the supermature sand grains were transported into the area of deposition only sporadically.

Cross-beds, ripple marks, and mud cracks are found in the Ravalli. All three features characterize the purplish-gray argillites and supermature sandstone beds of the Grinnell Formation. However, in the southwest corner (Ravalli Group undifferentiated), these features are much less abundant, especially mud cracks and crossbeds. Well-developed ripple marks trend northwest in the southwest map area.

In comparing the Ravalli Group of the SW Stryker quadrangle to the Ravalli Group (Grinnell Formation) of the Rocky Mountain Trench, a number of similarities and differences are evident. The silts of both localities are similar in shape and composition, but differ slightly in mean size. The mean silt size on the west is medium, whereas that of the east is coarse. The silt to clay ratio is about the same (50-70 to 50-30). Rounded sand grains are abundant in the northeast part of the area but are absent in the southwest part. These two areas appear to be similar in their environment of deposition interpreted from silts and clays (except for the slight increase in mean silt size), but the eastern area had an influx of dune or beach sand.

The Grinnell Formation of Glacier National Park was compared to the Grinnell of the trench in the map area. Its grain size, shape, and mineral composition in the park is very similar to that of the trench area. In the park it is subround to round, has a mean size of 0.30mm, and is chiefly quartz with a minor amount of smaller feldspar grains.

Therefore, from the limited number of thin sections available, one can postulate that the environment of deposition in the trench and park were similar for the upper Ravalli Group. However, this is not meant to imply that the upper 100 feet of Ravalli in the trench was being deposited at the same time as the upper 100 feet of Ravalli in the park.

Piegan Group

Overlying the Ravalli Group is a series of calcareous argillites and argillitic limestones called the Piegan Group. Fenton and Fenton (1937, pp. 1890-1900) first applied the name Piegan Group to a sequence of argillitic and calcareous beds overlying the Grinnell Formation in Glacier National Park. The type locality is Piegan Mountain in Glacier National Park. Johns (1959, p. 11) has continued to use the name Piegan for mapping purposes in the Kootenai-Flathead project. He correlates the Piegan Group in the Yaak River quadrangle with strata described by Gibson (1948, p. 13) as the Wallace Formation in the Libby quadrangle.

Ross (1959, p. 33) restricted the Piegan Group to include only the bluish-gray limestone in the Glacier National Park sequence. He also restricts the usage of Siyeh Formation to this bluish-gray limestone, thus making the two synonomous (fig. 8). He includes the underlying greenish-gray, calcareous argillites in the Grinnell Formation. Daly (1912, pp. 104-105) in the Whitefish Range and Sheldon (1961, p. 19) in the Purcell Mountains recognize the greenish-gray, calcareous argillites as a mappable lithologic unit above the Grinnell Formation. Because both the green argillite and the bluish-gray limestone are calcareous, they place this unit in the Piegan Group. Sheldon (p. 39) proposed that this unit be given formational rank and be included in the base of the Piegan Group as originally proposed by the Fentons. Sheldon agrees with Ross that the Siyeh Formation should be restricted to the bluish-gray limestone.

Whether the greenish-gray calcareous argillites should be included in the Ravalli Group or the Piegan Group is arbitrary. Because the greenish-gray argillites represent a unit between the Ravalli and Piegan Groups which is transitional vertically (Ross, 1959, p. 30; Sheldon, 1961, p. 18), and possibly also laterally, characteristics of both groups are found in the greenish-gray argillites. For this report, the greenish-gray argillites are placed in the Piegan Group (fig. 8). However, the arbitrariness of this decision will be shown by the following descriptions and discussions.

"Basal Piegan Formation." Predominantly greenish-gray calcareous argillites overlying the purplish-gray sandy argillites of the Ravalli Group and underlying the bluish-gray limestones were mapped as a separate lithologic unit during the investigation. The term "Basal Piegan Formation" is used to designate this lithologic unit with the understanding that W. Barnes and A. Smith (personal communication) will propose a formal name for this unit in their report.

Daly (1912, pp. 104-105) described three lithologic units in the Whitefish Range, the lowest of which correlates with the "Basal Piegan Formation" of this report. His description of the basal unit is as follows:

> 800 feet -- Rocks like those of the upper division (chiefly gray and greenish-gray, medium- to thin-bedded siliceous, often dolomitic metargillite, weathering brown and buff but without red beds or gray limestones; chiefly medium-bedded to thin-bedded green and greenish-gray, highly siliceous, sometimes dolomitic metargillite, weathering light brown, and less often, gray. Many sun-cracks and some ripple-marks occur at various horizons.

Sheldon (1961) describes this unit as the "lower grayish-green argillite unit, locally calcareous, about 2,000 feet thick."

In redefining the Piegan Group, Ross recognizes the transitional calcareous green argillites as he indicates in the following description of the Grinnell Formation (1959, p. 30):

> The uppermost member of the Grinnell argillite commonly consists of grayish-blue-green calcareous argillite and argillaceous limestone, constituting a transition zone below the Siyeh limestone of the Piegan Group. This member contains a few red-purple beds, and the unit below it contains some green beds.

From the above excerpts, one may conclude that most workers recognize that the greenish-gray calcareous argillites are a separately mappable lithologic unit, and represent a transition from the sediments of the Ravalli Group to the sediments of the Siyeh Formation (Siyeh Formation as defined by Ross, 1959, p. 33).

Outcrops of the "Basal Piegan Formation" form two parallel bands in the map area (Plate I). A wide band of gently dipping "Basal Piegan" sediments extends from the southern margin of the area northward to Dickey Lake in the east portion (Plate I). Vertical to overturned "Basal Piegan" strata occupy the area east of the Brush Pass thrust fault in the southwest part of the area. These beds dip more gently in the north part of the area. Where the beds are vertical the formation is more than 2,700 feet thick. In the SE Stryker 15-minute quadrangle, the thicknesses appear to be about the same (Plate I, II).

Beds of the "Basal Piegan Formation" are poorly exposed except in roadcuts or in places where glacial erosion has uncovered fresh bedrock. In several roadcut outcrops the "Basal Piegan" has been weathered to clay. The color of these clays is brown, and the calcareous material has been leached out. Original bedding is preserved. In the northwest part of the SW Stryker quadrangle, the "Basal Piegan Formation" contains more quartz silt resulting in beds that form well exposed resistant ledges.

Megascopically, the "Basal Piegan Formation" consists of dolomitic and sandy argillites. They are commonly light to medium green to greenish-gray, laminated to thin-bedded. Alternating light and medium green layers give a banded appearance to the argillites. Small crossbeds up to one centimeter thick are also differentiated by this same banding. Sand grains are more abundant in the lower part of the "Basal Piegan," whereas calcareous material increases upward in the section. This gradation is not as pronounced in the southwest corner of the SW Stryker quadrangle as in the northeast.

In thin section, the lower part of the "Basal Piegan" is similar to the highest Ravalli in most respects. The unimodal sand layers differ only in that the mean silt is somewhat smaller (0.25mm). The grains are subround to round and range in size from 0.10 to 0.50mm. They are well-sorted, supermature, fine to medium sand. As in the Grinnell, these sands occur interbedded with clay and silt layers.

The fine grained material consists of very fine to medium quartz silt, sericite, chlorite, and dolomite. The quartz silt is similar to that of the Grinnell in composition, size, and shape. Dolomite and calcite increase in abundance upward in the section. X-ray diffraction analyses indicate the composition of these sediments in the basal part of the formation to be quartz, feldspar, sericite, and chlorite. Dolomite and calcite are present in some of the lower strata. Pyrite cubes and limonite pseudomorphs after pyrite occur in the "Basal Piegan." Some of these cubes reach 6 centimeters in width (fig. 10).

Elliptical calcite segregations up to 10 centimeters in length characterize the upper part of the "Basal Piegan."

These segregations are generally aligned parallel to the bedding, but in places lie at an angle to the bedding. Although all the elliptical segregations appear similar on first examination, two types are present and they have two possible origins, primary and secondary. In segregations interpreted to be of primary origin, the enclosing laminae bend around the segregation of calcite. In the segregations interpreted to be of secondary origin, laminae can be traced through the segregation. The material surrounding both types of segregations contains a large percentage of dolomite.

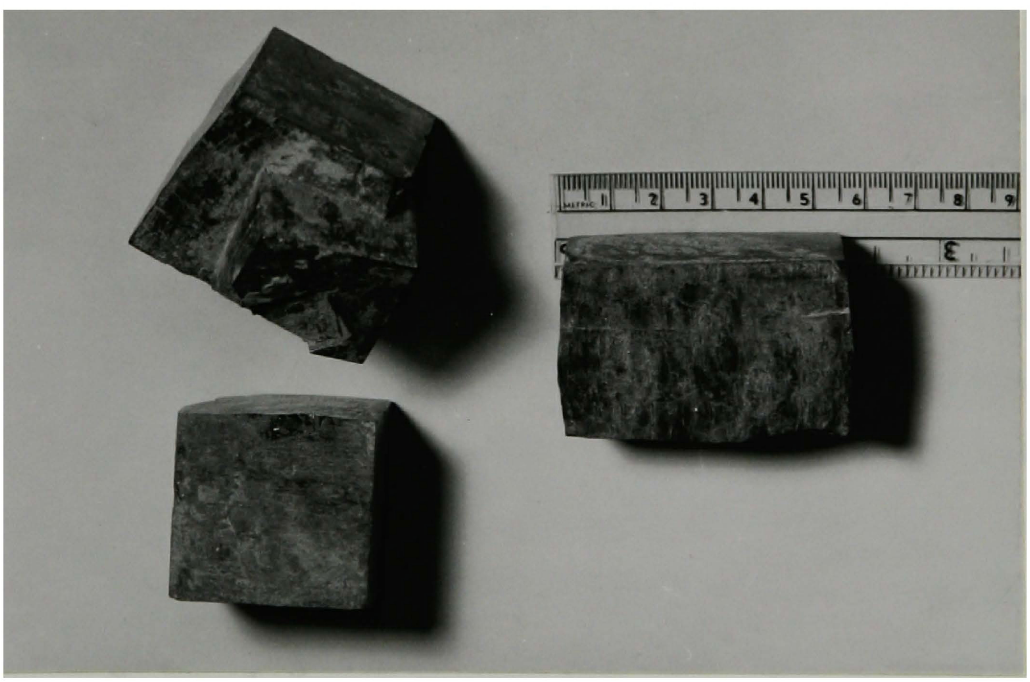

Figure 10. Limonite pseudomorphs after pyrite from the "Basal Piegan Formation."

The calcite segregations weather more rapidly than the dolomite and produce a deeply pitted surface, characteristic of the "Basal Piegan" and the lower Siyeh Formation. The pyrite cubes and limonite pseudomorphs also weather quickly and produce iron-stained, brownish surfaces. Normally, the weathered surfaces of the "Basal Piegan" are various shades of green.

Both symmetrical and asymmetrical ripple marks are present in this formation; their trend ranges from N. 30° W. to N. 10° E. The most frequently observed direction is about N. 15° W. This trend parallels the proposed shoreline of the marine Belt basin of Fenton and Fenton (1937, p. 1939). Mud cracks occur in the lower part of the formation, but not in the upper part.

In summary, the "Basal Piegan Formation" represents a transitional unit between the underlying sandy and silty argillites and the overlying dolomitic and argillitic limestones. In the lower part, the change from Ravalli to Piegan is shown by a color change, a slight reduction in mean grain size, and an increase in dolomite and calcite. However, the mineral compositions and the sorting and shapes of the grains are otherwise very similar. The decrease in stringers of rounded sand grains, general decrease in mean size of silt particles, decrease in mud cracks, and increase in carbonates proceeding up section, may possibly indicate an environment of deposition located somewhat farther offshore than that of the Grinnell Formation.

Siyeh Formation. A series of bluish-gray, argillitic and dolomitic limestones occur above the "Basal Piegan Formation." B. Willis (1902, p. 316) initially applied the name "Siyeh limestone" to a sequence of dark blue or grayish limestone interbedded with argillite at Mount Siyeh in Glacier National Park. This sequence is thought to contain the strata herein designated as "Basal Piegan Formation." Fenton and Fenton (1937, p. 1894) applied the name Siyeh Formation to essentially the same section as described by Willis (fig. 8). However, they divided the Siyeh into four members, the lowest of which (Collenia symmetrica zone) corresponds lithologically to the "Basal Piegan" of this report. The second member in ascending order is the Goathaunt Member and probably represents the lithologic equivalent of the Siyeh Formation of the map area. The third and fourth members, the Collenia frequens zone and the Granite Park Member, are not exposed in the area.

Ross (1959, p. 19) redefined the Siyeh Formation to include only the blue-gray limestone beds of the Glacier National Park section. This is approximately equivalent to the Goathaunt Member and possibly includes the Collenia frequens zone of the Fentons. The Siyeh Formation as restricted by Ross, and later adopted by Sheldon (1961, p. 39) in the Purcell Mountains, is used in this report.

The Siyeh Formation is the most widespread lithologic unit in the map area and covers more than 125 square miles (Plate I). It forms a wide outcrop belt through the center of the area ten miles wide and extends from the southern end of the quadrangles to the Rocky Mountain Trench. Because the upper Piegan rocks were not found in the map area, no complete thickness could be determined for the Siyeh. Maximum thickness determined by cross section (Plate II, section B-B') is about 4,800 feet.

Limestone of the Siyeh Formation forms the highest peaks in the area and crops out extensively on the higher ridges and the steep-sided valleys. Because joint patterns are well-developed, the Siyeh generally appears blocky (fig. 11); however, unbroken massive strata are also present.

Figure 11. Jointed Siyeh Formation with blocky appearance on Keith Mountain in the eastern part of the area.

Weathered surfaces are yellow to brown, depending on the dolomite content. Rocks with the most dolomite tend to be browner. Greenish-gray beds, composed of dolomitic argillite, locally have a weathered reddish-brown coating that ranges from 3mm to over 3 centimeters.

In hand specimen the Siyeh Formation consists of silty, dolomitic argillite, argillitic dolomite and limestone. Color ranges from shades of gray to olive-gray and greenish-gray. The limestones are commonly bluish-gray; the greenish-gray and olive-gray beds are generally more dolomitic. Stratification varies from laminated to thick-bedded.

In thin section the Siyeh is very similar to the "Basal Piegan." However, there is an increase in the dolomite and calcite content, and a reduction in clay. In some beds of the Siyeh Formation, the carbonate content (dolomite and calcite) reaches 50 percent. The quartz and feldspar silt content remains about the same (70 percent). The silt is very fine to medium grained, angular to subangular. X-ray diffraction examination showed no basic changes in mineralogy from that of the "Basal Piegan."

As mentioned previously, calcite segregations are present in both the "Basal Piegan" and the Siyeh Formation. In the Siyeh Formation these segregations are both perpendicular and parallel to the bedding (fig. 13). Hall (1962, pp. 34-36) presents an excellent discussion of these structures. Cubes and pockets of pyrite occur in the centers of the calcite segregations.

The "molar tooth" structure as described by Daly (1912, p. 74) and Fenton and Fenton (1937, pp. 1926-1928) is very rare and only tentatively identified in the map area. What is commonly called "poorly developed molar tooth" by many geologists is widespread in the area. This type is believed to be of inorganic origin. The rocks have a fractured appearance and the fractures appear to be filled with secondary calcite. Sheldon (1961, pp. 23-24) studied these structures in thin section and concluded that secondary calcite had filled the fractures, providing the vein-like patterns found in the Siyeh limestones. He reports calcite fillings cutting across earlier fillings.

An interesting cycle of sedimentation is present in a roadcut in sec. 6, T. 32 N., R. 25 W., in which the aforementioned structures are present. The first unit of this cycle is three feet of "poorly developed molar tooth" that grades upward into about three feet of homogeneous, dark gray, argillitic dolomite (fig. 12). Resting sharply on this unit is two to four inches of a brecciated algal-like limestone and dolomite, overlain by a four-foot bed of calcite segregations; the lower ones are parallel to bedding, and the upper ones are perpendicular to bedding (fig. 13). These perpendicular segregations grade into a second zone of "poorly developed molar tooth" structure. Variations of this cycle such as the absence of some units were noted in other localities.

The change from "Basal Piegan" to the Siyeh Formation is transitional. There is an increase in carbonate and a change from greenish-gray to bluish-gray. The two formations are similar in the types of minerals present, but differ in quantities. Again, as between the Ravalli and the "Basal Piegan," the boundary between these two units is arbitrary.

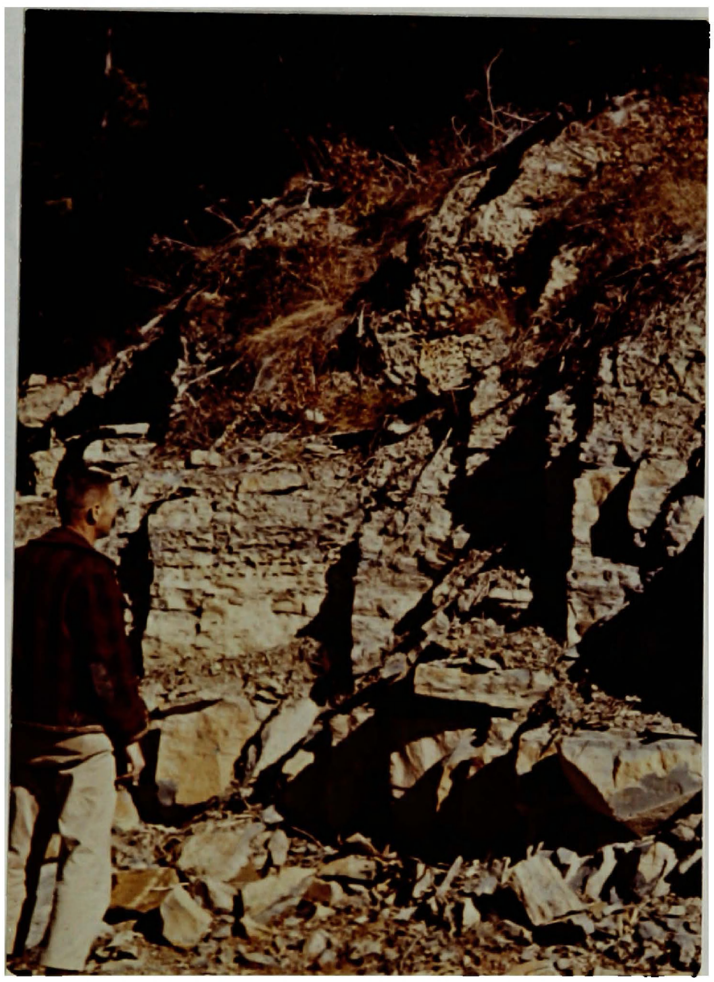

Figure 12. Siyeh Formation showing sequence from homogeneous argillitic dolomite up to "poorly developed molar tooth."

Strata of the Upper Piegan and the Missoula Group found above the Siyeh Formation in much of northwestern Montana has been removed by erosion in the map area.

Figure 13. Exposure of Siyeh Formation with calcite segregations parallel to bedding above pick and grading upward to segregations perpendicular to bedding.

QUATERNARY DEPOSITS

Pleistocene drift and Recent alluvium make up the Quaternary deposits in the map area. These were grouped together as Quaternary glacial deposits (Plate I) for this report. Descriptions and discussions of the glacial drift have been included in the section on Pleistocene Glaciation. The glacial drift is composed of till and outwash gravels.

Lacustrine silts occur in the valleys. These silts commonly overlie gravels and glacial tills.

Recent alluvium consists of reworked glacial material and eroded bedrock. Most of this alluvium is being deposited in and along the present stream channels. Clays, silts, and sands are being deposited in lakes and are included in the Recent alluvium.

STRUCTURAL GEOLOGY

GENERAL

Folds and faults in the SW and SE Stryker quadrangles have the same general structural trends characteristic of structures of northwestern Montana (McMannis, 1959). Both symmetrical and asymmetrical folds commonly strike N. 20° W. to N. 30° W. in the area. Longitudinal high angle normal and reverse faults are the dominant structural features. Several small transverse faults are located immediately west of the Rocky Mountain Trench.

In order to recognize faults in the map area, it was necessary to depend on the apparent displacement on aerial photographs or on the ground. Because of the lack of marker units in the homogeneous Beltian sediments, small faults with minor amounts of displacement may have been missed during the mapping. Criteria for determining faults such as fault gouge, drag, and fault breccia are rarely visible. Lineaments on aerial photographs were helpful in locating fault traces in the field.

FOLDS

The general northwest structural trend in the SW and SE Stryker quadrangles is determined by five major anticlines and synclines (Plate I). Two minor folds are located in the northern part of the map area.

The principal folds are found in the western and southern parts of the SW Stryker quadrangle. The most southwesterly fold is the northwest extension of the Elk Mountain anticline (Hall, 1962). This is a northwestward plunging asymmetrical anticline (Plate I). Dips on its west limb range from 10 to 20 degrees; those on the east limb vary from 60 degrees to slightly overturned. Johns (1962) reports this fold extends into the SE Pleasant Valley quadrangle. The axial trace of this fold occurs in outcrops of Ravalli rocks. On the eastern limb, both Ravalli and Piegan rocks are exposed.

Parallel to the Elk Mountain anticline and adjacent to it on the east is the northern extension of the asymmetrical Ingalls syncline (Hall, 1962). The eastern limb of the Elk Mountain anticline is the common west limb of the Ingalls syncline which continues its trend of N. 25° W. from the NW Pleasant Valley quadrangle. The dip of the east limb of this syncline varies from 5 to 15 degrees. Johns (1962) has traced this fold in the NE and SE Pleasant Valley quadrangle, indicating a total length of about 30 miles. Piegan rocks are found in the trough of the syncline.

A symmetrical anticline lying to the east of the Ingalls syncline plunges northwestward and trends from N. 20° W. to N. 35° W. for a distance of 10 miles. Average dips on both limbs vary from 5 to 15 degrees (fig. 14). The east flank of the Ingalls syncline is in common with the west limb of this anticline. Piegan rocks comprise the entire surface exposure of the anticline. This structure extends southward into the NW Pleasant Valley quadrangle and dies out northward in the vicinity of Beaver Creek.

Figure 14. Looking north at gentle east dipping limb of symmetrical anticline east of Ingalls syncline in the vicinity of Beaver Creek. Rocks belong to the Piegan Group.

Located nearly parallel to the anticline described above and adjacent to it on the east is an asymmetrical syncline approximately 10 miles long. Dips on the east limb of the syncline range from 5 to 25 degrees. The fold trends N. 15° W. to N. 30° W., and its trough is composed entirely of the Siyeh Formation.

An asymmetrical anticline extends into the area from the south along Gergen Creek, through Grouse Mountain, across Martin Creek, and dies out south of Sunday Creek. This fold is named the Grouse Mountain anticline (Plate I). The western limb of the fold has dips that range from 10 to 25 degrees, and the eastern limb dips up to 20 degrees. Sedimentary rocks of the Siyeh Formation cover the flanks and most of the axial region of the fold. In the canyon walls along Martin Creek, "Basal Piegan" rocks are exposed in the core of the anticline. The attitude of the beds is horizontal in the roadcut on Sunday Creek road. This fold was traced for six miles in the SW and SE Stryker quadrangles and may be the northern extension of the easternmost anticline of Johns (1962, Plate I).

A doubly plunging anticline, approximately six miles in length, is located along the western margin of the Rocky Mountain Trench in the vicinity of Sunday Creek (Plate I). Continuing northwestward, the axial trace of the anticline crosses into the trench and disappears under the glacial cover. This structure is named the Jumbo Lake anticline for its proximity to Jumbo Lake. The trend of the fold is N. 30° W., and dips recorded on the limbs range from 5 to 15 degrees. The boundary zone between the "Basal Piegan" and the Grinnell

Formations is exposed in the railroad cuts along the Great Northern railroad tracks, southeast of Dickey Lake in the plunging nose of this anticline.

West of the Jumbo Lake anticline, strata dip westward under the glacial deposits. At the head of Ivor Creek, beds dip northeast at 7 to 13 degrees under the glacial cover. These dips suggest the existence of a northwest plunging syncline in the vicinity of Dudley Slough.

A relatively small symmetrical anticline was mapped north of Edna Creek. The axial trace of this structure crosses Ivor Creek one mile northwest of Edna Creek (Plate I). The fold was traced approximately two miles and has a northwest trend. Average dips on its limbs are 8 to 15 degrees.

FAULTS

Three types of faults were mapped in the SW and SE Stryker quadrangles. The faults of largest magnitude consist of three longitudinal thrust faults, dipping steeply to the southwest. Also important are longitudinal normal faults concentrated in the Rocky Mountain Trench area. Two transverse normal faults are located in the northern part of the area.

The term "normal" fault is used in this report even though it was not possible to determine in the field which side of the fault was the hanging wall. Most of these faults are vertical or near vertical and are believed to have normal displacement.

Longitudinal Thrust Faults

The fault with the largest displacement in the map area is the Brush Pass thrust (Plate I) named by Hall (1962, pp. 41-42). A six mile segment of this fault cuts through the southwest corner of the area. This fault has been traced from Little Bitteroot Lake (Johns, 1962) in the SE Pleasant Valley quadrangle northward through the Ural quadrangle (Johns, 1961; 1962), a distance of at least 70 miles. The northern extension of this fault is called the Gut Creek-Pinkham Creek fault. Johns (1961, p. 29) has reported a stratigraphic throw of 7,000 feet in the Ural quadrangle where Prichard rocks have been thrust against Piegan rocks. The strike of this fault in the Stryker quadrangle is N. 20° W. to N. 30° W., and its dip is southwest. The main evidence for the dip of the fault is the asymmetry of the associated Elk Mountain anticline and Ingalls syncline. Hall (1962, p. 42) reports a disturbed zone dipping approximately 70 to 75 degrees south of the SW Stryker quadrangle. Stratigraphic throw in the map area could not be determined because rocks of the Ravalli Group are found on both sides of the structure. The throw could be as great as 7,000 feet and still produce the same mapped relationship.

A thrust of less magnitude extends northward from Hall's (1962, Plate I) area and was mapped two miles east of the Brush Pass thrust (Plate I). Hall (1962, p. 42) refers to this fault as the Dunsire thrust in the NW Pleasant Valley quadrangle. The thrust appears to die out before it reaches Fortine Creek. Strata west of the fault dip vertically and beds east of the fault are nearly horizontal. The fault zone is characterized by highly fractured rocks and irregular dipping blocks of strata. Siyeh sedimentary rocks are exposed on both sides of the fault and no exact displacement could be calculated. By projecting the base of the Siyeh along cross-section B-B' (Plate I) from its eastern outcrop, the stratigraphic throw is between 500 and 1,000 feet in the Skillet Creek area.

The remaining thrust occurs in the SE Stryker quadrangle along Martin Creek for which the structure is named in this report. The Martin Creek thrust begins in the southeast corner of the map area as a longitudinal fault and gradually changes into a transverse fault south of Ketowke Mountain. Strata on the northeast side of Martin Creek were dragged upward near the fault. The northeasterly inclination of these beds changes from about 20 degrees one-fourth mile northeast of the fault to nearly 60 degrees along the fault trace. The west side has moved up in relation to the downthrown east side. This fault is in "Basal Piegan" strata along Martin Creek and Siyeh strata south of Ketowke Mountain. The trace of the fault varies from N. 30° W. to N. 70° W. for a distance of approximately 8 miles. This fault is not present in the Sunday Creek area.

<u>Longitudinal Normal Faults</u>

Except for the Martin Creek thrust, most of the faults in the vicinity of the Rocky Mountain Trench have normal fault displacements. These faults form horsts and grabens in the trench proper. The main problem in correctly interpreting these faults is that the exposed strata consist of several hundred feet of interbedded red and green argillite belonging to the upper Grinnell and lower "Basal Piegan" Formations. Detailed stratigraphic studies are needed to decide on parameters for distinguishing the various lithologic units in the trench. With this information, the minor faults could be mapped in more detail than presented in this report.

The principal normal fault in the map area extends from the glacial deposits in the southeast to the glacial deposits in the northwest (Plate I). This fault is named the Sunday Lake fault through which it passes. Ravalli rocks on the east side have been faulted against "Basal Piegan" strata on the west. The fault trace, trending N. 35° W., is easily seen as a furrow on the aerial photographs. The amount of displacement along the fault decreases northwestward (Plate I, II). The movement along this fault is characteristic of the faults in the Whitefish Range east of the Rocky Mountain Trench in having the west side down relative to the east side (A. Smith, personal communication).

Two faults southwest of the Martin Creek thrust (Plate I) are normal faults that form a graben one and one-half miles wide. Displacement of this block is greatest in the southeastern part and diminishes northwestward until the displacement is negligible. Because the fault traces of these normal faults form straight lines regardless of topography, their dip is nearly vertical.

The small normal faults southwest of Upper Stillwater Lake have displacements of tens to several hundred feet. Only the two largest faults were included on the map (Plate I). These faults are readily discernable on aerial photographs and are easily checked by field investigation where accessible.

Transverse Faults

Two transverse faults striking N. 75° W. cut the Sunday Lake normal fault in the northern part of the map area. Movement along these faults produced approximately 300 to 400 feet of stratigraphic throw. The block between the parallel faults is upthrown. These faults cause "Basal Piegan" strata to be displaced westward into rocks of the Siyeh Formation on the surface.

The Sunday Lake fault is cut by these transverse faults in the vicinity of Jumbo Lake. Displacement is small compared to most of the faults in the map area.

JOINTS

The most prominent structural feature in both weathered and fresh rock outcrops are the joints which occur in all the Beltian rocks, but are especially well developed in parts of the upper Ravalli and in the Siyeh Formation. The lack of time prevented a detailed study of the joint patterns. However, the poles of 61 joint readings were plotted on the lower hemisphere of an equal area net (fig. 15). These readings represent only the most pronounced joints from the entire map area.

Two principal joint sets are shown in Figure 15. The dominant set strikes about N. 85° E. and dips vertically plus or minus 20 degrees. A less prominent set trends nearly perpendicular to the major trend. Its attitude is about N. 20° W. with dips from 70 to 90 degrees. A third group of points indicates a strike of N. 35° E. This third set may seem minor only because of inadequate sampling. The isolated and grouped nature of the points may indicate a stronger trend.

In the Rocky Mountain Trench, the joints in the Grinnell Formation are commonly filled with thin quartz veins up to several centimeters thick. The joint trends in this area are easily observed on aerial photographs because of the alignment of vegetation. Trees, shrubs, and grasses grow along the joints and produce dark lines on the aerial photographs.

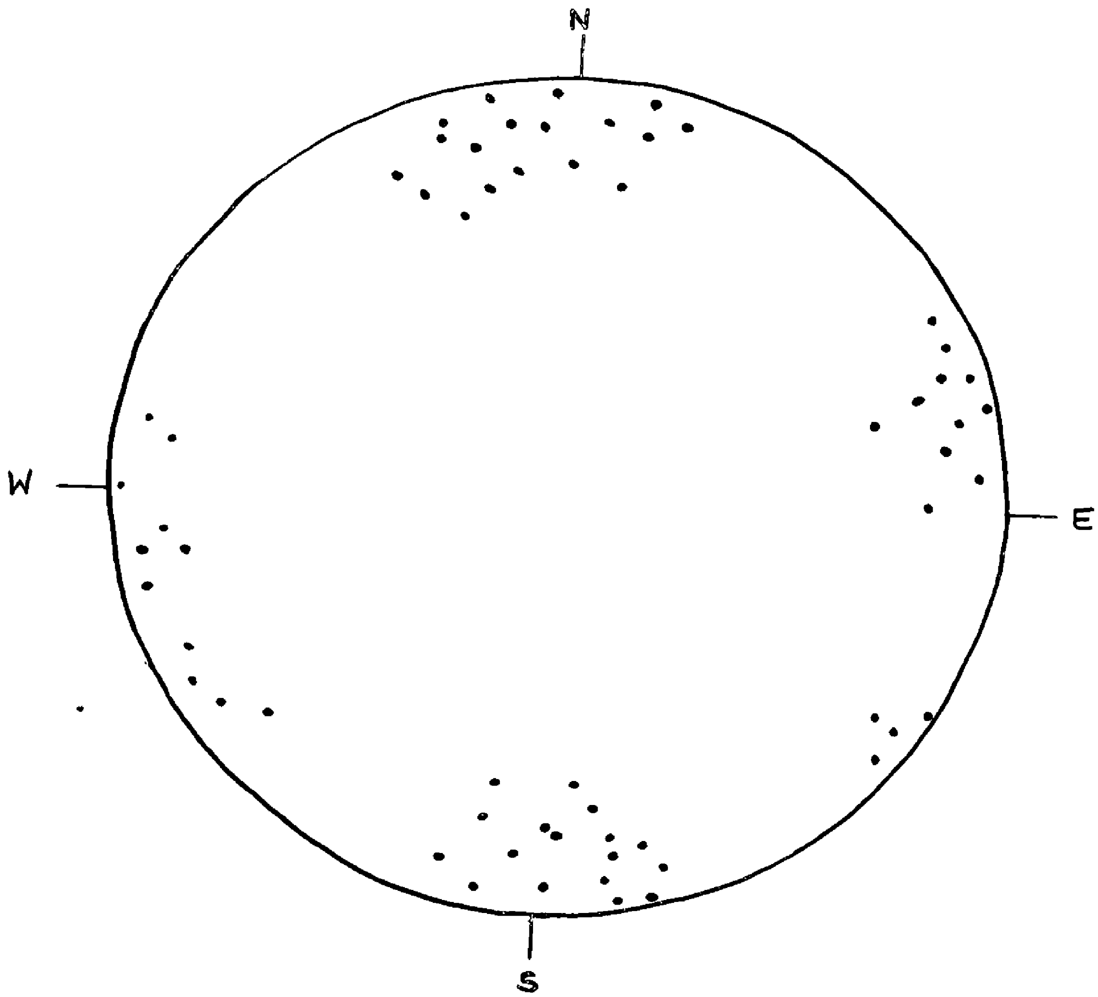

Figure 15. Stereographic plot on the lower hemisphere of the poles of 61 joints.

LITHOLOGIC CHANGE IN THE RAVALLI

The lateral lithic change in the upper Ravalli Group from the southwest corner of the SW Stryker quadrangle to the Rocky Mountain Trench has been described (p. 30). The overlying "Basal Piegan" and Siyeh Formations are individually uniform over the entire area. From this information, it is reasonable to conclude that the Ravalli sediments were deposited under slightly different environmental conditions in the southwest than in the northeast. However, both the "Basal Piegan" and Siyeh Formations appear to have been deposited under more homogeneous conditions throughout the area.

Both areas of Ravalli sedimentation contain the same types of clay and silt, but the northeastern area contains large influxes of coarse sand. The sand forms thin sheets (usually one to six centimeters) that blanket the mud. Roundness and sorting values of the supermature sand grains suggest either a beach or dune source. Because no stream channels were noted in these sediments, it is concluded that the high energy sands of the Grinnell Formation were not deposited by streams. One possible explanation for the blanket nature of these sands is subaerial distribution and deposition. In some poorly graded sand and pebble conglomerate beds, the deposition of the sand appears to have been into a water medium. The indigenous mud surface was broken up and redeposit with the sand. This could have been achieved by the wave action connected with strong winds.

In discussing the history and paleogeography in the next section, an hypothesis for the formation of the Ravalli, "Basal Piegan," and Siyeh lithologic units is presented.

BELT PALEOGEOGRAPHY

Ideas on Beltian paleogeography have been presented by Fenton and Fenton (1937, pp. 1938-1940). The following is a brief summary of their conclusions. The Beltian sea occupied a long and narrow basin that was shallower than any sea existing today. A shallow sea floor such as this would be affected by small waves, local emergence, and subsequent drying of the sediments. The sea would be too shallow for major tides. Precipitation on adjoining lands would have direct effect on the depth and distribution of the sea. Alternating periods of drought and heavy rainfall would produce periodic floods, and consequently, produce sand-mud rhythms such as those of the Grinnell Formation.

The Fentons state that the depth was uniform except during the deposition of the Siyeh, when the western side of the Beltian basin became shallower because of the rapid accumulation of clastics in that area. They state that the transition units from the Appekuny to the Grinnell, from the Grinnell to the Siyeh, and from the Siyeh to the Spokane are all similar in their lithologic characteristics. They conclude that each epoch was terminated by land changes, which resulted in an increased delivery of sediment to the basin. The various lithologies of the Belt Supergroup are then explained by increases or decreases in the deposition of clastic material, with the resulting decreases or increases in the deposition of carbonates. Sedimentary environments were classified as floodplain, estuarine, and marine.

In general, geologists appear to be in accord with the conclusions reached by the Fentons. As stated previously, most workers believe that the boundaries between the Belt formations are vertically transitional. However, many of the workers believe in the "onion skin" idea of formations in which the formations are stacked like pancakes one upon the other. And unfortunately, many of these geologists regard the transitional formation boundaries as time planes! To imagine conditions in which sedimentation over an area as large as the Beltian basin suddenly changes from floodplain to estuarine to basin environments, forming successive blanket deposits is rather difficult.

From examining lithologies in the map area and from reviewing the literature of the Belt formations, a generalized hypothesis for the deposition of the Beltian sediments in the map area follows. The upper Ravalli sediments in the SW Stryker quadrangle were deposited in the shallow water basinal part of the Beltian sea. The lower part of the Grinnell Formation in the Rocky Mountain Trench area, with its stringers of sand, represents the more shoreward deposition in a tidal flat where influx of sand from coastal dunes was heavy (fig. 16). Rounded sand grains were scattered over the tidal flats in blankets by severe winds. Cross-bedding indicates a westwar

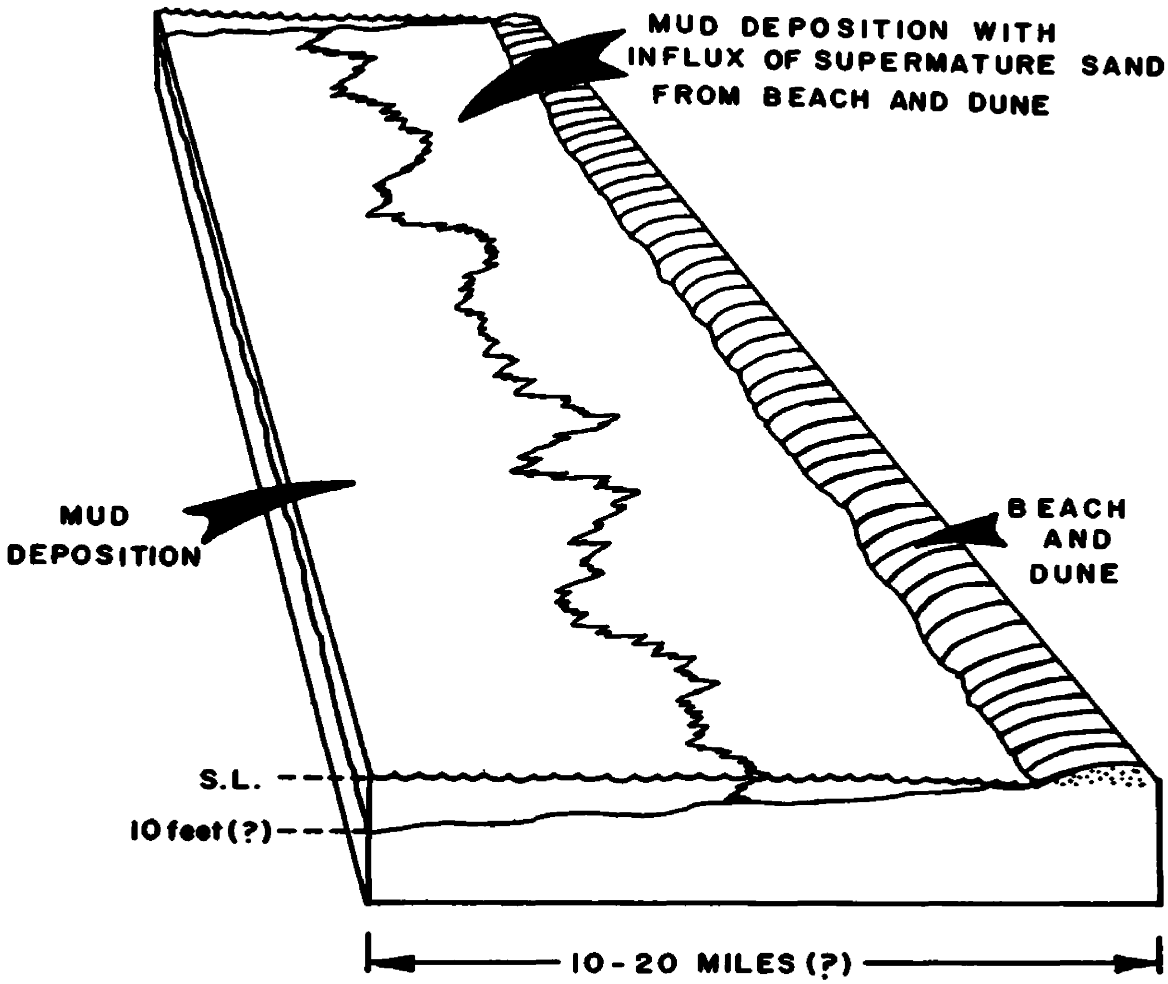

Figure 16. Generalized reconstruction of the environment of deposition for the upper Ravalli Group in the map area (Gilmour, 1963).

transport of these sands.

The "Basal Piegan," near the lower contact, has many characteristics in common with the Grinnell Formation. In places, the supermature sands extend into the "Basal Piegan" lithosome (Wheeler and Mallory, 1954). Mud cracks decrease in abundance upwards in the Piegan section. The green color and pyrite of these sediments may be indicative of a slightly reducing environment. Therefore, the "Basal Piegan" in the map area may represent the more seaward facies of the Grinnell tidal flat environment.

The Siyeh Formation differs lithologically from the Grinnell Formation chiefly in having more carbonate and a slightly smaller mean silt size. Again, the Siyeh Formation may represent an offshore environment, even farther offshore than the "Basal Piegan" sediments. Mud cracks are absent in this formation, but ripple marks and other sedimentary structures indicate a shallow basin of deposition for the Siyeh. The foregoing discussion is illustrated in Figure 17.

If subsidence, rate of sedimentation, and transgression of the land by water were all relatively constant with only minor fluctuations, and if the lithologies transgressed landward at an angle of about one degree, a lithotope (Wheeler and Mallory, 1954) only 15 to 20 miles wide is all that is needed to account for the thickness of the Grinnell Formation. The same is true for the "Basal Piegan Formation." A one degree angle of transgression could only be detected with

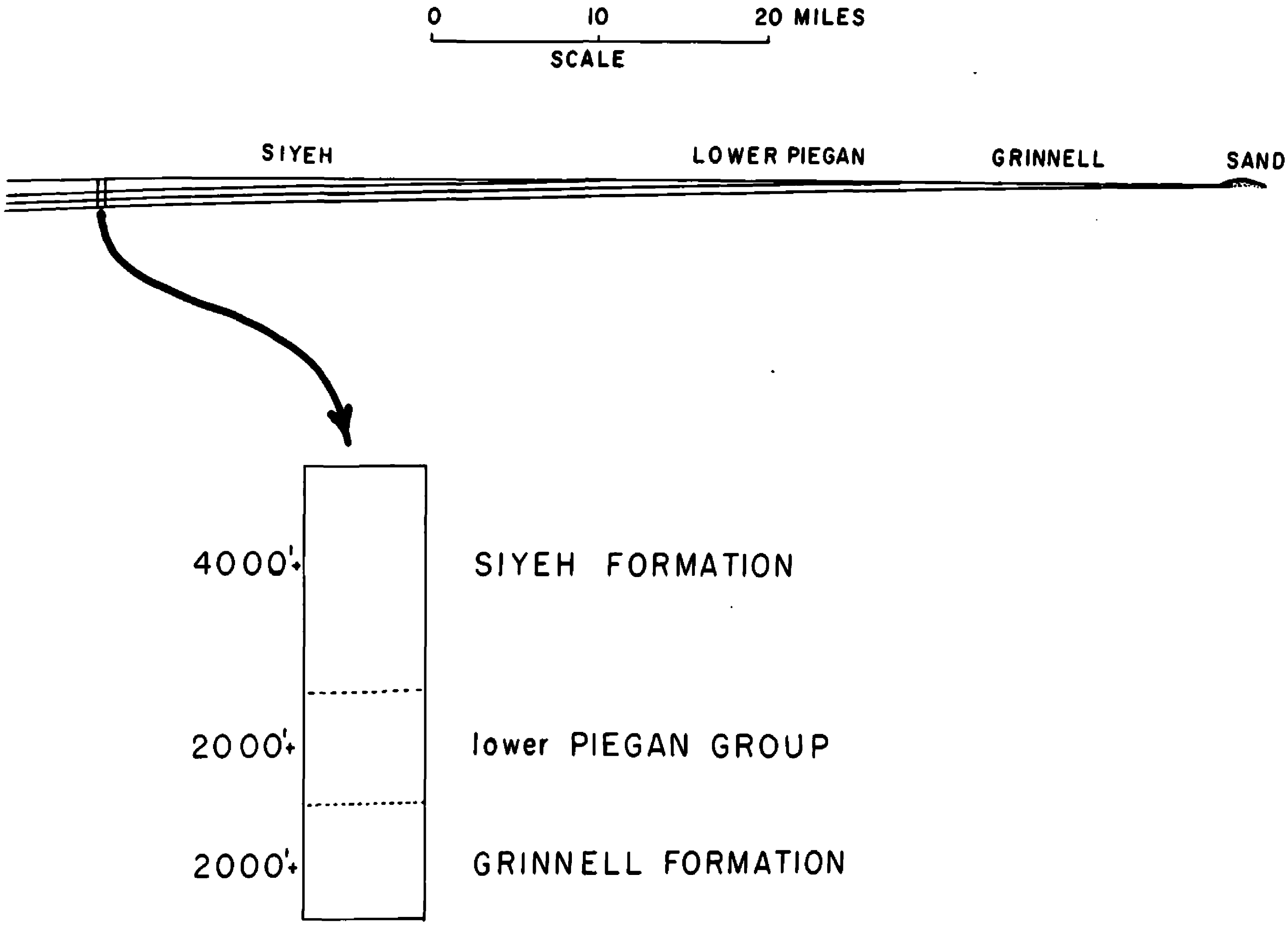

Figure [illegible]. True scale diagram that shows the eastward transgressive [illegible] at one degree in northwestern [illegible]. [illegible] section represents thickness of [illegible] in the thesis area.

excellent exposures perpendicular to the ancient shoreline and excellent stratigraphic control. With a one degree angle of transgression, there would be about 90 feet of sediments deposited per mile of transgression.

Other evidence that supports this hypothesis can be obtained from descriptions in other reports. Fenton and Fenton (1937) describe the various members of the formations in detail. The general sequence of sedimentation is similar. The ascending sequence is: calcareous beds (Altyn Formation), to greenish calcareous argillites (Appekuny Formation), to reddish argillites (Grinnell Formation), to greenish argillites ("Basal Piegan"), to calcareous beds (Siyeh Formation), to greenish argillites (Upper Piegan), to reddish argillites (Spokane Formation), to calcareous beds (Sheppard Formation). This is very generalized, but nevertheless, it is a repetitive sequence.

Although the environment of deposition in the preceding discussion is hypothetical, the evidence supports the argument presented. The writer believes that the key to interpreting the Belt stratigraphy will be detailed studies of the lithologies both vertically and laterally. In discussing the stratigraphy with various people who have worked in Beltian formations, there is general agreement that lateral changes do occur. Only detailed stratigraphic studies can verify these conclusions.

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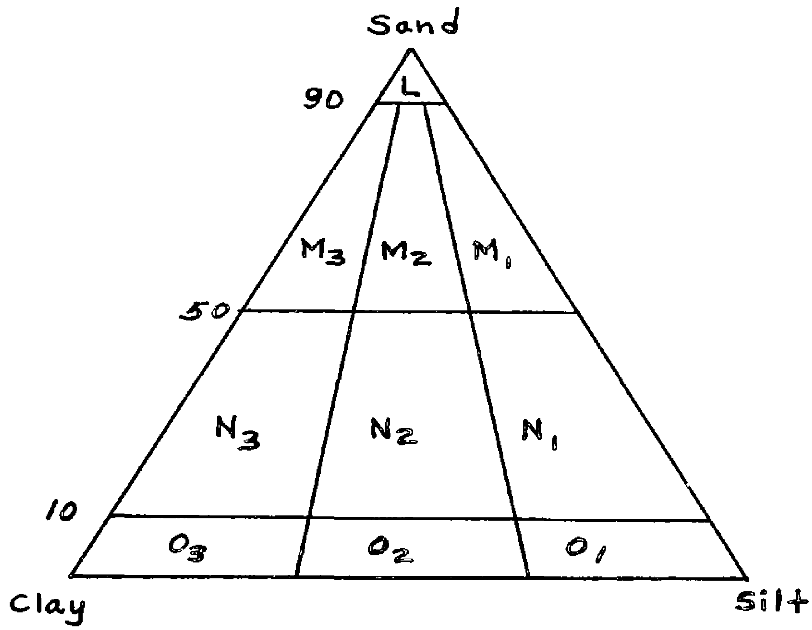
APPENDIX I



Textural groups as defined by the relative percentages of sand, silt, and clay for which the silt:clay ratio is determined. After Folk (1954, p. 349).

L	sand	sandstone
M1	silty sand	
M2	muddy sand	
M3	clayey sand	
N1	sandy silt	mudstone
N2	sandy mud	
N3	sandy clay	
01	silt	siltstone
02	mud	mudstone
03	clay	

APPENDIX II

Terminology for stratification in sedimentary rocks. After McKee and Weir (1953, p. 383).

Stratification	Thickness	Splitting Property
Very thick-bedded	Greater than 120 cm.	Massive
Thick-bedded	120 cm. to 60 cm.	Blocky
Thin-bedded	60 cm. to 5 cm.	Slabby
Very thin-bedded	5 cm. to 1 cm.	Flaggy
Laminated	1 cm. to 2 mm.	Shaly (claystone, siltstone)
		Platy (sandstone, limestone)
Thinly laminated	2 mm. or less	Papery

APPENDIX III

Section No.	Description	Location
6-62-6	Grinnell Formation: Immature, coarse silty medium sandstone. Quartz overgrowths. Well-rounded quartz in grains clay layers.	T. 33 N. R. 24 W. sec. 23 NW¼
6-62-8	"Basal Piegan"-Grinnell Formation: Supermature, well-sorted fine to medium sandstone. Quartz and feldspar.	T. 33 N. R. 24 W. sec. 9 SW¼
6-62-19	Grinnell Formation: Micaceous, quartz mudstone.	T. 33 N. R. 24 W. sec. 6 SW¼
6-62-20	Grinnell Formation: Interlaminated micaceous claystone and mudstone.	T. 33 N. R. 24 W. sec. 7 NE¼
6-62-27	"Basal Piegan Formation": Calcareous mudstone.	T. 33 N. R. 24 W. sec. 6 SW¼
7-62-1	Ravalli Group undiff.: Immature, very fine sandy mudstone. Grains of composite quartz. Graded bedding, burrows (?). Quartz and feldspar.	T. 32 N. R. 26 W. sec. 20 NE¼
7-62-3	"Basal Piegan Formation": Interlaminated microcrystalline carbonate and quartz mudstone.	T. 32 N. R. 26 W. sec. 21 NW¼
7-62-4	Siyeh Formation: Quartzose, micaceous dolomitic mudstone.	T. 32 N. R. 26 W. sec. 21 NE¼

Section No.	Description	Location
7-62-5	Siyeh Formation: Very fine-grained silty carbonate with pyrite.	T. 32 N. R. 26 W. sec. 27 NE¼
9-62-1	"Basal Piegan Formation": Repeated quartz siltstone laminae grading up to micro-granular carbonate producing micro-graded beds.	T. 32 N. R. 24 W. sec. 28 SE¼
9-62-4	Siyeh Formation: Silty microcrystalline limestone and dolomite.	T. 32 N. R. 24 W. sec. 19 SW¼
9-62-6	Grinnell Formation: Immature coarse silty medium sandstone.	T. 33 N. R. 24 W. sec. 35 SE¼
9-62-6x	Grinnell Formation: Super-mature, well-sorted medium sandstone. 2 clasts of mud-stone. Quartz and feldspar.	T. 33 N. R. 24 W. sec. 35 SE¼
9-62-7	Siyeh Formation: Micro-granular limestone with silty laminae.	T. 32 N. R. 25 W. sec. 27 NW¼