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Geology of the Esterbrook Area, Converse and Albany Counties, Wyoming

Michael Nolan Greeley

GEOLOGY OF THE ESTERBROOK AREA
CONVERSE AND ALBANY COUNTIES, WYOMING

BY

MICHAEL NOLAN GREELEY

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A

THESIS

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ABSTRACT

The Esterbrook area lies within the Laramie Range in Converse and Albany Counties, Wyoming. Exposures include Precambrian metamorphic and igneous rocks, the Tertiary White River formation, and Quaternary alluvium.

Hornblende schist and mica-quartz schist comprise the Precambrian metamorphic rocks. Foliation planes of these rocks trend northeast and dip steeply to the southeast. Metamorphic rocks of younger age probably lie to the southeast.

A distinctive, Precambrian silicic pluton of biotite-leucogranite with marginal zones of muscovite-leucogranite and alaskite passively intrudes the metamorphic rocks, generally parallel to the foliation trends. Numerous granite pegmatites show a zonal distribution around the pluton and appear to be genetically related to it. Dikes of gabbro and basalt follow major structural trends in the metamorphic and igneous rocks.

Pyrrhotite, galena, quartz-pyrite, and beryl-bearing mineral deposits are present in the metamorphic and igneous bodies. The deposits occur as fissure fillings and possible replacement bodies.

The crystalline rocks and their associated mineral deposits have been re-exhumed by the erosion of the Tertiary White River formation which gently laps onto the Laramie core. Quaternary alluvium lies in the mountain stream beds. The area is in a stage of late youth.

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I. INTRODUCTION

A. Location of Area

The geologically mapped area near Esterbrook, Wyoming, consists of twenty square miles in the northwest portion of the Esterbrook Quadrangle in southeast Wyoming. The area includes Sections 32, 33, 34, and 35 of R. 71 W., T. 29 N. and Sections 2,3,4,5,8,9,10,11,14,15,16,17,20,21,22, and 23 of R. 71 W., T. 28 N. It is approximately bounded by latitudes 42° 22' N and 42° 27' N and by longitudes 105° 19' W and 105° 24' W. The exact location of the mapped area in relation to the Converse-Albany County line is shown in Figure 1.

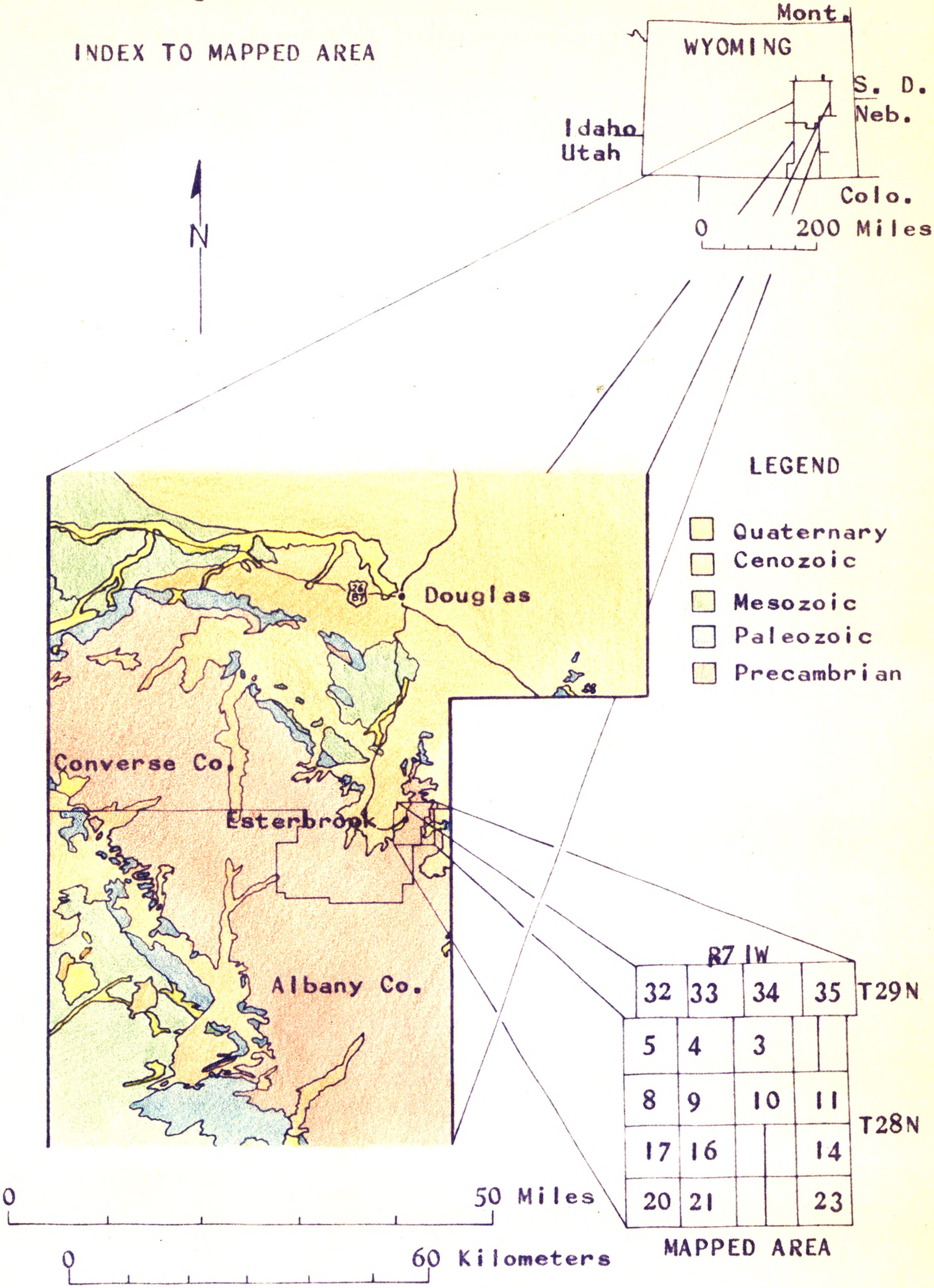
Access to the area may be obtained by taking a partly-paved dirt road from the town of Douglas, located on U. S. Highway 26-87, southward 32 miles to Esterbrook. The area may also be reached via a dirt road southwest from Glendo, situated on U. S. Highway 26-87, for approximately 28 miles to Esterbrook. Numerous jeep roads criss-cross the area-proper.

The elevation of the area is about 6500 feet. A good part of the land is covered by a stand of Ponderosa Pine which gives way to Lodgepole Pine at higher elevations. The area is a part of the Medicine Bow National Forest. Esterbrook, once a mining community, now mainly a recreation center during the summer months, is in the central part of the area. Its population varies from about 15 to 20. Facilities for camping, hiking, and swimming are available in the area.

While mining was the impetus for the development of the community, little or no activity is in progress at the present time. Most of the area is used as grazing land by cattle owners in this part of the state. Ullman Park comprises an important part of the grazing area.

Figure 1

INDEX TO MAPPED AREA



B. Objectives of the Study

A. C. Spencer in his general reconnaissance of the area in 1914 noted the general geologic setting and reported on several small mineral deposits. The character of the deposits and dearth of geologic informatioh in this area prompted the present investigation.

The principal objective therefore was to obtain and interpret geologic data on the little-known Precambrian rocks of this part of Wyoming. These had not been described previously or mapped except in a most general fashion. A second, but no less important, aspect of the study was to determine the setting and economic possibilities of the several mineral deposits reported within the area.

Since only reconnaissance-type surveys and geologic sketch maps were made in the past, an important goal was to provide a detailed geologic map of the area (Plate I). Petrographic details of the rock types were to be obtained by laboratory studies.

C. Field and Laboratory Methods

The summer of 1961 was devoted to field work in the area. A base camp was located in the small settlement of Esterbrook, Wyoming. Field work consisted of identifying the various rock types and their age relationships. Known mineral deposits and others of possible worth were mapped and specimens collected for laboratory study.

An enlarged portion of the U. S. Geological Survey Esterbrook 15-minute topographic quadrangle (1945) was used as a base map. Aerial photographs (approximate scale, 1:20,000), obtained from the U. S. Forest Service, served in determining location and correlation of photo and field features.

In the field, geological details were plotted on transparent overlays covering the above-mentioned 9" x 9" airphotos. Particular attention was devoted to lithology, joint orientation, and the planar and linear structures of the igneous and metamorphic rocks. The final geological map (Plate I) was prepared with the aid of a vertical sketchmaster at a scale of 1:24,000.

During the field work, eighty-one representative rock and mineral specimens were collected and labelled for laboratory study. Thin sections of the rocks and polished sections of the opaque minerals were made. These were studied under the polarizing and reflecting microscopes, respectively. Johannsen's classification (1939) was used for the igneous rock classification and Williams, Turner, and Gilbert's classification (1954) was used for the metamorphic suite.

D. Previous Work

Very little geologic information is available for the area. Spencer (1916, pp. 47-81), however, briefly described the economic geology of the North Laramie Mountains. He reported on the general geologic setting of the mineral deposits and gave some data on the mineral occurrences.

During the early 1900's, H. C. Beeler, State Geologist for Wyoming, prepared several unpublished reports on the various mines operating in the area at the time. These reports are on file at the Geological Survey of Wyoming at the University of Wyoming in Laramie. Although somewhat promotional in style, these reports provide invaluable information concerning several mineral deposits around Esterbrook at the time mining was active. They are useful in giving a general geologic setting for the known prospects and their development to that date. A complete listing of the Beeler reports on this area is given in the appended bibliography.

Brief mention of the area is made by Albanese (1949), Barlow (1950), Haun (1949), and others. Most of these were not directly concerned with the Precambrian rocks but dealt principally with stratigraphic and structural problems within the Quaternary, Tertiary, Mesozoic, and Paleozoic sediments surrounding the Precambrian hills. Other data on the regional geologic aspects of the Precambrian rocks are available from other source material listed in the bibliography.

E. Acknowledgements

The writer offers many thanks to Dr. Paul D. Proctor, Chairman of the Geology Department at the Missouri School of Mines and Metallurgy, for his introduction to the area and his careful assistance and friendly guidance without which completion of this project would have been impossible. In addition to Dr. Proctor, who spent several days in the field with the author, the writer feels especially indebted to his esteemed colleague, Mr. Joel J. Jurgens. He made a similar study of the area to the immediate north of Esterbrook. The writer spent numerous hours in discussion and interpretation and offers thanks for his many acts of kindness and cooperation throughout the work period. Thanks are also due other members of the faculty and graduate students of the Geology Department for their helpful suggestions.

Gratitude is expressed to Mrs. Margaret (Tippie) Freeman, members of her family, and other residents of Esterbrook, Wyoming, and the surrounding area for their warm hospitality. Appreciation is given to personnel of the Geology Department of the University of Wyoming who made available departmental facilities, archives of the Geological Survey of Wyoming, and other information as needed. Lastly, the writer feels indebted to Mrs. K. C. Bailey who drafted illustrations for the thesis.

II. GEOMORPHOLOGY

The area mapped lies principally within the Southern Rocky Mountains Province of the Rocky Mountain System (Fenneman, 1946) and is a part of the Colorado Front Range which extends into southeastern Wyoming. This extension is locally referred to as the Laramie Mountains and continues for approximately 150 miles north of the Wyoming-Colorado border (Fenneman, 1931). Easterly portions of the mapped area coincide with the old Missouri Plateau sections of the Great Plains.

The Laramie Mountains make up an elevated plateau which rises about 1500 feet above the adjacent Laramie Plains (Darton, 1910). Its elevation ranges for the most part from 8000 to 8500 feet. The mountain plateau appears to be rather uniform and tilted to the east. It extends across the underlying igneous and metamorphic rocks which have been eroded to a generally uniform level.

The old plain has been cut by many canyons, and numerous knobs and short ridges exist on its surface. Many slight topographic variations exist due to differential erosion of the different rock types present. The range is locally smooth and rounded in places and ragged and uneven in others.

Blackwelder (1909) considered the most recent or highest of the erosion surfaces of the Laramie Range to have formed during middle or late Miocene time and called it the Sherman Peneplain. Other writers tentatively correlated it with remnants of the widespread Rocky Mountain Peneplain of the Colorado Rockies. Van Tuyl and Lovering (1935) have since suggested its more exact correlation with the middle or upper Miocene Bergen Park surface of the Colorado Front Range.

Hallock (1933), however, suggests the presence of two peneplains distinctly different in age. The Sherman Peneplain is younger and truncates the older Rocky Mountain Peneplain. He suggests that the Laramie Range has undergone four cycles of erosion, the fourth continues and is producing a cycle of canyon-cutting which has not reached the upper courses of the streams.

The mapped area is similar in practically all respects to the rest of the Laramie Range but is approximately 1500 to 2000 feet lower in average elevation. The eastward tilt of the range and the area's location at the northern end of the mountain mass may explain the overall lower elevation. Esterbrook Hill (6801 feet) is the highest point within the area; the average elevation approximates 6500 feet.

The diversity of rock types has resulted in minor erosional variations in the topography. These range from the knobby, rounded appearance of the granitic areas to the moderately dissected portions of the sedimentary areas. The metamorphic rocks show either a fairly smooth surface or a rugged terrain and the Quaternary alluvium usually forms a rather smooth surface. In weathering, granitic areas form a grus-like cover and soil, and the schists a sandy or loamy detritus.

Three Cripples Creek and Horseshoe Creek are the two main streams which drain the Esterbrook area. These and most of the intermittent streams flow northeasterly and drain into the North Platte River. The v-shaped stream canyons are usually steep-sided, relatively narrow, and suggest a youthful stage. The area itself is in a stage of late youth.

General physiographic features of the area are shown in Figure 2.

III. REGIONAL GEOLOGIC SETTING

The Laramie Range is a northern continuation of the elongate, asymmetric, north trending anticlinal arch of the Colorado Front Range. Just south of Esterbrook, the arch bends and bears almost due west. The axial plane dips westerly (Haun, 1949). Structural trends, mainly foliation and principal joint systems, within the Laramie core are northeast (Spencer, 1916).

In northern Colorado the Front Range comprises a narrow assemblage of Precambrian igneous and metamorphic rocks, a few folded or faulted inliers of sedimentary rocks, and several Tertiary igneous bodies (Van Tuyl and Lovering, 1935). Up-warped Paleozoic and Mesozoic formations, in turn truncated by gently dipping Tertiary sediments, lap onto the Precambrian basement. The Precambrian schists and gneisses, derived from metamorphosed sediments, are intruded by the more abundant granite and granite gneiss.

The Sherman granite, volume-wise, is the most abundant rock in the Laramie Mountains. Its essential minerals include orthoclase, microcline, and some oligoclase, black hornblende, biotite, and quartz. Inclusions of hematite dust in the feldspars are accessory. This granite is invaded by smaller fine-grained and porphyritic granite dikes and stocks.

Precambrian gneisses, schists, and acidic and basic intrusives of the Laramie Range are subordinate in volume but well exposed. Granite gneiss is the most prominant type (Blackwelder, 1910). It is widespread and consists of two distinct types: (1) medium to coarse-grained, grayish pink, biotite gneiss and (2) fine to medium-grained, reddish gneiss. Both represent mildly metamorphosed granites. Dikes of fine-grained granite gneiss of the same general composition are commonly associated.

The biotite gneiss shows parallel streaking but only rare distinct bands or contorted laminae. Pink microcline and orthoclase, some white albite, quartz and biotite are the major minerals, and hornblende and epidote the accessories. Mashing and partial recrystallization of the minerals, indicating deformation, is recognized under the microscope.

The reddish gneiss usually contains few dark minerals. Gneissic structure is less apparent than in the biotite gneiss. Quartz, alkali feldspar, muscovite, and biotite are the essential minerals, iron oxides and hornblende may also be present. Intense mashing and abundant recrystallization of the rock is evident under the microscope.

Dark-green amphibolites, apparently the result of metamorphism of basic dikes and lava flows, constitute the major schists of the Laramie Mountains. The schists contain green hornblende, quartz, microcline, orthoclase, and predominantly labradorite. All of the constituents have undergone recrystallization. Less abundant schistose rhyolites and felsites, mica schists, mica gneisses, and occasional quartzites are associated with the amphibolites.

Dark gray granite porphyry containing sub-hedral phenocrysts of hornblende, quartz, and pink orthoclase is another major rock unit. The finely granular groundmass is composed of the same minerals with occasional shreds of biotite. Microcline is also present. Microscopic strain shadows and fractures indicate deformation.

A dull gray anorthosite is also reported. It consists of essential labradorite, diallage, and hornblende. Textures range from medium-granitoid or ophitic to porphyritic, and little or no evidence of alteration or deformation exists.

Syenites, granodiorites, diorites, gabbros, and gabbro gneisses are also exposed. These vary in texture from coarse-grained to partly dense or porphyritic. Unaltered rocks, katamorphically changed rocks, and gneissic structures occur among this group.

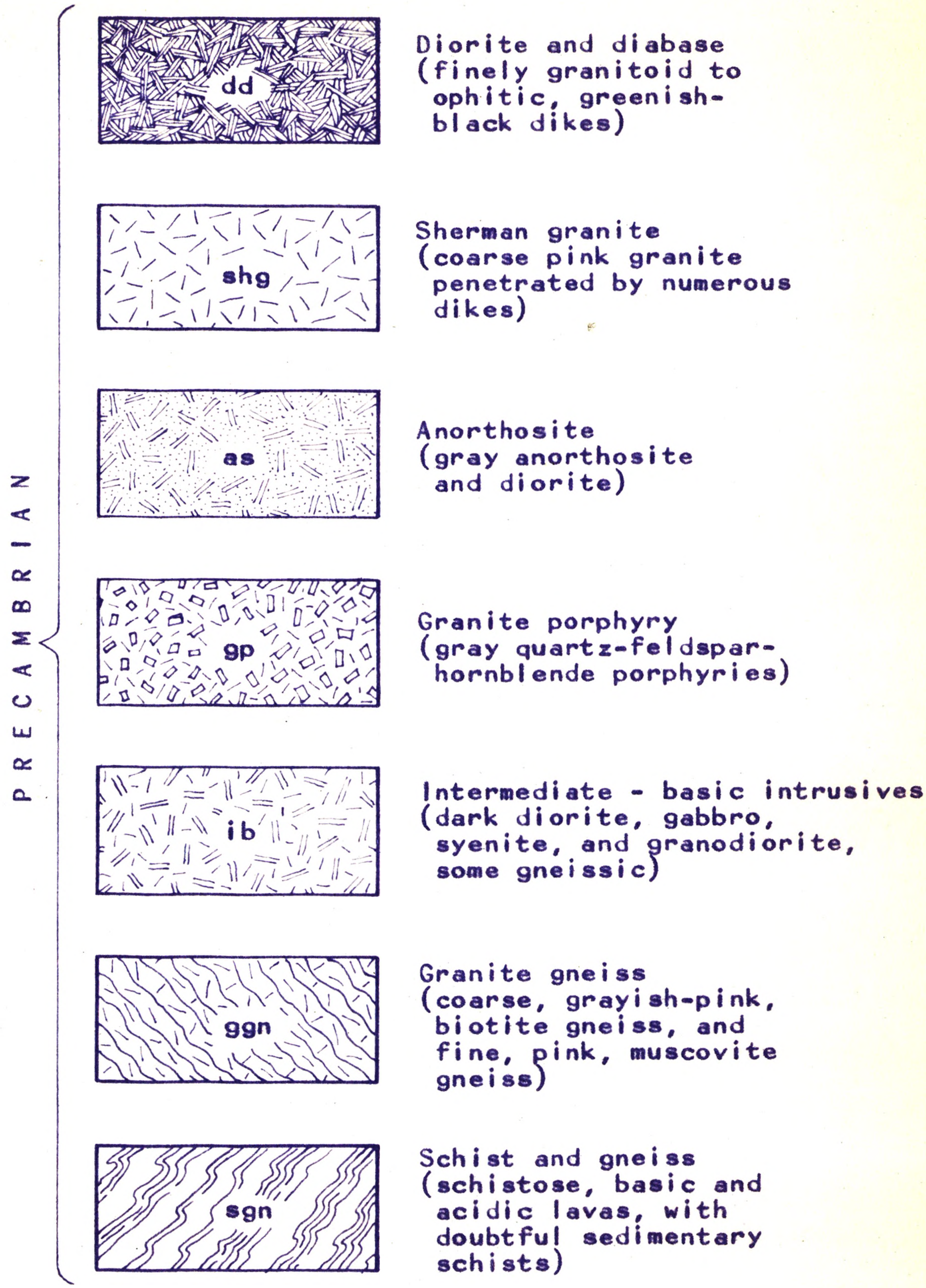
Small diorite and diabase dikes are also reported in the Precambrian mass. These greenish-black rocks have textures which vary from aphanitic to finely granitoid and ophitic in places. Labradorite and chlorite (?) are the essential minerals with lesser quantities of magnetite, pyrite, and apatite.

Blackwelder (1910) in conjunction with Darton and Siebenthal proposed a tentative rock column for the Laramie Range (Figure 3). Specific age of the rock within the Laramie core is not known. Hague (1877) suggested they be included in the Laurentian division of the Archean. King (1878), Van Hise (1909), and others tentatively classified them as Archean. Blackwelder (1910), in his extensive study of the southern range, placed them in the Archean (?) system.

It now appears that although a portion of these rocks (namely, the schists and gneisses) do resemble the Archean rocks as defined by geologists in the early 1900's, not all of them should be included in this older Precambrian period. The Sherman granite which intrudes practically all of the other Precambrian rocks probably formed 1400 million years ago (Aldrich, L. T., and other, 1957, Aldrich, L. T., and others 1958, and Gilleti and Gast, 1961). Giffen and Kulp (1960) place its age at about 1530 m.y. These age determinations indicate that the Sherman granite batholith probably formed between middle and late-middle Proterozoic time (based on the absolute time scale presented at the XXI International Geological Congress, 1960).

Figure 3

PRECAMBRIAN ROCK COLUMN OF THE SOUTHERN LARAMIE RANGE
(Modified after Darton, 1910)



IV. LOCAL GEOLOGY

A. Preliminary Statement

The Esterbrook area lies almost entirely within a Precambrian, finger-like projection of the Laramie Mountains (Figure 1). The major metamorphic rock in the area is a green hornblende schist, with minor associations of mica-quartz schist (Plate I). These units are apparently the oldest rocks in the area, and comprise 25 percent of the total 20 square miles.

A large body of silicic-granite crops out in the southern portion of the area. This leucogranite intrusion consists of several facies: (1) biotite-leucogranite, (2) muscovite-leucogranite, and (3) alaskite. The biotite-leucogranite contains numerous pegmatitic and aplitic phases which appear to be residual facies of the parent magma. The silicic granitoid rocks of the pluton occupy approximately 35 percent of the total mapped area. Northward into the area of metamorphic rocks, numerous pegmatite bodies occur which are apparently related to the parent magma of the silicic pluton.

Gabbros and basalts intrude the previously mentioned units and are therefore younger. These rocks are found in the granitic as well as the metamorphic area.

The Tertiary White River formation which occupies most of the north-west corner, or 20 percent of the area, laps onto the above mentioned units. Younger Quaternary gravels cover Ullman Park. Local inliers of Precambrian rocks are visible within the Park.

The mapped area is characterized by a northeasterly trend of the out-crops (Plate I). Steeply inclined foliation planes in the metamorphic rocks trend to the northeast and dip to the south (Figure 15). Bedding features are rare, but where observed, in these metamorphic rocks, their attitudes parallel the foliation planes. Three steeply inclined joint sets also occur within the metamorphic rocks.

Within the major igneous bodies, three well developed sets of steeply dipping joints are visible. The most prominent set bears northeasterly. Tabular gabbros and most of the pegmatites also form major linear features within the area. Strike of these bodies tends to parallel the northeast joint pattern of the igneous rocks and the northeast foliation of the metamorphic rocks. The much younger White River sediments unconformably overlie the metamorphic and igneous rocks and dip gently away from them.

Grain size terms applied in the petrographic section include: fine = less than 1 mm., medium = between 1 and 5 mm., coarse = between 5 and 30 mm., very coarse = greater than 30 mm.

B. Petrology and Petrography

1. Precambrian Metamorphic Rocks

Precambrian metamorphic rock units of two principal types outcrop in the mapped area. Both rock types belong to the amphibolite facies and are probably metasediments. They occur extensively in the northeast quarter of the area where they comprise about 25 percent of the total area of 20 square miles.

The most abundant metamorphic rock is a greenish-gray, to gray, hornblende schist. It comprises most of the metamorphic rocks within the area and is a well foliated, medium-grained amphibolite. Its foliation trends northeasterly. Chief constituents are quartz and hornblende. Weathering produces rusty colored outcrops consisting of low-lying rock debris. Deeper weathering of this rock results in an ochre-red, sandy soil.

Hornblende, epidote, quartz, calcite, and microcline are visible in the rock with average grain size of about 1 mm. In thin section a representative specimen exhibits moderate foliation produced by the planar arrangement of nematoblastic hornblende and epidote (Figure 4A). The hornblende and epidote grains are euhedral to subhedral. Quartz, calcite, and microcline grains are randomly arranged and generally anhedral. Some of the quartz and feldspar grains show undulatory extinction. Myrmekitic intergrowths are also visible. Calcite occurs either as individual grains or along grain boundaries. Minor amounts of sphene occur in the rock, and its habit is subhedral.

Bluish-green hornblende (35%), Quartz (30%), epidote (20%), microcline (13%), and one percent each of sphene and calcite make up the rock. Traces of chlorite and kaolin (?) occur as alteration products of the hornblende and the microcline, respectively.

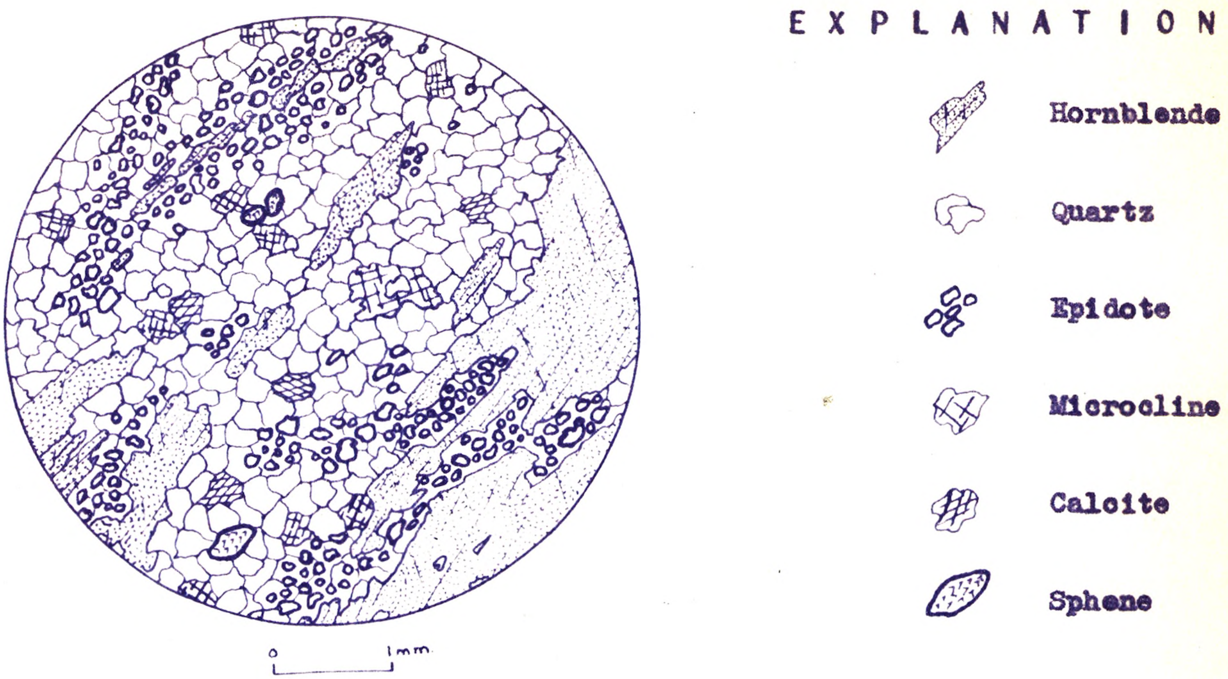
The above schist is widespread and locally shows slight mineralogical variations in the field. Some exposures contain fibrous hornblende and little or no calcite. Others contain less amounts of epidote. While many variations exist, no major differences in mineralogy were noted.

Based on the mineral assemblage and field occurrence, this rock is considered to have been derived from an impure marly or calcareous sediment, probably rich in Ca, Al, Mn, and Fe. The original sediment has apparently undergone regional metamorphism of a medium grade.

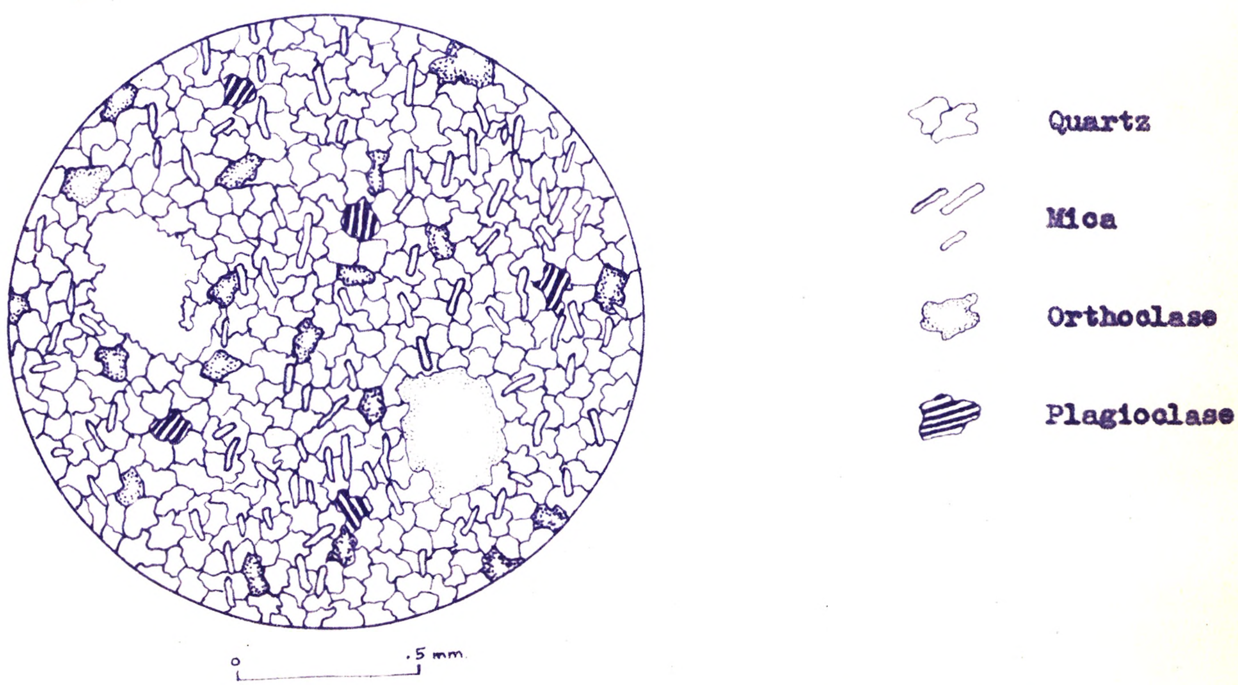
Another distinctive metamorphic rock in the mapped area is a fine to medium-grained, massive, mica-quartz schist. This light gray to gray rock is found principally within Section 34 (Plate I) and continues northward. Outcrops exhibit as much as three or four feet of relief and strike northeasterly (Figure 5). Weathered outcrops assume a ragged appearance, and

Figure 4

PRECAMBRIAN METAMORPHIC ROCKS IN THIN SECTION



A. Hornblende schist - NE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 16, T. 28 N., R. 71 W.



B. Mica-quartz schist - SE $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 34, T. 29 N., R. 71 W.

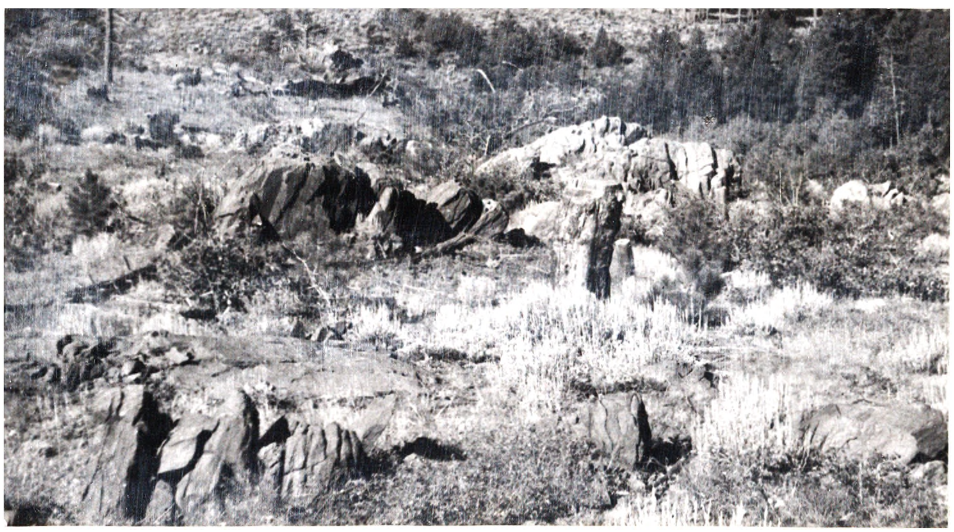


Figure 5 - Outcrop of Mica-Quartz Schist.
Strike S. 30° W., Sec. 34, T. 29 N., R. 71 W.

sandy soils are developed in some areas as a result of deeper weathering.

Under the microscope, this rock shows a poorly developed lepidoblastic texture due to the presence of abundant muscovite and biotite (Figure 4B). The reddish-brown biotite and clear muscovite flakes are anhedral to subhedral. Randomly arranged quartz and feldspars are anhedral and show strain shadows. Sphene and epidote particles are subhedral. Occasional porphyroblasts (1 mm.) of quartz or feldspar occur in a fine-grained matrix that averages less than .25 mm. in diameter.

Quartz (65%) is the most abundant mineral present. Orthoclase comprises about 17% of the rock, plagioclase 5%, and micas constitute approximately 12% of the rock. Trace amounts of sphene, epidote, magnetite, hematite, and chlorite are present.

Although the mineralogy of this rock remains fairly constant throughout, textures vary considerably within a short distance. Average grain size of the matrix may increase to nearly 1 mm. and may contain elongated mineral segregations up to several inches in length (Figure 6A). Segregations always parallel the foliation and may show distinct metamorphic zoning (Figure 6B).

An increase in abundance and in grain size of the micas generally occurs near pegmatite intrusions, as does the schistosity of the mica-quartz schist.

Based on mineral assemblage and field occurrence, this rock is considered to have been derived from a quartzo-feldspathic sediment. It belongs to the amphibolite facies and developed through medium-grade, regional metamorphism of an impure sandstone or some other arenaceous sediment.

2. Precambrian Igneous Rocks

Five distinct igneous units crop out in the mapped area and include

Figure 6A - Elongated zoned segregations in mica-quartz schist. Note metamorphic zoning with quartz center. Strike S. 30° W., Sec. 34, T. 29 N., R. 71 W.

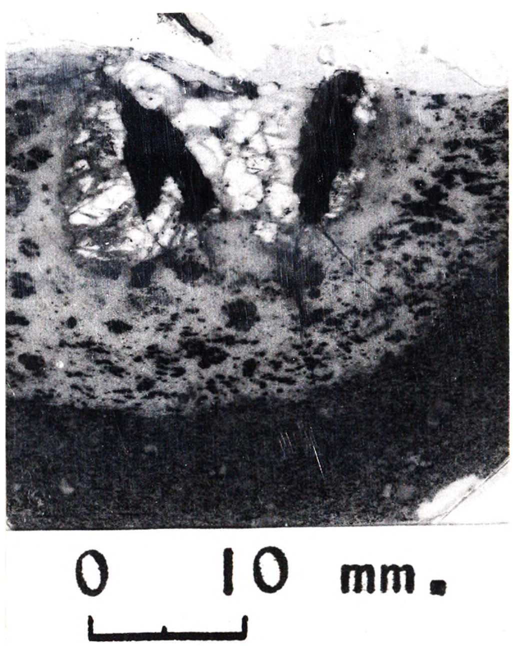


Figure 6B - Enlargement of zoned segregation in mica-quartz schist. Fine-grained zone consists of quartz, mica, and orthoclase.

rocks of both persilicic and basic composition. Pegmatites, alaskites, leucogranites, basalts, and gabbros are present. Approximately 40% of the area is made up of these Precambrian rocks.

Leucogranite is the most abundant igneous rock and is exposed in the southern portion of the area. The gross outline trends northeasterly and the exposures make up 30% of the overall area (Plate I). The rock is white to cream, massive, holocrystalline granite. Coarse-grained quartz, feldspar, and biotite, with occasional feldspar phenocrysts are characteristic. Pegmatitic and aplitic facies of this rock occur throughout the main mass. The weathered rock shows rounded, boulder-like appearance and rusty outcrops (Figure 7). A grus-like soil is common in some areas.

Thin-section study of a representative specimen shows hypidiomorphic-granular texture (Figure 8A). The grains are inequigranular but average about 5 mm. in diameter. Subhedral to anhedral feldspar occurs with euhedral to subhedral grains of biotite and muscovite. Quartz is always anhedral; in places it exhibits a sutured texture. Myrmekitic texture is common between plagioclase and microcline grain boundaries.

Essential minerals include orthoclase-microcline (62%), oligoclase (5%), quartz (30%), and biotite (2%). The feldspars and quartz commonly show undulatory extinction. Muscovite comprises less than 1 percent, and magnetite, zircon, sphene, and apatite occur in trace amounts. Biotite shows alteration to chlorite in places, and the plagioclase shows random flakes of sericite in small quantity. Traces of kaolin (?) occur with the potassium feldspars.

Abundant fine-grained quartz, microcline, muscovite, biotite, and myrmekite occur along grain boundaries and fractures. Equant inclusions of quartz are commonly present in the feldspars and occasional inclusions of

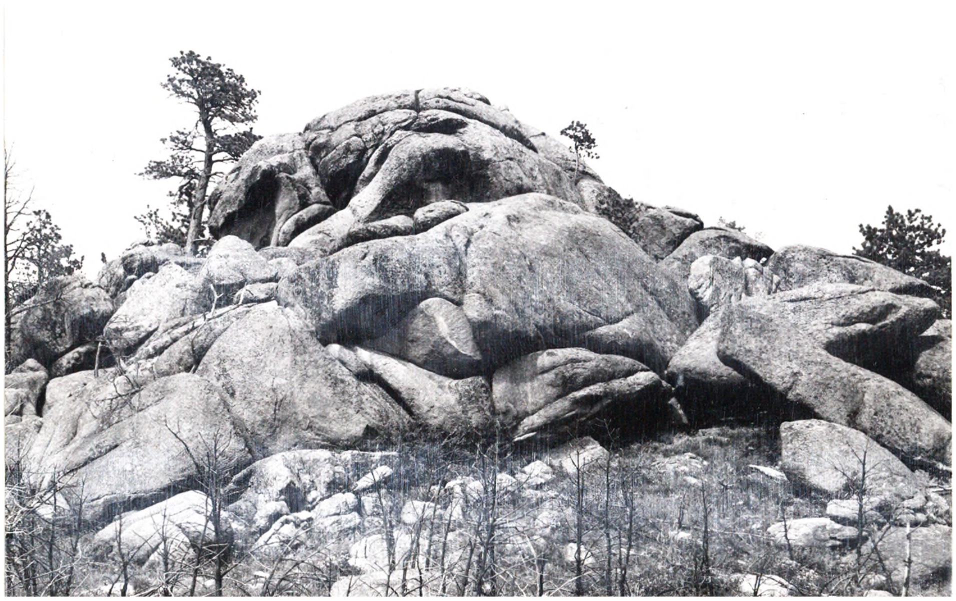
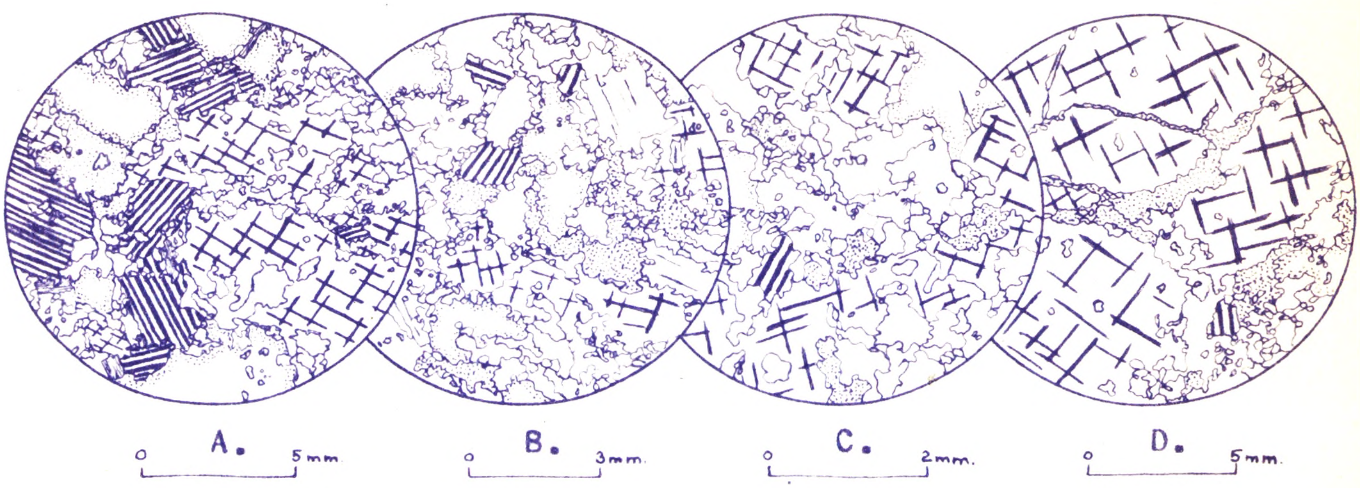


Figure 7 - Outcrop of biotite-leucogranite. Note exfoliation characteristics. Sec. 15, T. 28 N., R. 71 W.

Figure 8

PRECAMBRIAN SILICIC IGNEOUS ROCKS IN THIN SECTION



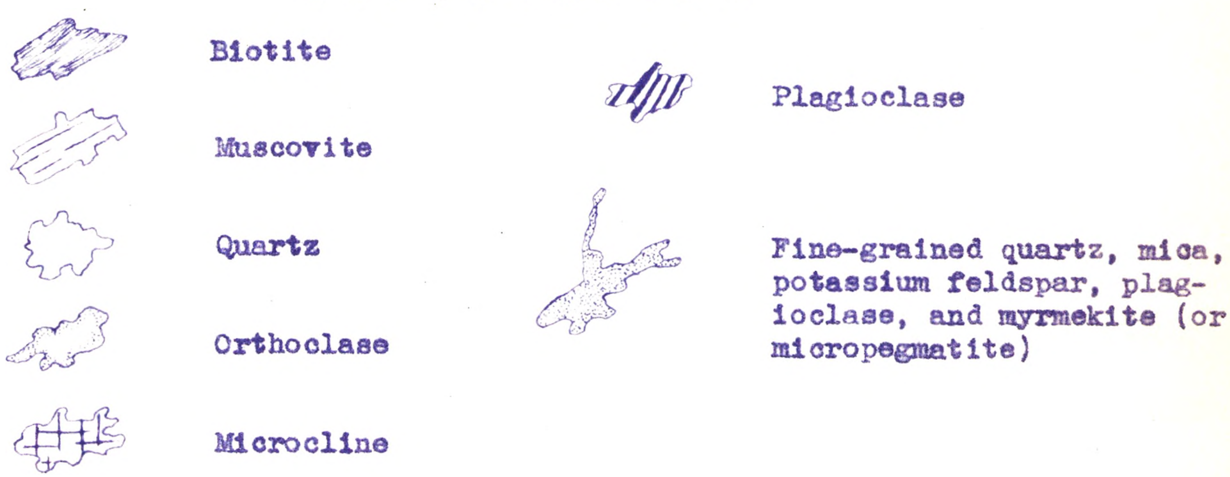
A. Biotite-leucogranite - SW ¼, SE ¼, Sec. 14, T. 28 N., R. 71 W. (126P)

B. Muscovite-leucogranite - NE ¼, SE ¼, Sec. 17, T. 28 N., R. 71 W. (126P)

C. Alaskite - SW ¼, NE ¼, Sec. 21, T. 28 N., R. 71 W. (116P)

D. Granite pegmatite - SE ¼, NW ¼, Sec. 34, T. 29 N., R. 71 W. (115D)

E X P L A N A T I O N



zircon occur in brown biotite. The rock is classified as a biotite-leucogranite.

A light colored igneous intrusive rock, much less abundant than the biotite-leucogranite, is exposed along the margins of the latter igneous mass. The lighter colored intrusive body rarely outcrops, develops low-lying topography, and is massive. The rock is a gray, medium-grained, holocrystalline granite. Grus-like soil is a common product of weathering. Small exposures of the rock occur in the SE 1/4 of Section 17 in the mapped area (Plate I), and a larger exposure occurs in the SW 1/4 of Section 2.

Thin-section study of the rock shows hypidiomorphic-granular texture (Figure 8B). The inequigranular grains average about 2 mm. in diameter. Feldspars vary from subhedral to anhedral whereas the mica is generally euhedral. Quartz often exhibits sutured texture and is anhedral. Micrographic intergrowths of microcline and quartz are also common.

Potassium feldspars (55%), oligoclase (11%), quartz (31%), and mafic minerals (1%) are the essential constituents of the rock. Strain shadows are visible in some of the quartz and feldspars. Muscovite comprises 2% of the volume. Accessory minerals include sphene, rutile (?), and apatite. They constitute about 1% of the rock volume. A minor quantity of sericite replaces the plagioclase feldspar, and traces of kaolin (?) replace the potassium feldspar.

A mosaic of fine-grained quartz, muscovite, microcline, and micropegmatite occurs along grain boundaries. Equant grains of quartz are commonly included in the feldspars. Some needle or hair-like rutile (?) crystals are visible in quartz. The rock is classified as a muscovite-leucogranite.

Another light colored igneous rock is closely associated with the leucogranite exposures. This rock is more abundant within the area of the biotite-leucogranite, but is occasionally found along its margin. Exposures of the mafic-free igneous rock are generally elongated northeastward. Outcrop characteristics resemble those of the biotite-leucogranite. The rock is pink, medium-grained, holocrystalline, and usually massive in appearance. Surface weathering results in a bleached appearance for the rock and the development of coarse residuum (Figure 9).

The rock shows typically granitic texture under the microscope (Figure 8C). Average grain size is 2 mm. and crystals are inequigranular. Feldspars are anhedral to subhedral, and quartz is always anhedral, showing sutured texture. Occasional intergrowths of myrmekite are present.

Essential minerals include orthoclase-microcline (60%), quartz (30%), and albite (10%). Microcline is the most abundant feldspar. Undulatory extinction is common within the quartz and plagioclase. Mafites are very rare or absent. Traces, however, of magnetite, chloritized (?) biotite, rutile (?), sphene, and apatite are present. Some sericite occurs in the albite grains.

Occasional patches or stringers of fine-grained quartz, alkali feldspar, and myrmekite occur in the rock. Equant or rounded blebs of quartz often occur within the feldspars. Microcline or albite is likewise included within some quartz grains. Rutile (?) needles are sometimes found in the quartz. Based on texture and mineral composition, the rock is classified as an alaskite.

Some exposures of the alaskite have pegmatitic texture, and others exhibit deformation cracks and fractures containing minor amounts of magnetite and hematite.

Granite pegmatites also crop out in the area. These rocks are generally restricted to peripheral areas surrounding the biotite-leucogranite,

Figure 9 - Outcrop of alaskite. Trend about N. 35° E., Sec. 21, T. 28 N., R. 71 W.

and become more numerous in the area of metamorphic rocks to the northeast. Outcrops vary in size and shape but are, in general, relatively straight and elongate in a northeasterly direction. Some, however, are gently curved and steeply inclined; others appear to be flat-lying.

The pegmatites are usually light-gray to gray, massive, and holocrystalline. Where surrounded by sediments or metamorphic rocks, they usually stand above these rocks from one to six feet (Figure 10A). Stringers occasionally diverge from the main body and penetrate the metamorphic rocks as shown in Figure 10B. Mineralogy of the pegmatites is generally simple and includes muscovite, biotite, quartz, and feldspar.

A thin-section study of this rock shows typical hypidiomorphic-granular, pegmatitic texture (Figure 8D). Average grain size is difficult to estimate since individual grains vary from about .25 mm. to 12 or 15 mm. The mica is usually fine-grained, the quartz fine to medium grained, and the feldspars medium to coarse-grained. The quartz and nearly all of the mica is anhedral, and the feldspars vary from subhedral to anhedral. Some of the quartz is sutured. Micrographic intergrowths of microcline and quartz are also common.

Figure 8D represents a thin-section view of the simple, granite pegmatite containing abundant microcline, quartz, some albite and a little orthoclase. The quartz and microcline crystals sometimes exhibit strain shadows. Muscovite and apatite are present in minor amounts. Sericite occurs in the albite as an alteration product.

Fine-grained quartz, muscovite, microcline, and albite are common as irregular patches and stringers. Inclusions of quartz and albite are common in the microcline.

Two silicic pegmatites containing less common minerals crop out within

Figure 10A - Outcrop of granite pegmatite in metamorphic rocks. Strike N. 30° E., Sec. 34, T. 29 N., R. 71 W.

Figure 10B - Light colored granite pegmatite stringers in mica-quartz schist. Sec. 34, T. 29 N., R. 71 W.

the mapped area. These occur in Section 34. One pegmatite grades into a pure quartz vein within about 60 feet along the strike. In addition to the normal granitic mineralogy, small amounts of apatite and beryl are present. Beryl comprises less than one percent of the rock and varies in size from 1/4 inch to 3 inches in diameter. Apatite content is minor but of conspicuous grain size, attaining an inch in diameter.

These more complex pegmatites show a marked zonal distribution of textural and mineralogical features (Figure 11). Three main zones make up the complete pegmatite: (1) border zone, (2) intermediate zone, and (3) core. These three zones do not always show distinct contacts but instead are often gradational.

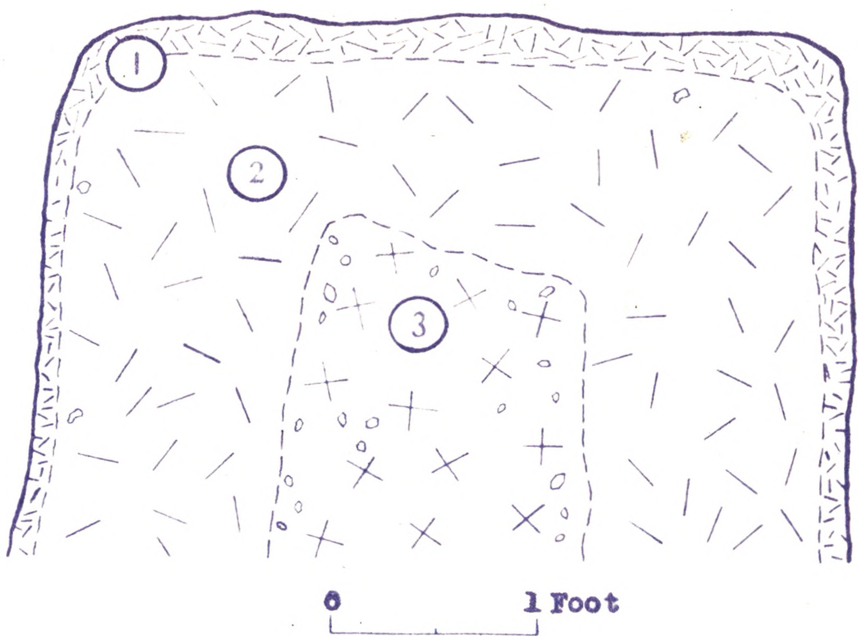
The outermost or border zone is the narrowest of the three zones, ranging from one to three inches in width. The texture is granitoid, and fine-grained quartz, plagioclase, and biotite comprise the essential minerals.

The intermediate zone is generally medium-grained, grading into the coarser-grained, central core. This intermediate zone contains abundant quartz and plagioclase with some biotite. Occasional blebs of yellowish-green apatite, 1/4 to 1 inch in diameter, occur in this zone.

The innermost zone or core is made up primarily of very coarse-grained, massive, milky quartz. It is practically barren of other minerals except for a few books of biotite. Along the border separating the core and the intermediate zone are numerous small books of biotite and crystals of beryl. The beryl is closely associated with the massive quartz and except for its hexagonal outline might be overlooked. Its unweathered, vitreous color varies from a pale white, similar to the quartz color, to a light green. Weathering produces a thin, brownish-colored skin on the exterior of the mineral. The beryl crystals range from 1/4 to 3 inches in diameter.

Figure II

ZONES IN APATITE-BERYL-BEARING GRANITE PEGMATITE



E X P L A N A T I O N

1. BORDER ZONE - fine-grained quartz, plagioclase, and biotite

2. INTERMEDIATE ZONE - medium-grained quartz, plagioclase, and minor biotite, apatite (◇)

3. CORE ZONE - coarse-grained quartz and minor biotite, beryl (○)

Basalts and gabbros also crop out within the mapped area. They occur as elongated masses trending northeastward and are exposed in the area covered by Precambrian rocks. They are dark green, massive, and holocrystalline. The aphanitic basalts tend to be more massive than the gabbros.

Abundant feldspar laths mixed with hornblende are characteristic. Weathering tends to produce an almost black, blocky residuum. Deeper weathering of these basic rocks generally yields deep ochre-red soils.

Thin-section study of the gabbro shows ophitic, hypidiomorphic-granular texture (Figure 12A). Average grain size is approximately 2 mm. and individual grains are inequigranular. Although the plagioclase laths appear to be euhedral, most of them are probably best described as subhedral. Hornblende varies from subhedral to anhedral as do the minor minerals.

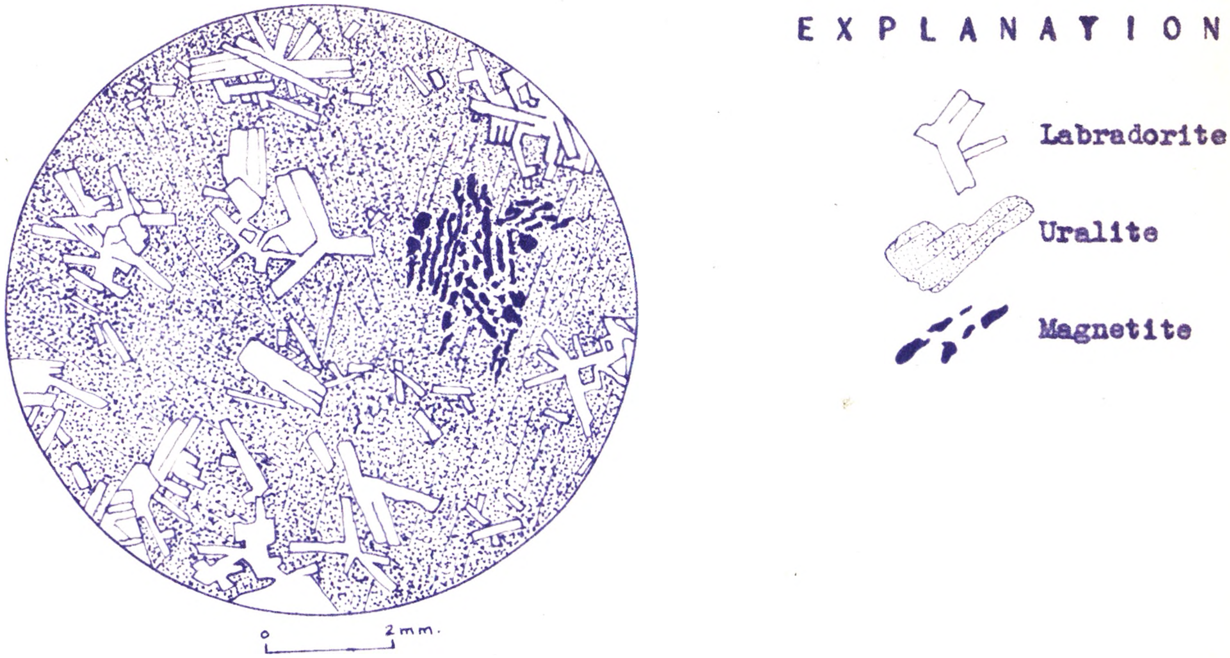
One sample is composed of two essential minerals, labradorite (40%) and bluish-green hornblende (54%). See Figure 12A. The hornblende appears to be of the uralite variety. Less than 1% quartz, about 3% magnetite, and 1% biotite make up the remainder of the main mineral constituents, however, traces of orthoclase may also be present. Minor amounts of saussurite, hematite, epidote, kaolin (?), and chlorite are also present. These latter may have resulted from complete uralitization of the original pyroxene and further alteration of the uralite and feldspar. The rock is classified as a uralite-gabbro.

Mineralogy of the basalt is essentially the same as that of the uralite-gabbro, however, grain sizes differ. The basalt is an aphanitic, microcrystalline rock, and the average grain size is .5 mm. or less. It is classified as a uralite-basalt.

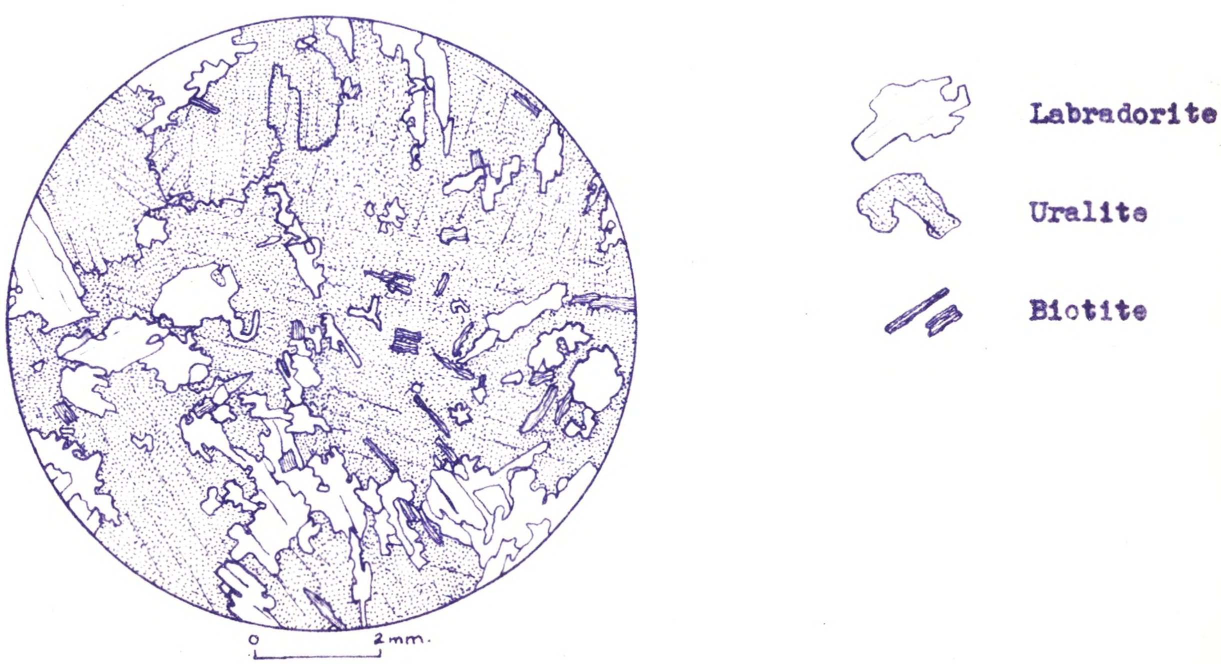
Another rock type, showing essentially the same mineralogy, is closely associated with the basalts and gabbros. It does, however, contain more

Figure 12

PRECAMBRIAN BASIC IGNEOUS ROCKS IN THIN SECTION



A. Uralite gabbro - SW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 35, T. 29 N., R. 71 W. (2312P)



B. Biotite-uralite gabbro - SW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 10, T. 28 N., R. 71 W. (2312P) biotite (10%). See Figure 12B. The reddish-brown biotite is subhedral to anhedral, and it may be entirely original or partly secondary.

Outcrops of this rock are rare in the thesis area. The rock always occurs as small patches associated with uralite-gabbro in an area largely composed of metamorphic rocks in the northeast quarter of the mapped region. Texture and composition indicate that the rock is a biotite-uralite gabbro.

3. Tertiary Sedimentary Rocks

Approximately 20% of the mapped area consists of the White River formation of Oligocene age. These rocks occur principally within the northwest quarter of the area, but also crop out in Sections 14 and 35 (Plate I). Originally, they covered most of the Precambrian region (Spencer, 1916) but have been eroded back and now lap unconformably onto the crystalline rocks of the Laramie core.

These rocks consist essentially of conglomeritic claystones. They erode easily and result in a moderately disected terrain of rolling topography. A typical view of the White River formation is shown in Figure 13A.

Though composed of two distinct members, only one member of the White River formation is recognized in the mapped area. The lithology and occurrence most nearly conforms to descriptions of the Brule clay of Darton and others (1910) and Barnett (1914, 1915). The claystone consists of a fine-grained calcareous matrix containing sub-rounded to sub-angular particles of quartz, feldspar, and traces of magnetite (Figure 13B). These clastic minerals range in diameter from .25 mm. to about 3 mm. Most of the grains are in the .25 mm. size range and are homogeneously distributed. They make up approximately 20% of the rock.

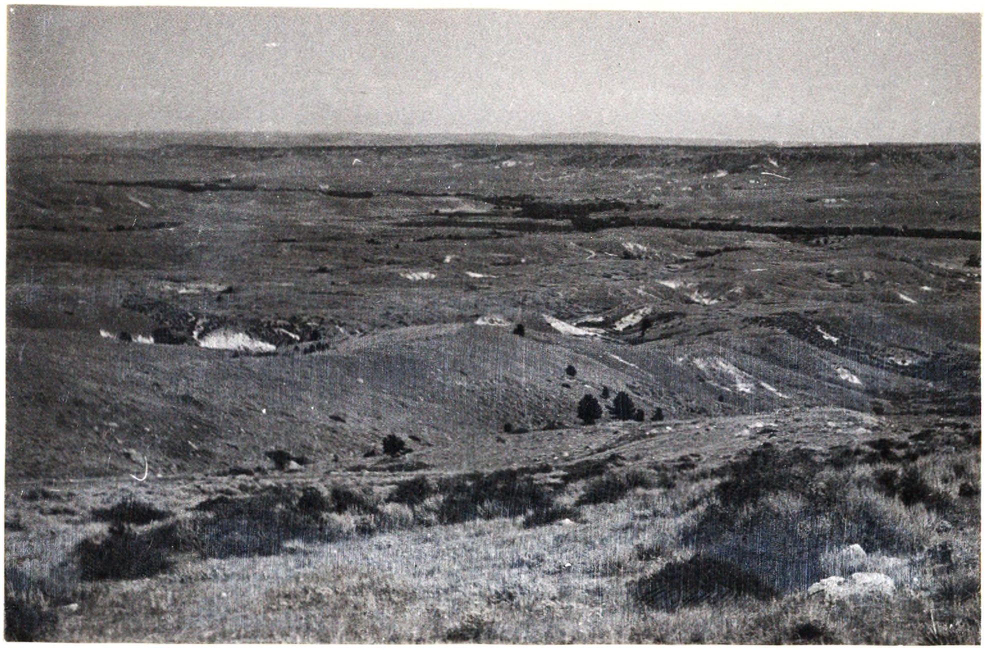


Figure 13A - Photograph of Tertiary White River formation. Note rolling topography and white patches in the formation. View is ENE from Sec. 35, T. 29 N., R. 71 W.

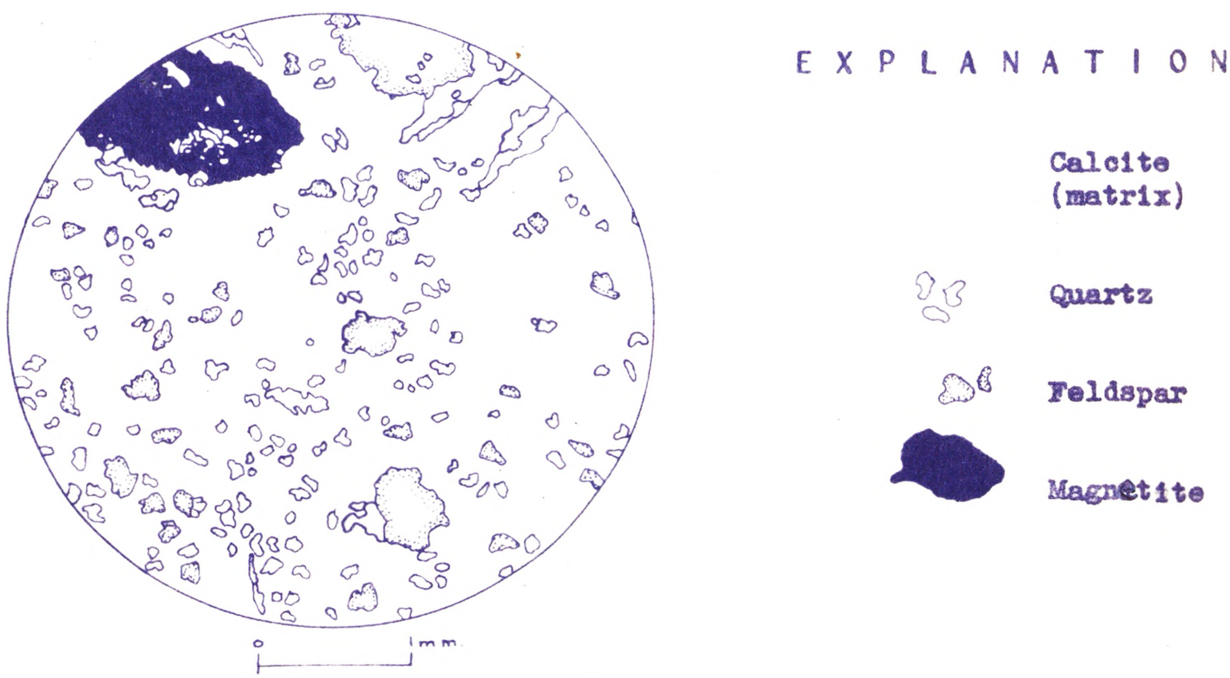


Figure 13B - Thin section of Tertiary White River formation - SW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 33, T. 29 N., R. 71 W.

4. Quaternary Surficial Deposits

Quaternary alluvial sediments are concentrated chiefly in Ullman Park in the southwest corner of the area (Plate I). These alluvial deposits consist of clay, silt, sand, gravel, and boulders derived from adjacent Precambrian rocks. Transportation and deposition has been by mountain streams. The coarser detritus is angular to sub-rounded, and the alluvium is usually covered by a thin layer of soil and grass (Figure 14).

C. Structure

1. Metamorphic Rock Structures

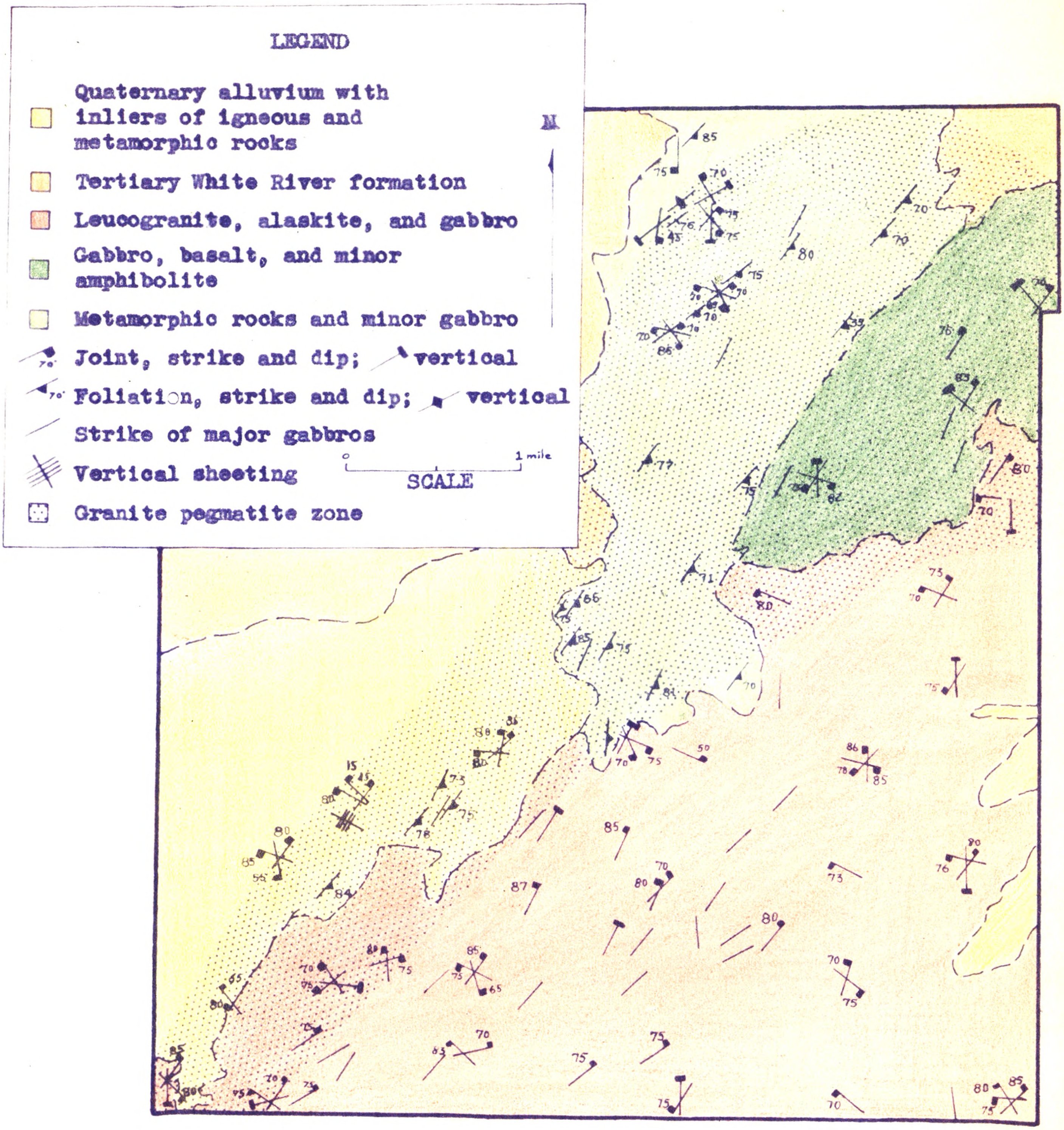
Foliation planes are better developed in the hornblende schists than in the massive mica-quartz schist. Both schists, however, show a general foliation trend of approximately N. 30° E., with a southeasterly dip of 75° (Figure 15). Lineation in these rocks is very difficult to determine. A few readings on the hornblende in the schist indicate the direction of lineation parallels the foliation and plunges about 70° to the northeast.

A quartzite bed about four feet in thickness in Section 34 exhibits bedding which dips 75° to the southeast. The quartzite strikes approximately N. 30° E. Jurgens (personal communication, 1961) maps a more extensive quartzite in his area which may show similar relationships. This quartzite bed is located approximately one mile northeast of the quartzite in the mapped area of this report. Original cross-bedding from both outcrop areas suggest that a younger sequence of sedimentary rocks lies to the southeast. While the character of the metamorphosed sediments prohibits accurate correlation of relict bedding or other sedimentary features with schistosity, the two examples noted suggest that the original bedding may closely parallel the present foliation.

Figure 14 - Picture of Ullman Park grazing area on Quaternary alluvium. View is south towards Laramie Peak from Sec. 9, T. 28 N., R. 71 W.

Figure 15

STRUCTURAL MAP OF ESTERBROOK AREA
(Converse and Albany Cos., Wyo.)
(1962)



Structures studied within the metamorphic terrain fail to indicate the presence of folding. Flexures may exist, however, but more detailed knowledge of relict sedimentary features and foliation, lineation, and other structural criteria will be needed to outline any such folds that may be present. Megascopic features of the rock outcrops did not yield such data.

Similarity of foliation trends and bedding directions, both in this area and for several miles to the north, the absence of any marked change in type or character of the metamorphic rocks near the granitic mass, and the known northeasterly trend of metamorphic structures in the Laramie Range suggest that the area was regionally metamorphosed prior to emplacement of the pluton. The presence of biotite, muscovite, hornblende, and epidote as stress minerals, the foliation characteristics, and the lineation indicate a stress environment and a possible dynamometamorphic cause for the regional features observed.

Joints in the metamorphic rocks are difficult to determine because of scarcity and character of the outcrops. The more massive rocks, however, such as the mica-quartz schist sometimes display joint sets. Three main sets have been mapped: (1) NNE, (2) NW, (3) WNW. The northeast set dips south about 70° and the northwest set dips south approximately 85°. The third set trends west-northwest and usually dips 70° to the southwest.

Comparison of the NNE joint set in the metamorphic rocks to the foliation planes shows a marked similarity. Both planar features trend approximately N. 30° E. and dip between 70-75° to the south. Furthermore, both of these features tend to parallel the relict bedding of the metamorphosed sediments. Stress minerals such as hornblende, epidote, muscovite, and biotite are contained within the planes of foliation and apparently arranged themselves perpendicular to a major axis of stress. Since the joint planes of the NNE set parallel the foliation planes and bedding planes of the metamorphic rocks, the NNE set probably represents bedding cleavage produced as a result of isoclinal folding or flow parallel to the original bedding. Dearth of field data indicating such folding in the area prevents a firm conclusion that the cleavage is actually a slaty cleavage parallel to axial planes.

If a strain ellipsoid is oriented so that its axis of greatest strain lies parallel to the direction of the strike of the bedding cleavage, the axis of least strain will be 90° away or perpendicular to the NNE joint set (Figure 16A). Other fractures or joint sets may be expected to form as a result of stresses imposed on the metamorphic rocks, according to this orientation of the strain ellipsoid (Billings, 1954).

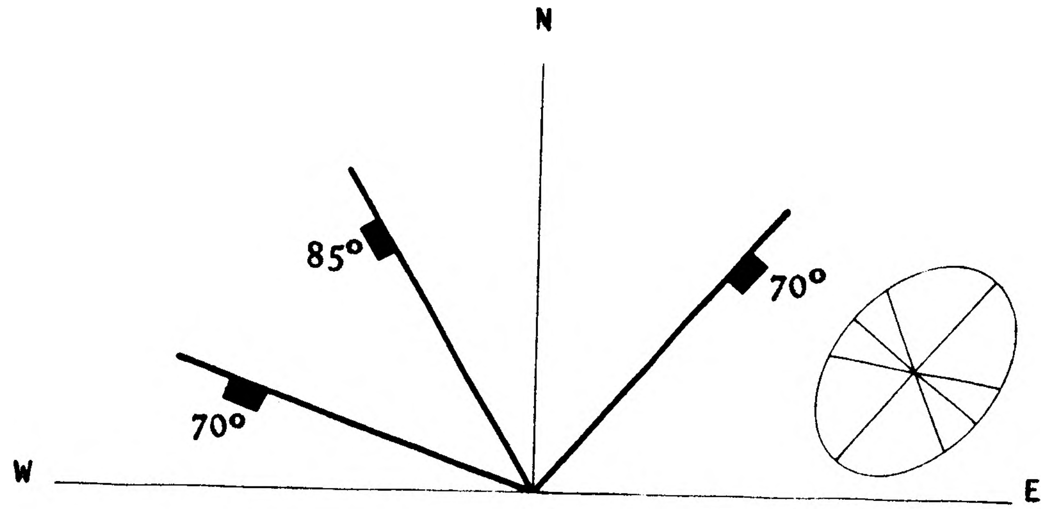
One joint set which may parallel a shear plane of a strain ellipsoid is the NW joint set observed in the metamorphic rocks. The joints of this set lie at an angle of about 20° to the axis of least strain in the previously oriented strain ellipsoid. These joints are probably planes which correspond to one set of shears forming at approximately 20° to the axis of least strain and/or greatest principal stress axis during isoclinal folding of the metamorphic rocks. The other set, the WNW trending joints, appears to be the shear set which should form at the same time as the NW set.

2. Igneous Rock Structures

Three main sets of joints occur in the silicic igneous rocks: (1) NNE, (2) NW, and (3) N (Figure 15). The first two sets have average inclinations of 80°, the NNE set dips to the north and the NW set to the south. The north trending set is usually vertical or steeply inclined to the west. Locally, closely spaced vertical joints, here termed sheeting, trend north-

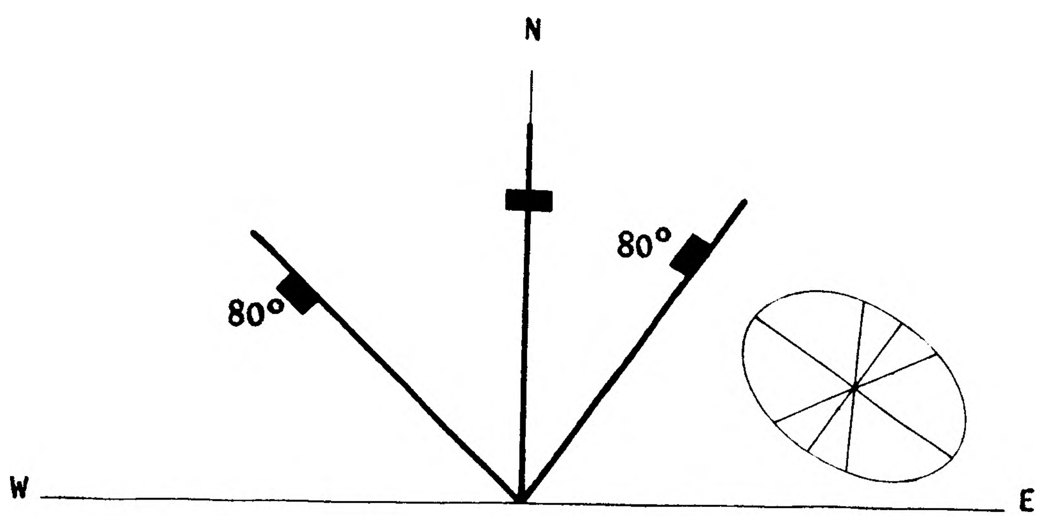
Figure 16

PREFERRED JOINTS IN METAMORPHIC AND IGNEOUS ROCKS, ESTERBROOK AREA, WYOMING
(with possible orientation of strain ellipsoid)



A.

Metamorphic Rocks



B.

Igneous Rocks

northeast.

The origin of the three main joint sets within the pluton is difficult to determine since no flow structures were recognized in the field. Basic dikes found in the igneous mass, however, show a preference for the NNE joint set. Since joints of this set contain nearly all of the later basic dikes, the joints are probably primary and represent tension fractures developed during the consolidation and contraction of the cooling magma (Balk, 1937). These fractures were open joints which were later filled by basic intrusions.

If a strain ellipsoid is oriented so that the axis of least strain lies parallel to the direction of the tension joints, the axis of greatest strain will be perpendicular to the trend represented by the tension joints (Figure 16B). Corresponding to the direction of the greatest strain is a joint set trending NW. The joints of this set lie at an angle of 75-80° to the direction of the tension joints. Since the NW trending joints are approximately perpendicular to the NNE joints, the northwest direction probably represents an extension direction. Joints parallel to this direction may represent the direction of greatest strain. These joints may be extension fractures formed during emplacement of the pluton and may be the result of compressive forces acting in a northeast direction. The N trending joints within the pluton make an angle of 30-40° to the so-called extension joints. This N set of joints may represent shears in the consolidating magma. These fractures could have formed as a result of compressive forces acting in a NE direction (Billings, 1954) and/or be the result of shears developed during contraction of the cooling magma.

Barlow (1950) shows that the principal structures within the sediments overlying the Precambrian basement generally parallel the main NW trending anticlinal axis of the Laramie Range. Information is lacking,,however, which would permit possible relating of the structures in the igneous rocks of the Esterbrook area with those nearer the anticlinal axis within the Laramie core.

No flow structures were recognized within the igneous rocks, and contact relationships between the pluton and the country rock are relatively sharp and non-gradational. No field examples were observed of country rock showing recrystallization or granitic-like texture and composition nearer the igneous bodies. The biotite-leucogranite appears to have a rough marginal or peripheral zone of alaskite and muscovite-leucogranite. Beyond the major igneous bodies, numerous granite pegmatites occur in the metamorphic, country rock (Figure 15). This general zoned pattern of the igneous rocks and the contact relationships suggest that the igneous bodies are definitely intrusive in character. The alaskites, muscovite-leucogranites, and pegmatites probably represent differentiated phases of the parent magma.

Emplacement of the massive intrusive was probably passive in character since no evidence was observed of distortion of the foliation or of the few bedding features visible in the metamorphic rocks at or near the margins of the intrusive body. These planar structures maintain a northeasterly trend throughout the mapped area and to the north of it. Lack of any metamorphic foliation in the granitic bodies indicates that these bodies are younger than the metamorphism of the area. During emplacement, the pluton appears to have risen generally parallel to the foliation of the metamorphic rocks, but in detail the contacts along the northeast margin are discordant. Except for the northeast trend, the main igneous mass shows no evidence of preference for pre-existing structures. The silicic pluton was probably emplaced by magmatic stoping.

3. Sedimentary Rock Structures

Younger, nonmetamorphosed sediments within the area show no conspicuous secondary structures. They have gentle dips away from the adjacent Precambrian rocks. These dips are considered to be those formed on the original Precambrian surface.

No faults were recognized anywhere within the area studied. A fault has been mapped, however, in the SW 1/4 of Section 12, R. 71 W., T. 28 N., approximately 1/4 mile east of the mapped area (Love, J. D., and others, 1955). This fault trends NNE and places Permian sedimentary rocks in contact with the Precambrian biotite-leucogranite. Other faults (Love, J. D., and others, 1955) are present in Section 18, R. 70 W., T. 28 N., approximately one mile southeast of the previously mentioned fault.

V. MINERAL DEPOSITS

A. Introduction

Mineral deposits of the Esterbrook area are classified into four main groups, based on mineralogical assemblages: (1) pyrrhotite-quartz-minor chalcopyrite, sphalerite, (2) galena-pyrite-calcite-quartz, (3) quartz-pyrite, and (4) quartz-feldspar-mica-beryl. Distribution of these deposits is shown in Figure 17. Galena deposits in the early 1900's yielded lead and associated minor silver. Pyrrhotite deposits were mined principally for trace amounts of copper. Active mining ceased about 1915 and only intermittent prospecting has been done since then.

All of the sulfide deposits are tabular or lense-like in form. They strike northeast, parallel to the main structural trends within the country rocks and have vertical dips. Pyrrhotite bodies are known in the Precambrian igneous and metamorphic rocks, and the one known galena deposit occurs in the metamorphic rocks. Quartz-pyrite veins have been altered to gossan-like lenticular bodies in the metamorphic rocks. Two granite pegmatites in the metamorphic rocks contain minor amounts of beryl and apatite.

The mineral deposits are not deeply weathered, and little supergene enrichment has taken place. Locally small pockets of azurite, malachite, and/or cerrusite occur within the limonite gossan.

B. Pyrrhotite-quartz-minor chalcopyrite, sphalerite deposits

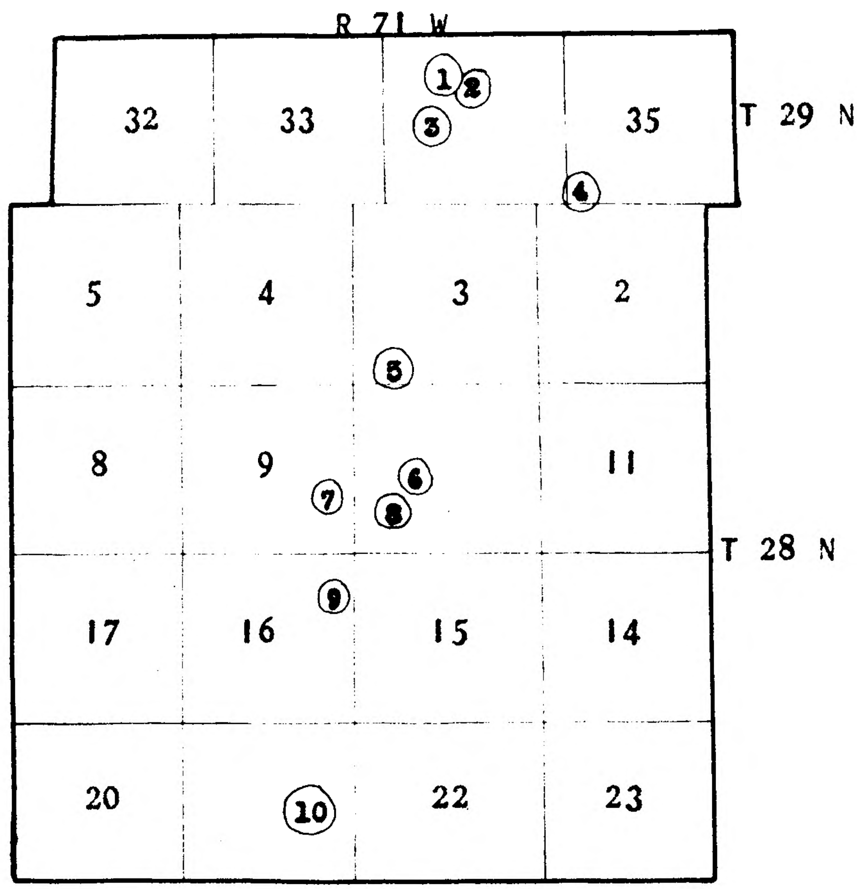
Pyrrhotite deposits are known in six locations: (1) Kreisley, (2) Tenderfoot, (3) McGhee, (4) Big Five, (5) Three Cripples, and (6) Maggie Murphy (Figure 17). They consist of massive pyrrhotite, with blebs of quartz and traces of chalcopyrite. According to Spencer (1916), the deposits vary in size but may attain widths up to 50 feet, and lengths of several hundred feet. They strike N. 30-35° E., and have vertical dips.

Figure 17

DISTRIBUTION OF MINERAL DEPOSITS OF THE ESTERBROOK AREA,
(CONVERSE AND ALBANY COS., WYOMING)

EXPLANATION

1. Apatite-beryl
2. Apatite-beryl
3. Pyrite-quartz (Maverick)
4. Pyrrhotite (Kreisley)
5. Pyrrhotite (Tenderfoot)
6. Pyrrhotite (McGhee)
7. Galena (Esterbrook)
8. Pyrrhotite (Big Five)
9. Pyrrhotite (Three Cripples)
10. Pyrrhotite (Maggie Murphy)



Shafts on some of the deposits were reported to have reached depths approximating 100 feet. However, exposures examined did not indicate these dimensions. The maximum size of outcrop noted was that of the Three Cripples deposit, which is approximately 10 feet wide by 50 feet in length. The other deposits are smaller.

Inaccessibility of the mine workings prevented detailed study of these pyrrhotite lodes. However dump materials were studied and samples taken for polished section examination. Under the reflecting microscope, the samples show abundant pyrrhotite and quartz (Figure 18). Both minerals are intimately mixed; fine to medium-grained quartz is randomly distributed throughout the pyrrhotite, and grains of pyrrhotite are often included in the quartz.

Minor amounts of chalcopyrite and traces of sphalerite are also present. Fine to coarse-grained chalcopyrite is usually locked to pyrrhotite but is occasionally included in the quartz. Fine-grained sphalerite is either included in the quartz or locked to pyrrhotite and chalcopyrite. No evidence of exsolved chalcopyrite in sphalerite was noted.

Disordered fragments of amphibolite (?) country rock occur in some of the samples. Individual fragments show a schistose arrangement of pyrrhotite and chalcopyrite. Veinlets of limonite cut the country rock fragments and individual minerals of the samples. See Figure 19.

The sulfide minerals have mutual boundaries and therefore apparently crystallized together. Pyrrhotite may have begun to separate first, however, with overlapping deposition of quartz, chalcopyrite, and sphalerite. Limonite probably deposited last along later fractures. In the field, massive pyrrhotite deposits show a distinctive cap of limonite.

The source of these deposits is unknown. Abundant coarse-grained

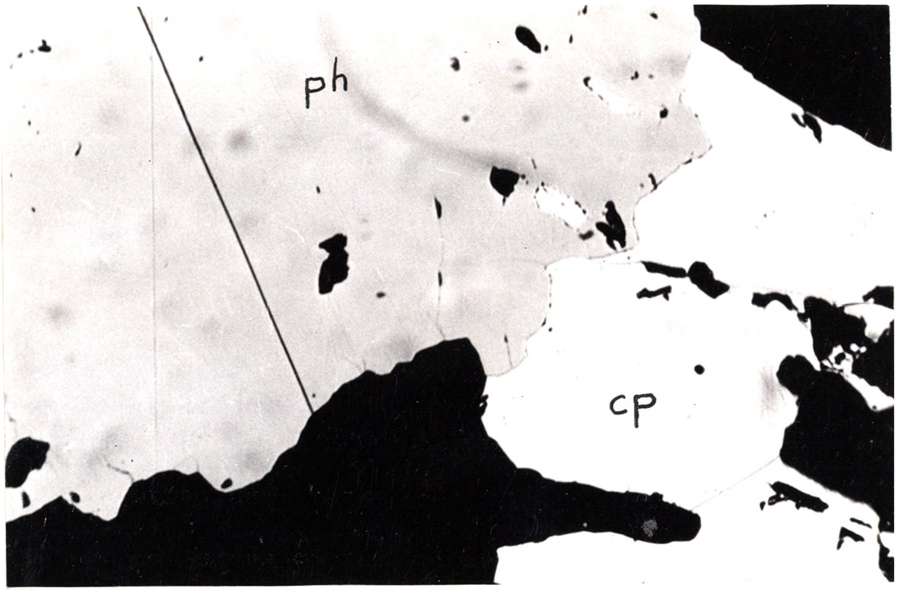


Figure 18 - Polished section of pyrrhotite-chalcopyrite-quartz. Sulfides and gangue show mutual boundaries. Dump sample from Three Cripples property, oil immersion, 100x.

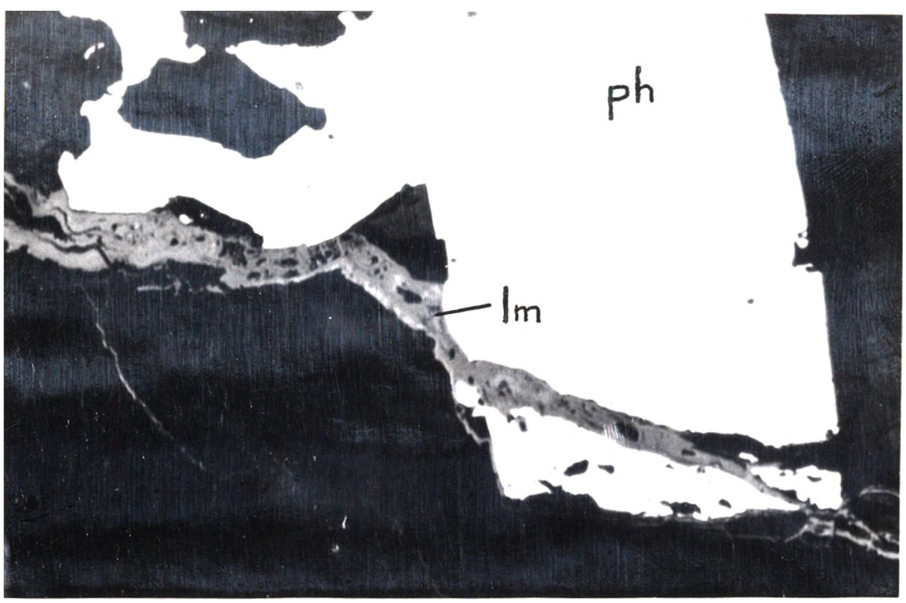


Figure 19 - Polished section of pyrrhotite-limonite-quartz. Limonite cuts sulfide and gangue. Dump sample from Three Cripples property, oil immersion, 100x.

pyrrhotite and brecciation characteristics suggest mineralization at high temperatures and pressures, possibly derived from a magmatic source. These deposits may represent filling and partial replacement of country rock by iron and sulphur-bearing solutions.

C. Galena-pyrite-calcite-quartz deposit

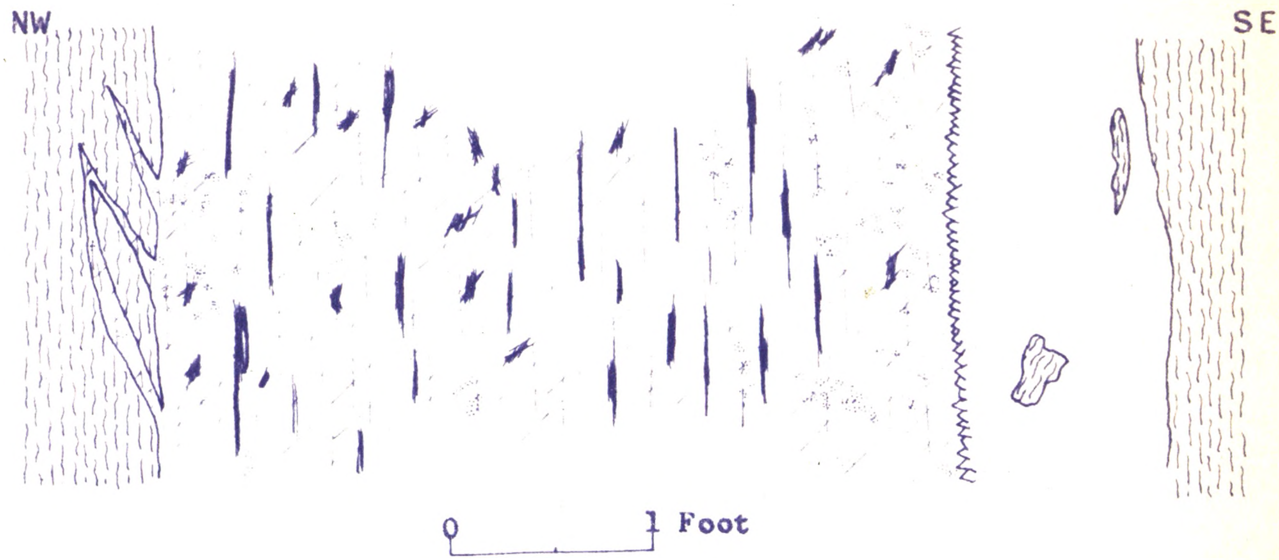
The only known deposit of galena occurs as a tabular, open-space filling in green hornblende schist on the Esterbrook property. The body strikes N. 30° E., and is vertical. Mineralogy consists of galena, pyrite, calcite, and quartz. Supergene cerrusite, minor amounts of limonite, and covellite also occur, as do traces of malachite.

The vein occurs as a vertical body approximately four feet in thickness (Figure 20). The deposit consists of asymmetric filling by quartz, calcite, and minor sulfides. Approximately one foot of quartz appears to have been deposited first in a fracture in the hornblende schist. This period of mineralization was terminated by the deposition of quartz crystals pointing toward the northwest wall of the vein. Deposition resumed with the formation of coarsely-crystalline calcite and thin interlayers of galena. Some of the layered calcite contains intergrowths of subhedral to euhedral quartz. This period of deposition attained four feet in width. The wall rock appears fresh and unaltered, but small veinlets of calcite cut it.

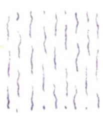
Three shafts indicate that the mineralization extends for approximately 500 feet along the strike of the lode (Spencer, 1916). One shaft reportedly is about 350 feet deep. On the main level at 335 feet, two drifts are reported, one 300 feet to the south and the other 100 feet to the north. Nothing that resembles ore remains on the dump, but it is reported (Spencer, 1916) that solid shoots of galena six feet wide were mined in the underground workings.

Figure 20

CROSS-SECTION SKETCH OF ESTERBROOK
GALENA-PYRITE-CALCITE-QUARTZ FISSURE VEIN



EXPLANATION

 Hornblende schist country rock

 Veined quartz with terminated crystals

 Medium to coarse-grained calcite (vert. layering)

 Quartz disseminations

 Thin, interlayered galena stringers and patches

Under the reflecting microscope, polished sections of the dump samples show abundant cerrusite replacing galena (Figure 21). Clear medium-grained quartz and medium-grained calcite comprise the remaining minerals. Traces of pyrite, limonite, and malachite are present.

Open-space filling characteristics, i.e., veining of the wall rock, and very little wall rock alteration suggest that the deposit is a shallow-depth fissure filling. Apparently, ascending hydrothermal solutions migrated into the fracture and deposited the quartz, calcite, galena, and associated minerals. Oxidation by supergene solutions has formed cerrusite from galena. The deposit would be classified as shallow-depth epithermal (Lindgren, 1933).

D. Quartz-pyrite deposits

Veins of quartz-pyrite occur in the hornblende schist. These veins are 3-4 feet wide, strike N. 30-35° E., are vertical, and may extend to 50 feet in length. They are usually barren of any mineralization except for occasional bunches of pyrite within the massive quartz. At the surface, the pyrite oxidized to limonite. Under the reflecting microscope, quartz and minor pyrite is mixed with colloform limonite, and occasional patches of malachite are also visible in the gangue (Figure 22).

The quartz-pyrite deposits have undergone little exploitation in the area. At the Maverick property, a 50-foot shaft was sunk on one vein, but it is now inaccessible. Numerous prospect pits have been dug in this type of deposit.

The pyritiferous quartz veins occur principally within the same zone as the pegmatites, although examples of gradation between the two types of deposits were not noted. Some pegmatites, however, do grade into almost solid quartz deposits, but these show no pyrite. There is a doubtful genetic relationship between the two.

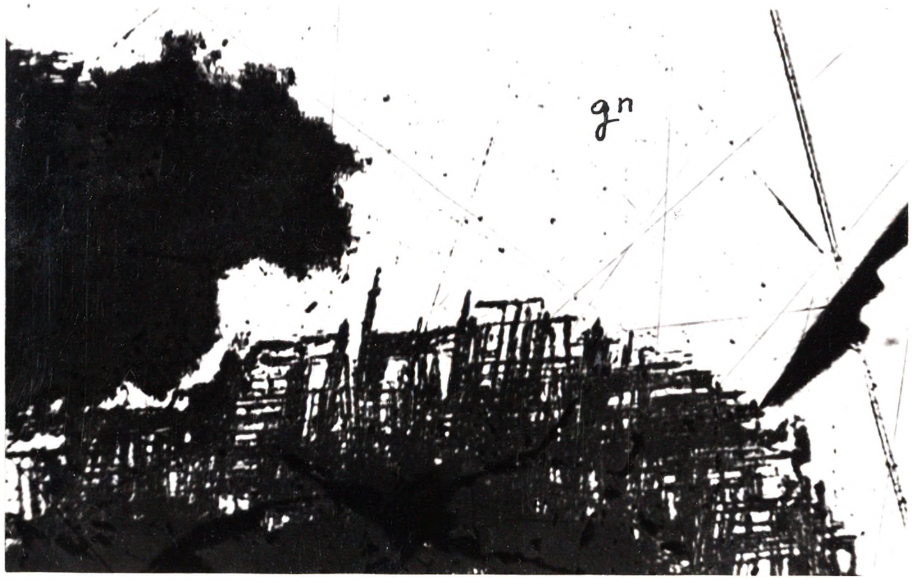


Figure 21 - Polished section of galena-cerrusite-covellite. Cerrusite enters galena along cleavage directions. Minor covellite is scattered along the borders of the carbonate. Dump sample from Esterbrook property, oil immersion, 100x.

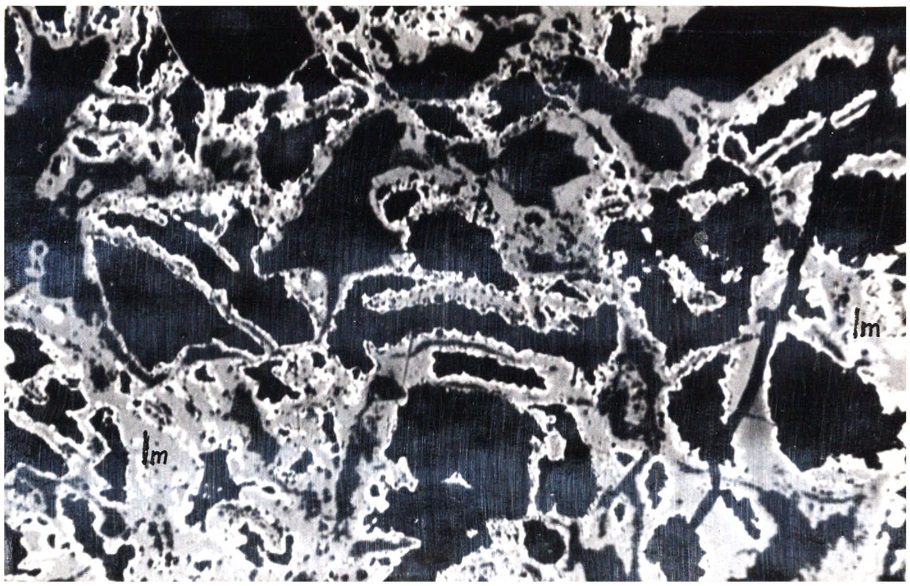


Figure 22 - Polished section of limonite-quartz. Limonite shows colloform-like texture. Sample from Maverick property, oil immersion, 100x.

E. Quartz-feldspar-mica-beryl deposits

Numerous pegmatites of granitic composition occur within the pegmatite zone shown in Figure 15. Only two of these pegmatites, within the area, contain unusual mineral content. These two show visible amounts of beryl.

These two beryl-bearing pegmatites strike parallel to the foliation of the hornblende schist, are vertical, and cut the foliation planes. In size, they are from 2-5 feet in width and up to 300 feet in length. The pegmatites show zoned characteristics with a quartz-beryl core (see Figure 11). Individual beryl crystals vary in size from 1/4 to 3 inches in diameter within the massive quartz. As noted, the beryl comprises less than one percent of the pegmatite core.

F. Economic Possibilities of the Area

Geologic characteristics of the known deposits suggest a poor economic potential. The pyrrhotite deposits as exposed are not of an encouraging size. Magnetic surveys over the known bodies might permit a more critical evaluation of these deposits. The galena-bearing deposit is particularly discouraging because of its relatively small size and single occurence. No value is attached to the quartz-pyrite veins. The beryl content in the two pegmatites studied is much less than one percent of the overall pegmatite and therefore does not seem to warrant exploitation.

VI. SUMMARY AND CONCLUSIONS

Several rock types were noted in the Esterbrook area. These include metamorphic and igneous rocks of Precambrian age and sedimentary rocks of Cenozoic age. A geologic map shows their distribution, and the cross-sections their structure. The oldest rocks of the area are metamorphosed sediments, comprising hornblende schist and mica-quartz schist. They exhibit characteristics of the amphibolite facies produced through regional dynamo-metamorphism of argillaceous marls and impure, quartzo-feldspathic sands. The original sediments were deposited during early Precambrian time, and could have been formed in a deltaic-type environment. Sometime after their deposition and induration, these sedimentary rocks probably experienced a period of isoclinal-type folding and regional metamorphism. Bedding cleavage and shears developed as a probable result of stress exerted in a NW direction. The metamorphic rocks of younger age probably lie to the southeast.

Later, in Precambrian time, a pluton of silicic composition was emplaced, probably by magmatic stoping. This magma rose into the metamorphic rocks, for the most part concordant to the foliation. The main igneous mass is a biotite-leucogranite. Small marginal zones of muscovite-leucogranite and alaskite formed, probably through fractional crystallization of the original magma. Pegmatitic fluids, representing the last residual phase of the magma, invaded the metamorphic country rock parallel to principal structural trends to form a marginal zone closely associated with the pluton. The crystalline rocks and their associated mineral deposits have been exposed through processes of erosion acting on the Tertiary White River formation, which originally covered the area.

Fractures, developed in the pluton during emplacement and subsequent cooling, produced joint sets of a tensional, extensional, and shear-type character possibly as a result of cooling stresses. Tension joints remained open and many were filled with aplitic and pegmatitic differentiates of the parent magma, particularly along its periphery. Basic intrusions of gabbro also filled these tension joints and may represent a complementary dike set.

More information is needed to determine the exact nature of the pyrrhotite bodies, however, they are apparently related to magmatic activity during Precambrian time and may represent a high-temperature partial replacement of the country rock. Zonal arrangement of the quartz-pyrite veins coincident to that of the pegmatites suggests a temperature-pressure control near the main pluton and a possible genetic relationship to the intrusive body. The galena-pyrite-calcite-quartz vein shows shallow-depth characteristics and is not considered to be related to the exposed pluton.

While basic data of importance was gathered in the present study, further work seems warranted. Structures within the igneous body outside this area should be carefully studied to determine if primary flow features, schlieren, linear parallelism of minerals, and so forth are present. A careful classification of the different joint sets and the mineralization they contain may also yield important data that will contribute to a better understanding of this pluton.

A detailed petrofabric analysis of the metamorphic rocks within and outside the area is also warranted. Petrofabric analyses of the rocks, including lineation directions and plunge and grain orientation, would be helpful in determining the nature of the metamorphism and the stresses involved and might reveal folds not recognized in this study.

Although a favorable economic potential of the mineral deposits is doubtful, magnetic surveys of the pyrrhotite bodies should be run to ascertain their overall size. Conclusions, from this investigation, as to the size of these bodies are not in accord with older reports.

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VITA

Michael Nolan Greeley was born to Mr. and Mrs. Godfrey McKay Greeley on the 27th of September, 1937, in Nashville, Tennessee. He graduated from West High School in 1955, in Knoxville, Tennessee. There he continued his education, receiving a B. S. degree in Geology in 1959 at the University of Tennessee. For the next five months, he obtained instruction in Spanish and related subjects at the National University of Mexico, Mexico City, Mexico.

In the fall of 1960, he began a two year program of graduate study leading to a Master of Science degree in Geology at the Missouri School of Mines and Metallurgy, Rolla, Missouri. He held a Graduate Assistantship from September, 1961, to June, 1962. Upon completion of the graduate program, he will enter active duty for two years as a 2nd Lieutenant in the United States Army.

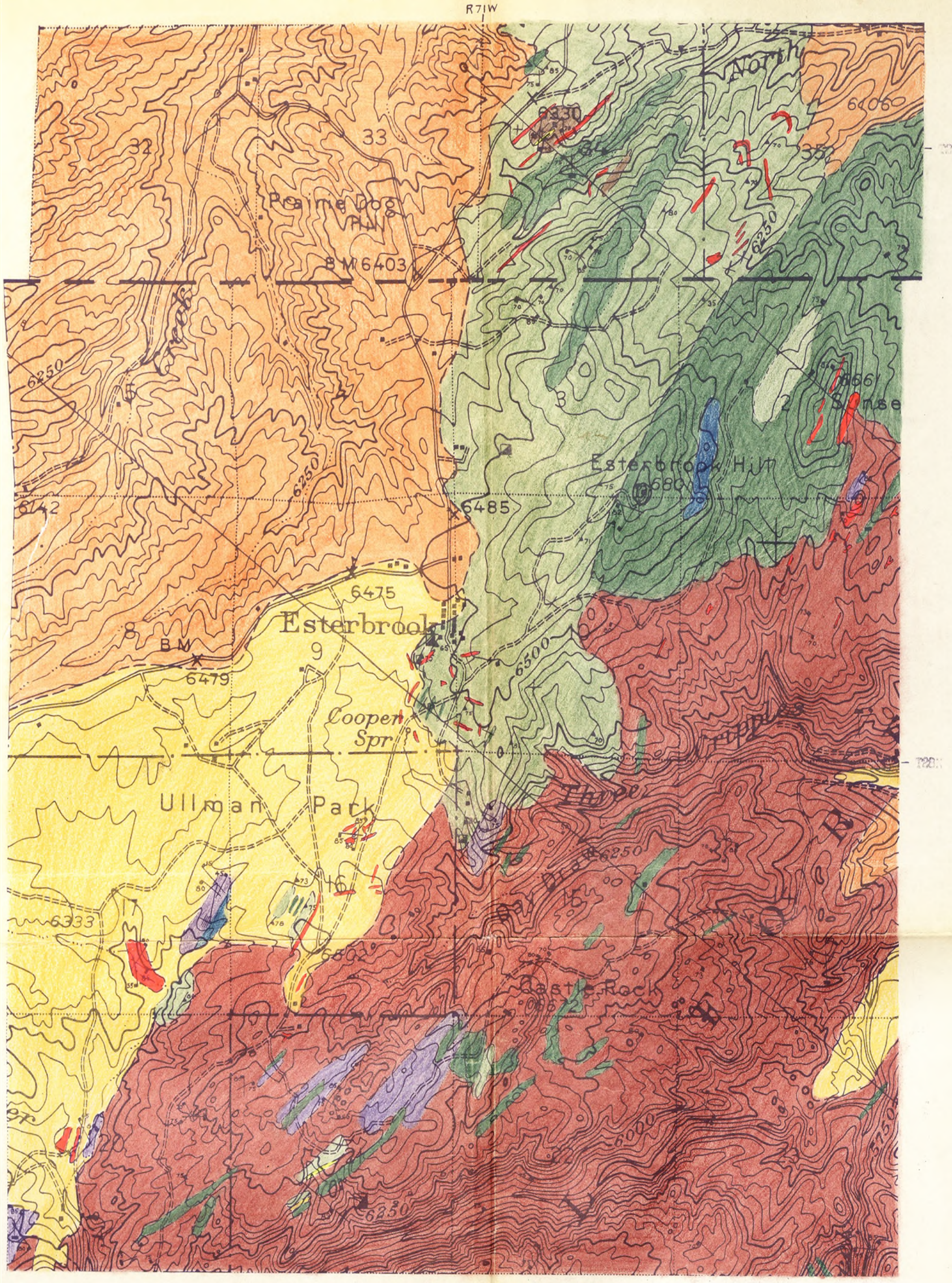
Plate I

GEOLOGIC MAP AND SECTIONS OF ESTERBROOK AREA, CONVERSE AND ALBANY COUNTIES, WYOMING

by

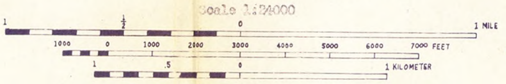
MICHAEL N. GREELEY

1962



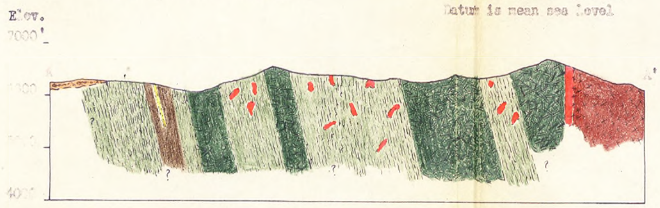
GEOLOGIC MAP OF ESTERBROOK AREA, WYOMING

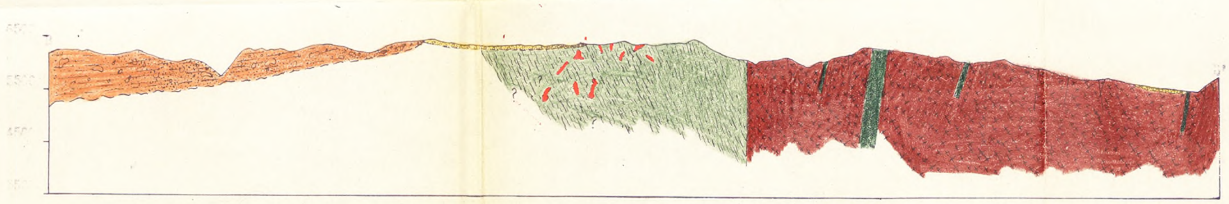
Scale 1:24000



Contour interval 50 feet
Datum is mean sea level

GEOLOGIC CROSS SECTIONS





Base from U.S. Geological Survey Esterbrook topographic quadrangle 1945

LEGEND

SEDIMENTARY ROCKS

QUATERNARY Recent

- ALLUVIUM (poorly sorted, recent stream deposits)

TERTIARY Oligocene

- WHITE RIVER FORMATION (sandy, conglomeritic claystone)

PRECAMBRIAN

IGNEOUS ROCKS

- GABBRO AND BASALT (greenish-black, ophitic dikes and sills)
- GRANITE PEGMATITE (light-gray, granite pegmatite dikes)
- ALASKITE (pink, medium-grained, quartz-feldspar intrusive)
- MUSCOVITE LEUCOGRANITE (gray, medium-grained granite intrusive)
- BIOTITE LEUCOGRANITE (cream-colored, coarse-grained, granite with pegmatite and aplite facies)

METAMORPHIC ROCKS

- QUARTZITE (yellowish-white, fine-grained metaquartzite)
- MICA-QUARTZ SCHIST (light-gray to gray, fine to medium-grained sedimentary schist)
- HORNBLENDE SCHIST (greenish-gray, medium-grained, sedimentary, hornblende schist)

Contact, known, indicated, and inferred

Joint, strike and dip; vertical

Foliation, strike and dip; vertical

Strike and dip (in quartzite)

Vertical sheeting with strike

Geologic section line

National forest boundary

Abandoned mine shaft

Prospect pit

Approximate mean declination, 1955

Figure 2 - Panoramic view of western portion of thesis area. Center of picture is approximately WNW. Laramie Mountains in left background trend NW. Forested foreground is the granitic portion of the Esterbrook area. Smooth, non-wooded middle ground is underlain by Quaternary alluvium and rear middle ground is Tertiary White River formation. Picture taken from Sec. 21, T. 28 N., R. 71 W.