THE GEOLOGICAL SURVEY OF WYOMING

D. L. BLACKSTONE, JR., State Geologist

PRELIMINARY REPORT NO. 7

The Centennial Ridge Gold-Platinum District, Albany County, Wyoming

BY

M. E. McCALLUM

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(1968) 1982

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INTRODUCTION

The Centennial Ridge mining district is located in portions of T. 15 N., T. 16 N., and R. 78 W. along the eastern slope of the Medicine Bow Mountains in southeastern Wyoming. The district includes Centennial Ridge and Middle Fork Canyon of the Little Laramie River and extends north to Wyoming State Highway 130 (Fig. 1).

Most of the area is accessible approximately eight months of the year by a network of lumber roads and jeep trails. No vehicular access is currently available to the southern part of the area (south of the Columbine Mine). A railhead of the Laramie, Hahns Peak & Pacific Railroad is present at Centennial, a small town at the northeast edge of the district on Wyoming State Highway 130 about 30 miles west of Laramie.

Mapping was done on enlarged aerial photographs having a scale of approximately 1,130 feet to the inch. Geologic data were transferred from the photographs to a base (approximately 1,000 feet to the inch) enlarged from the U.S. Geological Survey Centennial quadrangle that had an original scale of one inch equals 2,000 feet.

The study was supported by research grants from the Geological Survey of Wyoming, the Geological Society of America (Project Grant No. 843-60), and the Colorado State University (FIC Grant No. 5301-9), and for this aid appreciation is here expressed. The writer also wishes to thank Mr. E. K. Burhans for the use of personal file reports on the Independence Gold Mining Company properties, and Professor R. S. Houston, Department of Geology, University of Wyoming, who kindly reviewed the manuscript.

TOPOGRAPHY AND CLIMATE

Topographic relief in the area is rather moderate, ranging from about 700 feet to 1,600 feet. Maximum relief occurs along the east flank of Centennial Ridge and in lower Middle Fork Canyon where elevations rise from approximately 8,200 feet and 8,600 feet respectively to nearly 9,800 feet in less than one mile. The roughly flat-topped summit of Centennial Ridge and the northwestern part of the mapped area range in elevation from about 9,600 to 9,800 feet, and are part of the eastern extension of a slightly dissected erosion surface which slopes gradually to the east and southeast at about 120 feet per mile from a high point in the vicinity of Snowy Range Pass (elevation - 10,847 feet).

Dense stands of lodgepole pine cover most of the low relief surface areas, whereas spruce, pine, and fir are abundant in the valleys and canyons. Many of the valleys are choked locally with thick growths of alder and/or aspen, and numerous species of bushes and grasses cover stream bank meadows and bogs. Much of the eastern flank of Centennial Ridge has a sparse cover of sage brush and grasses with thick stands of aspen along the lower slopes near the contact between Precambrian and post-Precambrian rock units.

Rock exposures are fairly abundant in the general area of Centennial Ridge and particularly so along the sides of Middle Fork Canyon. Few outcrops are present on the erosion surface proper and in other heavily timbered areas.

The climate is typical of intermediate mountain terranes in the region; but a few bitter cold winters with very heavy snowfalls have been recorded. Roads into the area are usually snowbound from January to April or early May; however, many of these could easily be kept open if commercial operations should warrant it.

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* Associate Professor of Geology
Colorado State University, Fort Collins, Colorado.

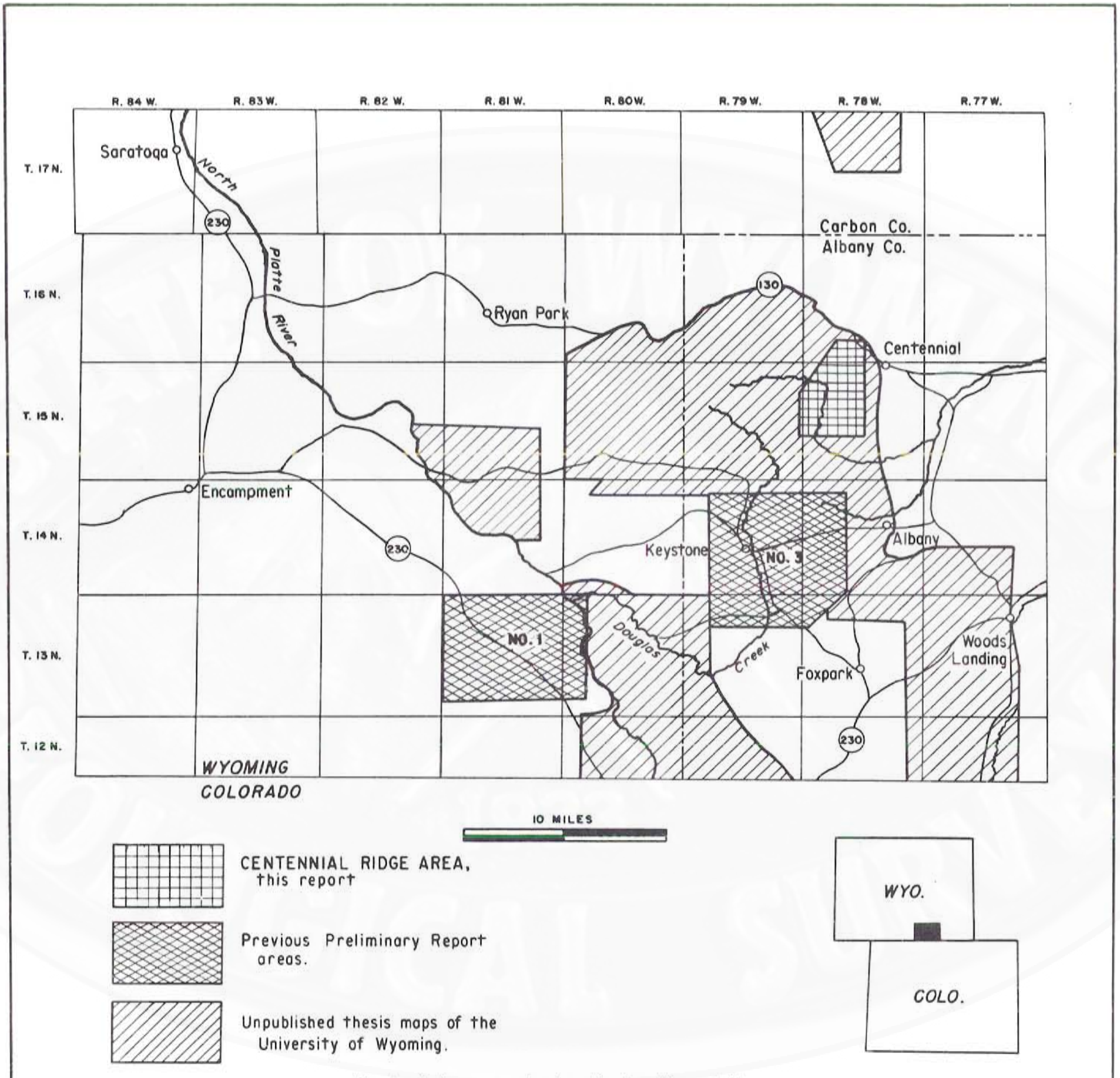

Fig. 1. Index map showing the location of the Centennial Ridge gold-platinum district.

DWN. — J. F. F.

HISTORY AND DEVELOPMENT

Mineralization in the Centennial Ridge district was first reported in the 1870's with the discovery of gold, shortly following similar discoveries in the central part of the Medicine Bow Range. Numerous placer claims were filed and worked, but all recorded ore production in the district has been from lode operations. The Centennial Mine ($SE\frac{1}{4}$, sec. 4, T. 15 N., R. 78 W.), which was opened up in 1876 (Beeler, 1906, p. 11), and the Utopia mine (secs. 4 and 9, T. 15 N., R. 78 W.) which opened somewhat later, both produced small amounts of gold. The only other known ore production in the district was from gold bearing quartz vein surface workings of the Free Gold claim on the summit of Centennial Ridge (secs. 8 and 9, T. 15 N., R. 78 W.) (Hess, 1926, p. 129).

Shortly after 1900, platinum and palladium were reported and extracted from copper ores of the New Rambler Mine[1], several miles southwest of the Centennial Ridge district. This discovery triggered a new wave of prospecting in the area and accounts of valuable platinum deposits have periodically filtered out to the public over the past 65 years. Phenomenal ore assay values for platinum group elements have led numerous people into promotional ventures and sincere developmental efforts, but to date there has been no known production of these "ores" from the Centennial Ridge district. A few parties are currently investigating the feasibility of future development and production of mineral properties in the district.

GENERAL GEOLOGY

Bedrock in the district ranges in age from Precambrian through Recent, but since the post-Precambrian units are of little apparent economic significance, they are all included under a single map unit (Pl. 1). Post-Precambrian materials include upper Paleozoic and Mesozoic sediments and Pleistocene pediment gravels on the east flank of Centennial Ridge; isolated exposures of Tertiary conglomerate and extensive covers of Pliocene (?)- Pleistocene gravel on erosion surface remnants; glacial deposits west of Centennial (secs. 32 and 33, T. 16 N., R. 78 W.); and alluvial, colluvial, and talus deposits distributed throughout the mapped area.

The Precambrian rocks may be conveniently divided into six general units as follows:

1. Mafic Series sequence (p€ms); amphibole-biotite rich schists and gneisses.
2. Lime-silicate rocks; pyroxene-rich gneiss (p€pg), lime silicate marble (p€lms), and skarn-like rocks (p€sk).
3. Felsic gneisses; consisting of cataclastic biotite augen gneiss (p€ag), mylonitic biotite-epidote-plagioclase gneiss (p€mg), and quartz monzonite gneiss (p€qmg) units.
4. Amphibolitized meta-igneous rocks (p€a); principally orthoamphibolite, metadiorite, metagabbro, and metapyroxenite.
5. Granitic intrusive rocks (p€Sq; p€ai); granite, quartz monzonite and pegmatites.
6. Shear zone tectonites; ultramylonite, mylonite, submylonite, cataclasite, phyllonite, fault breccia, and fault gouge.

Rocks of these general units are found throughout the area and most foliated or schistose varieties trend to the northeast and dip steeply (chiefly 55° to vertical) both to the southeast and northwest. Intrusive bodies tend to be essentially concordant with their metamorphic hosts and thus generally have the same northeasterly trend. Major shear zones also tend towards concordancy with regional trends, although the prominent shear zone in upper Middle Fork Canyon (secs. 8 and 5, T. 15 N., R. 78 W.) is quite strikingly discordant.

Mafic Series Sequence

Rocks of the Mafic Series sequence are found throughout the district but are chiefly concentrated in a mile wide northeasterly trending belt extending from the southwest corner of the area to the northeast flank of Centennial Ridge (sec. 4, T. 15 N., R. 78 W.). This sequence consists of a variety of amphibole and biotite rich

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1/ According to Osterwald, et al (1959, p. 134): "In 1902, $6,000.00 was paid for platinum ores from the Rambler Mine at Holmes and there were small amounts produced between the years 1915 and 1920."

schists and gneisses which appear to be the oldest rocks in the area. Included in the map unit are many thin sheets, small lenses, and irregular masses of amphibolitized meta-igneous rocks which are too small to be mapped separately.

Mafic Series rocks are primarily dark colored, fine- to coarse-grained, biotite, biotite-hornblende, biotite-garnet, biotite-hornblende-garnet, biotite-cummingtonite-hornblende-garnet, hornblende-plagioclase-garnet, and hornblende-plagioclase, schists and gneisses. These units are completely intergradational with one another and are probably similar in age. Mineralogical differences likely reflect compositional variations in the original sedimentary (?) rock assemblage. Some of the units are strikingly porphyroblastic, containing large crystals or crystal aggregates (up to one inch across) of garnet, plagioclase, or pyroxene. Most of the units have a moderately strong foliation imparted by the planar orientation of biotite, chlorite, and amphibole. Lineations formed by oriented amphibole crystals, chlorite and biotite streaks and smears, quartz rods, and fold axes are quite common and reflect at least two and possibly three different deformational episodes.

Like most of the rocks in the region, Mafic Series units show the effects of shearing. Some mafic-rich schists and gneisses have been converted to intensely granulated tabular bodies of submylonite[2] and mylonite, but original rock composition is generally still recognizable in the cataclastic products.

Quartz veins ranging in size from tiny microscopic veinlets up to massive veins 10 to 15 feet wide commonly occur in units of this sequence. The quartz varies from milky white to gray to pale blue gray and locally contains free gold and iron sulphides. Most of the gold mined in the district was extracted from these quartz veins in secs.4, 8, and 9, T. 15 N., R. 78 W. in the northeastern part of Centennial Ridge.

Mafic Series rocks grade into felsic gneisses in an interlayered and interfingering fashion in both northwest and southeast directions. Field relations suggest that the associated felsic rocks are younger and may owe their existence at least in part to transformation of the older mafic units. Remnants of Mafic Series rocks are scattered throughout the various felsic gneiss units of the region, and inclusions in the coarse-grained Sherman-type granite appear to be similar rock types.

Lime-Silicate Rocks

Lime-silicate rocks are largely confined to the central and eastern parts of the district. They occur intercalated with Mafic Series units with which they are probably time equivalents, and commonly exhibit complex interfingering, interlayering, and highly gradational contact relationships. Individual layers and lenses range from a few inches to several hundred feet in thickness and up to nearly a mile in length, but average dimensions are on the order of a few tens of feet in width and several hundred yards in length. The usual small size of the bodies and their complex interrelationships with Mafic Series units present difficulties for mapping these rocks as discrete units. Therefore, the lime-silicate map units encompass areas where lime-rich rocks predominate.

The lime-silicate rocks consist chiefly of lime-bearing silicate minerals and calcite and may be roughly divided into three major types: 1) massive to crudely layered pyroxene-rich gneiss, 2) strongly layered lime-silicate marble, and 3) massive to layered skarn-like rock.

The pyroxene-rich gneiss is a green to greenish black, coarse-grained, weakly to moderately foliated, locally porphyroblastic rock composed of clinopyroxene (diopside and diopsidic augite), hornblende, chlorite, and calcite, with lesser amounts of plagioclase (andesine to labradorite), quartz, epidote and minor accessory minerals. Much of the rock is considerably altered (pyroxene to hornblende; hornblende to chlorite) and secondary calcite occurs as thin layers and in a complex network of tiny crosscutting veinlets.

The most abundant lime-rich unit in the area is a gray to buff, medium- to coarse-grained strongly layered impure marble. Individual layers in the marble range from fractions of a millimeter up to several inches thick (average about 2 to 15 mm.) and vary in color as a function of different mineralogic composition. Alternate layers are generally calcite and/or quartz-microcline rich vs. hornblende-plagioclase (calcic andesine) -quartz rich. Occasional layers are enriched in epidote, diopside, and sphene. Slender prismatic hornblende crystals are often oriented in a matrix of calcite, quartz and feldspar producing very pronounced lineations. This marble is typically differentially weathered, the more resistant hornblendic and felsic layers standing out in bold relief whereas calcite rich layers characteristically form a series of parallel channels in outcrop surfaces. Locally, the unit has been strongly contorted, and concentration of calcite in crests and troughs of small folds suggests some flowage. Deformational features are quite abundant in the marble where the unit is in close proximity to shear zones.

2/ Term proposed for medium-grained cataclastic rocks that have been somewhat chemically reconstituted. Intermediate between cataclasites and mylonites of Williams, Turner, and Gilbert (1955, p. 175, 200-205), and comparable to submylonite gneiss of Waters and Campbell (1935, p. 478-479).

Skarn-like rocks, which comprise the smallest fraction of the lime-silicate sequence, occur as thin lenticular bodies intimately associated with narrow bodies of Mafic Series rocks juxtaposed to younger felsic gneisses. Proximity to felsic rock types coupled with local potash enrichment strongly suggests that granitic solutions may have induced metasomatism in an originally calcareous unit (possibly analogous to the layered marble). The skarn-like rocks are pink to brownish green, fine- to coarse-grained, and massive to crudely layered, and consist mainly of calcite, garnet (grossularite), diopside, and epidote, with varying amounts of quartz, microcline, clinozoisite, and idocrase.

Felsic Gneisses

Felsic gneisses include a variety of moderately to strongly foliated quartz-feldspar rich rocks which are abundant in the northern and southern parts of the district. All of these gneisses show variable effects of cataclasis, and locally grade into shear zone tectonites. Foliation is primarily formed by the alignment of biotite, chlorite, and/or muscovite or by the cataclastic segregation of leucocratic and melanocratic minerals into discrete layers.

North and west of the Independence Mine claims, cataclastic biotite augen gneiss and quartz monzonite gneiss predominate. These two units are gradational with one another and the quartz monzonite gneiss contains numerous layers, lenses and stringers of dark gneisses and schists of the Mafic Series sequence, along with thin sills (?) of granite and quartz monzonite. The augen gneiss is a gray-black to grayish-white biotite-quartz-plagioclase-microcline rock with pronounced crystals and aggregates (up to two inches long) of quartz, plagioclase, and/or microcline in a medium- to fine-grained cataclastic matrix. Many of the feldspar augen crosscut foliation indicating some post-cataclasis crystallization. The quartz monzonite gneiss unit is pink to buff and gray in color and is composed primarily of quartz, potash feldspar, and plagioclase in nearly equal proportions, with lesser amounts of biotite, muscovite, and chlorite. This gneiss locally grades into small irregular masses of nonfoliated granite, alaskite, quartz monzonite, and pegmatite, which may represent the non-granulated (nonfoliated) remnants of a large composite igneous body.

A somewhat more intensely granulated felsic gneiss unit, the mylonitic biotite-epidote-plagioclase gneiss, occurs in the southern part of the area interlayered with amphibole-biotite rich gneisses and schists (Mafic Series) and amphibolitized meta-igneous rocks. This unit is typically pink to gray in color, medium- to coarse-grained, and consists chiefly of plagioclase and quartz with subordinate amounts of biotite, epidote, microcline, and chlorite. Contacts between the gneiss and intercalated amphibolitized meta-igneous units are generally gradational through a few feet but are occasionally sharp suggesting an older age for the gneiss. Small pegmatites (less than five feet thick) and quartz vein networks riddle the unit locally.

Amphibolitized Meta-igneous Rocks

The amphibolitized meta-igneous group is a general map unit category involving a wide range of amphibole-plagioclase rich rock types of presumably igneous origin. Rocks of this group are widespread throughout the area and appear to be younger than most of the major metamorphic units. Although in some cases clearly crosscutting relationships with enclosing rocks may be observed, the mafic bodies are generally conformable. Amphibolitized rocks are most abundant in a northeasterly trending belt extending from the southwest corner of the mapped area to the central portion of Centennial Ridge, where they are typically associated with gneisses and schists of the Mafic Series. Many types also occur interlayered with felsic gneisses at the north and south ends of the district.

The amphibolitized rocks are predominately dark green to black in color, medium- to coarse-grained, and range from crystalloblastic to relict diabasic, ophitic, and gabbroic in texture. Partially uralitized pyroxenes are common in some varieties as also are variable chloritized amphiboles. Most of these rocks are classified as orthoamphibolites, but where crystallization is less complete they are designated as metadiorite, metagabbro, and metapyroxenite. The various types of mafic rocks appear to be quite gradational with one another, both laterally and along strike, and are probably close time equivalents. Gradational contacts also occur locally with felsic gneiss units, a relationship which may have resulted from partial transformation of host rocks during emplacement or from later rheomorphism of the felsic rock units.

Many of the amphibolitized rocks show a moderate to strong gneissic foliation which was probably developed by cataclasis. Such foliation is generally best expressed along the margins of meta-igneous masses, suggesting that these bodies acted as relatively resistant buttresses to the forces of cataclasis. Mafic bodies within or crosscut by shear zones have been intensely granulated and chloritized, some converted to mafic submylonites and/or mylonites.

Granitic Intrusive Rocks

Many small intrusive bodies of silicic igneous rocks are found throughout the area. Most occur as sills and lenses, but dikes and irregular bodies are prominent locally. These rocks may be conveniently divided into three separate units: 1) small felsic intrusives; 2) Sherman-type granite; and 3) pegmatites.

Small felsic intrusives

The small felsic intrusives have their greatest concentration in the northern part of the district where sills and lenses of granite and quartz monzonite are intercalated with rocks of the Mafic Series and quartz monzonite gneiss sequence. Occasional discordant bodies are also present, but are more common in the central and southern portions of Centennial Ridge. Pink to gray and white, muscovite-biotite granite and alaskitic albite rich varieties (alkali granite) with aplitic and pegmatitic phases comprise the bulk of the intrusives but quartz monzonitic bodies are abundant locally. Some sheared intrusives have developed a weak gneissic foliation and are enriched in quartz and potash feldspar.

Sherman-type granite

A small exposure of granite and quartz monzonite occurs at the southern end of Centennial Ridge at the southern border of the mapped area (sec. 20, T.15 N., R.78 W.). This exposure is part of the northernmost extension of a large, irregular body of granite called Sherman-type granite in view of its similarity to the Sherman granite in the Laramie Range as named by Darton, Blackwelder, and Siebenthal (1910), and is probably correlative with the Pikes Peak type granite described by Houston (1961, p. 11) and Currey (1965, p. 6) southwest of the Centennial Ridge area. The granite is principally a pink to pinkish-gray, medium- to coarse-grained rock with quartz monzonitic phases, and consists of microcline, quartz, and plagioclase in rather variable proportions, with considerable accessory biotite and hornblende. Some of the granite is strongly porphyritic; individual phenocrysts of microcline range up to $1\frac{1}{2}$ inches long and are commonly twinned according to the Carlsbad Law.

The Sherman-type granite weathers readily to form a hummocky to knobby topography characterized by abundant rounded to mushroom or pedestal shaped, joint controlled exposures. Soil is usually poorly developed to absent as the deeply weathered granitic rock typically produces a blanket-like cover of porous grus.

Pegmatites

Pegmatite bodies are found throughout the district but are most abundant in association with the biotite-hornblende rich rocks of the Mafic Series. Most occur as rather small lenticular forms that range from about 1 to 80 feet wide and a few feet to nearly 500 feet long (occasionally longer). Pegmatites that are conformable with foliation trends of host rocks far outnumber those with crosscutting relationships; however, occasional bodies may exhibit both conformable and disconformable relationships, and both varieties are apparently contemporaneous. Contacts with host rocks are usually quite sharp, although highly gradational boundaries do occur in some bodies. Fine-grained borders and weak mineralogical zoning are sometimes present in pegmatites with sharp contacts. Most of the pegmatites have been subjected to only minor deformation except for a few that crosscut shear zones and have been shattered by local reactivation of movement along these structural trends.

Two major types of pegmatite have been recognized: 1) quartz-microcline-plagioclase pegmatites, and 2) tourmaline rich pegmatites. The first type is characteristically very coarse-grained, massive, pink to pinkish white to red, and deficient in accessory minerals (less than two percent). These pegmatites contain variable feldspar and quartz content and although microcline generally exceeds plagioclase (usually albitic), plagioclase exceeds microcline in some bodies. The more plagioclase rich forms tend to have slightly higher muscovite content and a less sodic plagioclase (oligoclase). Perthitic (and antiperthitic) and myrmekitic intergrowths are very common. Muscovite is the most abundant accessory mineral and may be accompanied by traces of magnetite, apatite, garnet (almandine ?) and sphene.

Tourmaline-rich pegmatites contain appreciable schorlite (black tourmaline) and are generally richer in other accessory minerals. These rocks are also quite coarse-grained, and range in color from pink to white and gray. The tourmaline occurs chiefly as isolated crystals (up to one inch in diameter and four inches long) and irregular crystal aggregates, but occasionally forms rosettes. Tourmaline in pegmatites near shear zones is commonly shattered and individual crystals may exhibit tiny offsets along hundreds of shatter planes. Individual pegmatites may contain up to 15% schorlite locally and all are appreciably enriched in muscovite and garnet with lesser amounts of magnetite, hematite, limonite, pyrite, biotite, chlorite, sphene, apatite, columbite, and allanite. These tourmaline rich pegmatites are mineralogically somewhat similar to rare earth bearing pegmatites reported by Houston (1961) in the Big Creek area on the southwest flank of the Medicine Bow Mountains. Although no pegmatites containing appreciable quantities of rare earth minerals were observed in the Centennial Ridge district, both allanite and columbite are present in some bodies as minor accessory minerals.

Shear Zone Tectonites

This unit consists of a rather broad assemblage of rocks that owe their present form to variable degrees of shear stress and related phenomena. Although many similar rocks occur on a smaller scale throughout other units in the district, the tectonite map unit defines or delineates the larger, more important shear zones. Included in this unit are rocks ranging from the cataclasites which are products of crushing and granulation without chemical reconstitution to submylonites, ultramylonites, and phyllonites, all of which have been chemically reconstituted to variable extents (see McCallum, 1964, p. 103 and 19 for more complete discussion). Also present are occasional fault breccias and graphitic fault gouges which are probably products of renewed movement (Laramide ?) along older structural trends (Precambrian).

The tectonites occur as roughly tabular to crudely lensatic zones that range from a few feet to several hundred feet in width and may be traced for a few tens of yards to several miles along strike. Most of the tectonites in the area are essentially concordant; however, in upper Middle Fork Canyon, shear zones are strongly discordant to surrounding units.

The physical properties of shear zone tectonites are extremely varied as a function of parent rock properties. Since tectonites in the Centennial Ridge district are chiefly derived from dominantly mafic rocks (Mafic Series, and amphibolitized meta-igneous rocks) they tend to be dark in color and contain high concentrations of mafic mineral derivatives, particularly chlorite and epidote along with feldspar and quartz. Most are quite fine-grained and dense and some appear to have been in part silicified. Many have a finely layered structure, and these phases grade into the more typical massive densely textured variety. Crushed and fractured porphyroclasts of feldspar, quartz, hornblende, and accessory minerals commonly occur in coarser phases.

Many of the tectonites have been locally mineralized. Fe and Cu sulphide enrichment is most common, but siderite, magnetite, hematite, galena (argentiferrous), chrysocolla, Cu carbonates, and the gangue minerals quartz, calcite, dolomite, fluorite, prehnite, diopside, epidote, and K-feldspar may be present. Analyses of Fe sulphide aggregates from tectonites in upper Middle Fork Canyon also indicate the presence of small amounts of Au, Ag, Ni, Mn, and Pb (NRRI, 1961, D. B. Field, analyst), and the Pt group elements platinum, palladium, and iridium have been reported from similar samples by Hess (1926, p. 130-133) and several Rocky Mountain area assayists (E. K. Burhans,[3] 1961, personal files).

STRUCTURE

Shear zones are the most prominent structural features in the district. Major trends were apparently established at a rather early time subsequent to Precambrian regional metamorphism, and periodic reactivation occurred along some of these zones at least through early Laramide time (late Cretaceous). Most of the shear zones show little apparent displacement, but appear rather as zones of granulation and pulverization caused by a grinding action accompanied by little or no appreciable displacive movement of the bordering rock masses. A few include or are superposed upon major faults with significant displacements (e.g. shear zones in upper Middle Fork Canyon and southern end of Centennial Ridge). Associated with many of the shear zones are numerous small subsidiary folds, faults, and joints that developed during the deformational episodes.

Shear zone reactivation is expressed by resheared and recrystallized tectonites, neomineralization, shattering, brecciation, and formation of fault gouge. Two shear zones (upper Middle Fork Canyon and southern end Centennial Ridge) can be traced into flanking tear faults that involve post-Precambrian sediments. Similar relationships have been observed north of Centennial (Houston and McCallum, 1961), indicating a Precambrian control for most of the Laramide tear faults along the east flank of the Range. Extensions of the Laramide tear faults into shear zone tectonites are recognized by the presence of abundant shattered and brecciated material, fault gouge, and occasional highly polished and slickensided surfaces.

No major folds were recognized in the district; however, isoclinal folding may be an important structural element in the intermixing of units throughout most of the mapped area. Although no definite evidence was observed, isoclinal folding accompanying cataclasis may have produced the intermixing and layering of unlike units by the extreme attenuation and stretching out of fold limbs over considerable distances along strike. The complex interfingering of some units (e.g. lime-silicate marble) may actually represent the plunging of tightly folded isoclinal structures rather than facies relationships. Minor fold structures and crenulations may be found in nearly all units, and various forms appear to be unrelated in time. At least three separate deformations were involved. Locally, rocks adjacent to small faults and shear zones are tightly folded and distorted.

3/ Secretary, Independence Gold Mining Company, Denver, Colorado.

Most of the Precambrian rocks in the area have very pronounced foliation and many exhibit well developed lineations. Foliation is primarily a product of alignment of biotite, muscovite, chlorite, and amphibole, or segregation of these and other minerals into discrete layers. Layering in most cases was probably developed by metamorphic differentiation processes accompanying cataclasis. Although foliation in some of the metasedimentary units such as the lime-silicate marble may represent strongly modified relict bedding, foliation in all rocks of the area is probably best attributed to strictly metamorphic processes.

Linear features are quite abundant in many of the foliate rocks and occasionally occur in nonfoliate varieties. Recorded lineations include biotite, muscovite, and chlorite streaks, aligned amphibole crystals, stretched quartz rods, feldspar crystal laths and lenses, Mn and Fe oxide smears, and axes of minor folds and crenulations. The interrelationships of these linear features suggest that the area has been subjected to three or more periods of deformation. Mineral lineations lack consistent plunge directions and axial trends of minor folds and crenulations are quite inconsistent with most mineral lineation trends and with each other, which probably indicates successive refolding of older established trends. In some outcrops two distinct sets of crenulations have been masked by the development of prominent minor folds with unrelated axial trends. Axes of a few minor folds have been clearly refolded and at several localities small pegmatite dikes cutting previously folded gneiss have themselves been folded. Further evidence of multiple deformational episodes in the area includes the presence of folded shear zone tectonites, shattered and brecciated tectonites, and multi-generation joint systems.

ECONOMIC GEOLOGY

Economic interest in the Centennial Ridge district is principally related to primary and placer gold and gold-platinum deposits. Rare earth bearing pegmatites of questionable productive potential are also considered.

Primary Gold Deposits

As far as is known, total ore production in the district has been from primary gold deposits. The gold occurs in quartz veins that parallel the foliation and schistosity of biotite and hornblende rich gneisses and schists of the Mafic Series. At the Free Gold claims on top of Centennial Ridge, free gold associated with limonite (after pyrite) was extracted from a two foot wide vein of gray quartz (Hess, 1926, p. 129). Many of the quartzose veins in the area contain considerable soda feldspar, hornblende, and calcite, and gold is reportedly associated with decomposed hornblende. At the Utopia mine small amounts of gold occur along shear zones in a hornblende schist, and Dart (Osterwald et al, 1959, p. 76) reports that much of the gold is associated with garnets and quartz streaks. Ore control at the Centennial mine (the third producer in the area) is apparently similar to that at the Utopia workings. Emplacement of the mineralized quartz veins is believed to be genetically related to emplacement of the pegmatites which also are confined chiefly to Mafic Series units.

Primary Gold-Platinum Deposits

Primary gold-platinum deposits have been reported from numerous localities throughout the district (Table 1). The gold and platinum group elements platinum, palladium, iridium, osmium, rhodium, and ruthenium are apparently associated with sulphides and/or arsenides which have been concentrated as fracture and breccia fillings and pods where shear zones, faults, or quartz veins cut Mafic Series or particularly amphibolitized meta-igneous rock units. This relationship suggests that much of the primary gold-platinum ore is derived from mafic to ultramafic parents, although conceivably completely unrelated mineralizing solutions could have introduced the metals into the area along the numerous faults and fractures.

The best known assay values are from small sulphide masses and adjacent sulphide rich zones in mafic host rocks. Maximum sulfide concentrations are generally found associated with graphitic fault gouge, brecciated mafic mylonites, and strongly chloritized wall rock. Sulphide veins up to four inches thick have been reported in drifts cutting the upper Middle Fork Creek shear zone (Independence Gold Mining Company claims). Pyrite is the predominant sulphide in these deposits, although small amounts of arsenopyrite and cobaltian pyrite may be present. Most of the deposits show at least some degree of sulphide alteration to limonitic mixtures, commonly as aureoles, and the cobaltian pyrite is usually coated with a reddish brown hydro-hematite. Occurring with the sulphide masses are chlorite, epidote, calcite, dolomite, siderite, alum, and minor quartz with occasional prehnite. Chalcopyrite may occur locally along with small amounts of malachite, azurite, and chrysocolla.

The mineral occurrence of the platinum metals is not known; however, considering the presence of arsenic in these ores and the recognition of platinum arsenide (sperrylite, $PtAs_2$) at the New Rambler Mine workings a few miles to the southwest, the platinum metals probably occur in small crystals of sperrylite disseminated in the iron sulphide. They may also occur in cooperite, a platinum sulpharsenide ($Pt(AsS)_2$), although this mineral has never been reported from the region. Kohanowski (1953, report on Independence Gold Mining Company claims, E. K. Burhan, personal files) tentatively identified platiniridium from several Independence Mine samples, but none was observed by the writer during this investigation.

Table 1.

Assays from the Centennial Ridge Gold-Platinum District

Claim	Au oz.	Ag oz.	Pt oz.	Ir oz.	Pd oz.	Os oz.	Ru oz.	Rh	Cu	Ni
Utopia (a)	Tr. to 3.46	None to 1.64	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Free Gold (a)	.08 to 2.54	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Queen (b)	Tr.	1.0	0.03	0.05	-	n.d.	n.d.	n.d.	n.d.	n.d.
Queen (94)	-	-	-	-	-	-	-	-	+	-
Kentucky Derby (c)	-	-	-	Tr.	Tr.	Tr.	-	-	n.d.	n.d.
Kentucky Derby (302)	Tr.	0.02	-	-	-	-	-	-	+	-
Kentucky Derby KD2 (d)	n.d.	n.d.	0.0032	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Independence (c)	0.31	n.d.	?	?	?	?	n.d.	0.41	n.d.	n.d.
Independence (c)	0.36	n.d.	?	?	?	?	n.d.	0.45	n.d.	n.d.
Independence (a)	0.08	0.22	0.27	0.46	-	0.1002	-	0.0302	n.d.	n.d.
Independence (303)	0.01	0.08	-	-	-	-	-	-	+	+
Independence I 2 (d)	n.d.	n.d.	0.0128	n.d.	0.0192	n.d.	n.d.	n.d.	n.d.	n.d.
Cliff (b)	+	-	Tr. ?	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Empire (b)	Tr.	0.5	0.12	0.07	-	n.d.	n.d.	n.d.	n.d.	n.d.
Empire (b)	-	Tr.	0.06	Tr.	0.01	n.d.	n.d.	n.d.	n.d.	n.d.
Columbine (111)	-	-	-	-	-	-	-	-	+	-
Queen Mill Placer (c)	+	-	Tr. ?	+	Tr.	Tr.	-	-	n.d.	n.d.
Independence Placer (c)	Tr.	-	-	-	Tr.	+	Tr.	Tr. ?	n.d.	n.d.
Fall Creek Placer (c)	-	-	-	-	-	Tr.	-	Tr. ?	n.d.	n.d.
Archer Placer (c)	+	-	Tr. ?	+	Tr. ?	Tr. ?	Tr.	-	n.d.	n.d.

(a) Geol. Survey Wyo. files.
(b) Assay values reported by F. L. Hess (1926).
(c) Private communications.
(d) Assays from Paul Theobald, U.S. Geological Survey, Denver, Colorado.
Analyst, C. E. Thompson. Values are approximate in ounces per ton.

Numbers refer to sample locations on Plate 1, samples analyzed by D. B. Field, NRRI, Laramie, Wyoming.

n.d. No determination
\+ Present
? Questionable assay, not listed

Like the platinum metals, gold and silver are also associated with the sulphide masses, gold probably chiefly in the free state and silver as finely disseminated argentite (Ag_2S), proustite (Ag_3AsS_3), or argentiferous galena ($(Pb, Ag)S$). Minor amounts of nickel are also present in some of the deposits.

The origin of the primary gold and platinum metals deposits is poorly understood. The close association of these deposits to mafic host rock very strongly suggests a genetic relationship. It is tentatively postulated that the platinum metals were derived from mafic rock sulphides by hydrothermal activity during late Precambrian time. This hydrothermal episode was probably related to pegmatite emplacement, and was likely the same event that was responsible for the formation of quartz vein associated primary gold deposits. As the gold bearing solutions migrated along fractures and shear planes in mafic rocks, platinum bearing sulphides may have been extracted from wall rocks, concentrated in the solutions, and deposited toward the surface in available low pressure openings. Some of these deposits may have been further remobilized at the time of Laramide faulting and brecciation, and redeposited in accord with the later structures.

Primary Deposit Mines

Most of the mines in the area have long since been closed and abandoned. Mine buildings are either gone or are in conditions of hopeless disrepair, and underground workings are essentially inaccessible due to caving and/or flooding. Consequently, subsurface information is based primarily on old mine records and reports. Brief discussion of a few of the more important mines in the district is given below.

Centennial Mine. Sec. 4, T. 15 N., R. 78 W. The Centennial Mine, the first known lode mine in the district, was opened in 1876 (Beeler, 1906, p. 11). Several drifts and prospect pits were developed in iron stained hornblendic gneisses and schists about one mile south of the village of Centennial. Free gold was present associated with shear zones and quartz veins, and a total production of at least $90,000 in free milling gold ore was realized. Ore production ceased when the workings penetrated a "flat fault" which supposedly cut off the mineralized zone.

Utopia Mine. Secs. 4 and 9, T. 15 N., R. 78 W. Three westerly trending drifts were opened in schists and gneisses of the Mafic Series in the early 1900's near the base of Centennial Ridge about one-quarter mile south of the Centennial Mine workings. Small amounts of gold were associated with shear zones, quartz streaks, and garnets in hornblende schists (Dart, 1929). Cross faults were supposedly responsible for cutting off the mineralized zone as was the case in the nearby Centennial tunnels. Minor amount of gold associated with decomposed hornblende in felsic veins paralleling schistosity were reported from the Utopia workings upslope from the main drifts (Hess, 1926, p. 129). Assays of samples collected from the Utopia tunnels by Dart in 1929 (p. 8) range from 0-1.64 ounces of silver and a trace to 3.46 ounces of gold per ton.

Free Gold Claim. Secs. 8 and 9, T. 15 N., R. 78 W. The Free Gold claim, originally known as the Billy Waters, is situated on top of Centennial Ridge. Nearly 800 feet of surface workings have been developed along a two foot wide gray quartz vein that parallels schistosity of the surrounding hornblendic and chloritic schists of the Mafic Series. The quartz carries oxidized pyrite and free gold and reportedly at least 100 tons of ore was milled (Hess, 1926, p. 129).

Platinum City Mine. Sec. 16, T. 15 N., R. 78 W. The Platinum City Mine is located on a wide belt of amphibolitized meta-igneous rocks in mafic gneisses and schists along the lower east flank of Centennial Ridge about two miles south of Centennial. Several prospect drifts and crosscuts have been driven where pegmatite, quartz, and sulphide veins cut the dominantly hornblendic rocks. Honeycombed quartz at the surface reportedly contained free gold, whereas sulphide veins and pods supposedly contained both gold and platinum metals. NRRI assays on dump samples collected in 1961 showed only copper and iron.

Queen Mine. Sec. 16, T. 15 N., R. 78 W. A 90 foot shaft was sunk in amphibolite and metagabbro emplaced in hornblendic and felsic gneiss. The rocks exposed in the shaft are cut by numerous small faults and veins of calcite and pegmatite. The faults commonly contain up to an inch of gouge, some of which is rich in sulphides, and may include thin calcite seams. Some of the gouge material collected in 1924 by Hess (1926, p. 133) assayed 0.03 oz. platinum, 0.05 oz. iridium, and less than 1 oz. silver per short ton, with a trace of gold. Dump samples assayed by the NRRI in 1961 (Table 1) contained only copper and iron.

Kentucky Derby Mine. Sec. 8, T. 15 N., R. 78 W. The Kentucky Derby workings are situated in the shear zone along upper Middle Fork near the waterfall which marks an abrupt change in stream flow direction. A short crosscut penetrates strongly shattered and sulphide enriched, dark, dense shear zone tectonites. The mineralized zone has been appreciably oxidized and the sulphide masses are characteristically coated with films of limonite and alum. The platinum group metals osmium, palladium, iridium, and platinum along with gold have been reported from these ores (see Table 1). NRRI assays of grab samples collected from the adit show the presence of copper, gold, and silver, but no platinum group metals were recognized.

Independence Mine. Sec. 8, T. 15 N., R. 78 W. Workings of the Independence Mine are in the same shear zone as those of the Kentucky Derby, and mineralization is quite similar. The mine was opened as a crosscut tunnel which extends about 95 feet into the shear zone and cuts five sulphide enriched "veins". At the second vein, a distance of about 45 feet from the portal, a drift was driven some 25 feet to the southwest along the mineralized trend where it deviates to the south for nearly 50 feet before it again intersects the first "vein" encountered in the main crosscut. The drift then parallels this "vein" for another 45 feet. Gold, silver, and the platinum metals are all associated with the sulphides which occur as fracture and breccia fillings, pods, and small grains disseminated through tectonites. Available assay values range widely both as a function of sample source and assayer (Table 1). Osterwald (1959, p. 75, and 135) lists the following values from "mine-run ore": 0.08 oz. gold, 0.22 oz. silver, 0.27 oz. platinum, 0.46 oz. iridium, 0.0302 oz. rhodium, and 0.1002 oz. osmium per ton of ore. NRRI tests on sulphide samples from the second "vein" failed to show any platinum group metals, but .01 oz. gold and 0.8 oz. silver per ton and traces of copper and nickel were reported.

Cliff Mine. Sec. 8, T. 15 N., R. 78 W. A 775 foot drift was driven northeastward in part along a 2-3 inch thick quartz vein that parallels schistosity and cataclastic foliation of the enclosing mafic schists and submylonites. According to Hess (1926, p. 132) "neither gold nor platinum was reported in this drift." A 325 crosscut extending to the northwest from near the end of the main drift cuts four quartz and sulphide bearing fracture zones, at least one of which supposedly contained gold. Traces of platinum were reported from a short drift paralleling one of the fracture zones (Hess, 1926, p. 132).

Empire Mine. Secs. 8 and 17, T. 15 N., R. 78 W. In 1896, two copper prospect tunnels were driven along iron stained shear planes in a shear zone paralleling schistosity and foliation of the adjacent biotitic and hornblendic schists and gneisses. The upper drift penetrates the shear zone for about 100 feet and the lower drift about 170 feet. Sulphides taken from two crosscutting fracture systems and assayed in 1923 reportedly contained platinum metals along with gold and silver. Hess (1926, p. 130-132) reports the following value ranges: silver, a trace to 0.986 oz. per ton; gold, a trace to 0.06 oz. per ton; platinum, a trace to 1.04 ozs. per ton; iridium (as determined may also include some rhodium, ruthenium, and/or osmium) up to 2.84 ozs. per ton; and palladium, up to 9.08 ozs. per ton. A third tunnel was driven through talus into mafic schists and gneisses several hundred yards south of the first two drifts. Samples collected by Hess (1926, p. 32) from fault gouge in this tunnel showed little more than traces of platinum and gold and less than an ounce of silver per ton.

Columbine Mine. Sec. 17, T. 15 N., R. 78 W. In the late 1920's a drift was driven parallel to schistosity and cataclastic foliation into biotite-hornblende schist and submylonite about 200 feet above Middle Fork. Iron stained shear planes and finely disseminated sulphides in submylonite were observed but only copper and iron were reported in assays from dump material (NRRI, Table 1). Questionable quantities of platinum metals and gold have been reported from shattered vein material a few hundred feet below the portal (E. K. Burhans, 1961, personal files).

Placer Deposits

Quaternary alluvial deposits along the Middle Fork and its tributaries have been periodically located as placers over the past 75 years. Most interest has been centered on two large "flats" along Middle Fork in secs. 8 and 17, T. 15 N., R. 78 W. The upper "flat" extends from a point on the stream near the Independence Mine to a point south of the Empire Mine workings, and involves both modern flood plain gravels and terrace deposits. Considerable early work was done on the terrace gravels along the west side of the stream which were claimed to carry high gold concentrations. However, no production figures are available, and the failure of later hydraulicing operations suggests that little gold was actually recovered. Results of more recent panned concentrate assays from gravels near the head of the "flat" show small amounts of both platinum metals and gold (Independence placer).

The lower "flat," situated along the west side of sec. 17 near the Columbine claims, is much smaller than the upper "flat" and consists of comparable deposits. Here also terrace gravels were worked many years ago and no production figures are available. Minor amounts of free gold have been seen in the pan from alluvial materials taken from bedrock at the lower end of the "flat", and concentrates taken from the Archer placer claim in this area reportedly carried platinum metals, gold, free mercury (?), and "heavy" galena (E. K. Burhans, 1961, personal files).

Recent work on placer claims along Queen Mill run (NE$\frac{1}{4}$, sec. 8, T. 15 N., R. 78 W.) and Fall Creek (sec. 7, T. 15 N., R. 78 W.) indicates the presence of at least trace amounts of platinum metals and some gold. Evidence of minor placer operations may be seen in alluvial deposits along Middle Fork in the SE$\frac{1}{4}$, sec 6, T. 15 N., R. 78 W., but no known values were reported from these workings.

Pegmatites

Prospect pits have been sunk in several of the pegmatites in the district. Most of the examined pits appeared to be barren, but a few contained small amounts of allanite and columbite, and conceivably might contain other rare earth minerals.

SUGGESTIONS FOR PROSPECTING

Development to date in the Centennial district has definitely indicated the presence of platinum metals, gold, and silver, and further investigations seem warranted. With the exception of some free gold in quartz veins, most of the metals of interest appear to be included in sulphides closely associated with faults and shear zones involving mafic schists and gneisses and amphibolitized meta-igneous rocks. Presently established shear zone trends should be further explored and a search should be made in mafic units for other less well defined shear zones that may be mineralized. Particular attention should be devoted to the system of shear zones trending to the southwest through sec. 18, T. 15 N., R. 78 W. towards the New Rambler Mine district which lies a few miles along strike. These shear zones are known to be at least locally mineralized, and may define a narrow, several mile long belt of potential low grade ore extending from the New Rambler area to the upper Middle Fork Canyon area (northeast of Kentucky Derby workings). Electrical and magnetic methods might prove to be useful in isolating zones of high sulfide concentration, and geochemical surveys should also be considered. A more extensive diamond drilling program is needed in those areas where the presence of platinum metals has been reasonably well confirmed.

Most of the alluvial deposits in the area do not appear to be particularly amenable to further exploration. Deposits in the two "flats" of Middle Fork Canyon have the greatest apparent potential, but the considerable thickness of fill and high water table have severely hindered previous exploration efforts. Boulder gravels capping portions of the erosion surface in the northern and western parts of the district have been prospected locally but are considered to be of little economic value.

Pegmatites in the district have shown no observable commercial potential. However, rare earth bearing pegmatites studied by Houston (1961) to the southwest have similar geologic relationships as those near Centennial (most occur in amphibole-biotite rich schists and gneisses) and a genetic association is implied. A systematic study of pegmatites in Mafic Series rocks, with particular emphasis on the tourmaline rich variety, might reveal a few bodies with greater rare earth mineral concentrations than any yet reported.

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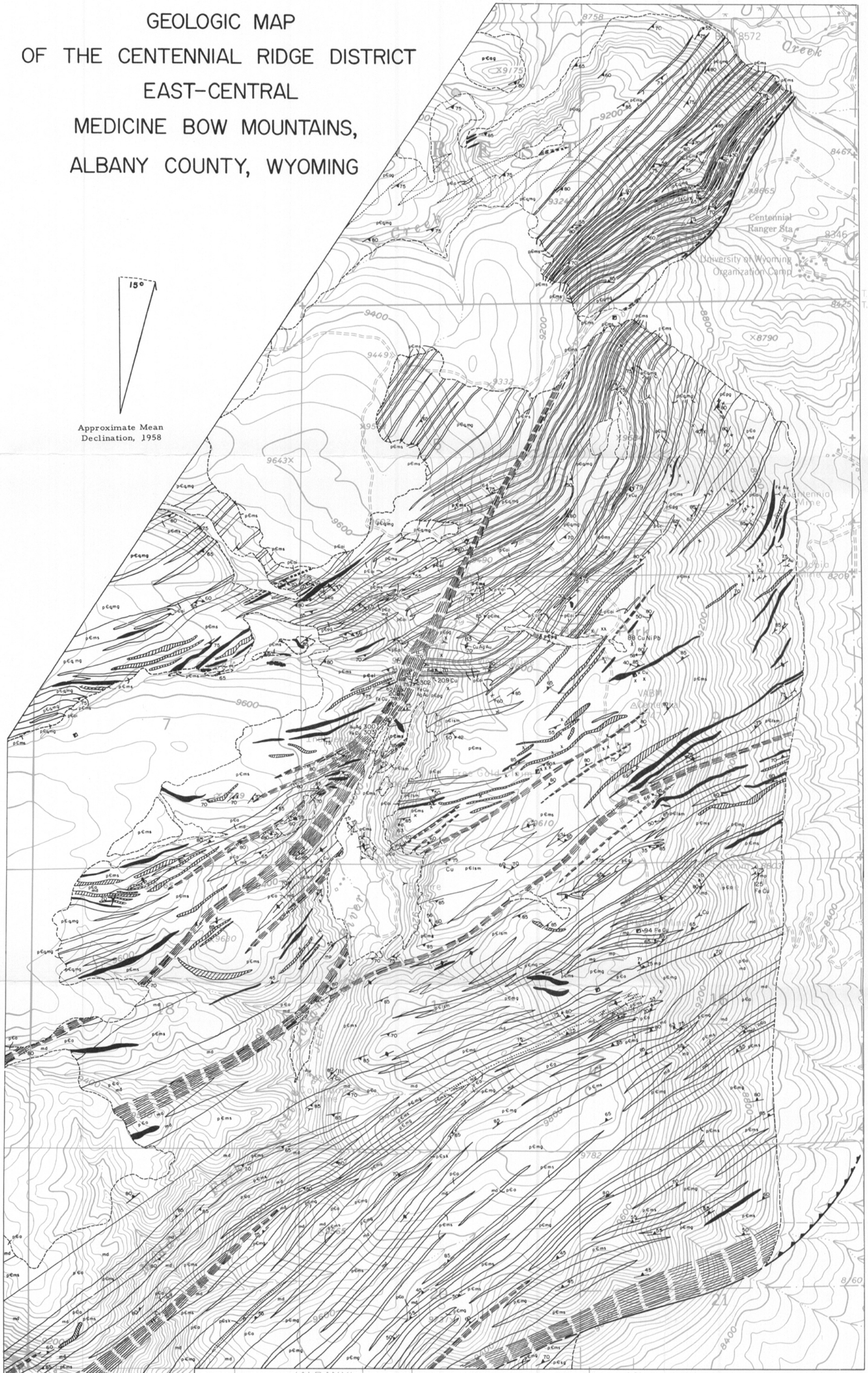
GEOLOGIC MAP OF THE CENTENNIAL RIDGE DISTRICT EAST-CENTRAL MEDICINE BOW MOUNTAINS, ALBANY COUNTY, WYOMING



Approximate Mean Declination, 1958

Topography by U.S. Geological Survey, 1961

Geology by M.E. McCallum, 1960-61

LITHOLOGIC UNITS

PRECAMBRIAN — Age Relationships Uncertain

POST-PRECAMBRIAN SEDIMENTS
Alluvium, colluvium, talus, pediment gravel, glacial deposits, lag(?) gravel, and Tertiary, Mesozoic, and Paleozoic sedimentary deposits.

PEGMATITE
Pink to white, quartz-microcline-plagioclase rich variety.
Pink to white, quartz-feldspar-tourmaline rich variety.

p€Sg — SHERMAN-TYPE GRANITE
Pink to salmon red, coarse-grained granite with quartz monzonitic phases. Commonly porphyritic.

SHEAR ZONE TECTONITES
Varicolored ultramylonite, mylonite, submylonite, cataclasite, phyllonite, fault breccia, and fault gouge.

p€ai — SMALL FELSIC INTRUSIVES
Small sills, dikes, lenses, and irregular masses of pink to white, fine- to coarse-grained granitic and quartz monzonitic rocks.

p€a — AMPHIBOLITIZED META-IGNEOUS ROCKS
Green to black, fine- to coarse-grained rocks composed chiefly of amphibole and plagioclase. Most are termed ortho-amphibolites but where recrystallization is incomplete, rock units are designated as follows:
- md; metadiorite
- mg; metagabbro
- mp; metapyroxenite

p€ag — CATACLASTIC BIOTITE AUGEN GNEISS
Gray black to grayish white, coarse-grained, strongly foliated and granulated biotite rich gneiss containing abundant large augen of quartz and feldspar.

p€mg — MYLONITIC BIOTITE-EPIDOTE-PLAGIOCLASE GNEISS
Diverse sequence of mylonitic rocks. Chiefly pink to gray, fine-to medium-grained mylonitic gneisses rich in biotite, epidote, plagioclase, and quartz.

p€qmg — QUARTZ MONZONITE GNEISS
Pink, buff, to gray, medium- to coarse-grained gneiss composed of nearly equal proportions of quartz, microcline, and plagioclase. Locally contains irregular zones of nonfoliated granite, alaskite, quartz monzonite, and pegmatite.

p€pg / p€lsm / p€sk — LIME-SILICATE ROCKS
Moderately to strongly foliated, Ca-silicate and calcite rich metasedimentary rocks.
- p€pg - pyroxene-rich gneiss; green to greenish black, coarse-grained, weakly to moderately foliated, diopside-hornblende-chlorite-calcite gneiss.
- p€lsm - lime-silicate marble; gray to buff, medium- to coarse-grained, strongly layered, impure marble. Alternate layers are calcite and/or quartz-microcline rich vs. hornblende-plagioclase-quartz rich. Epidote, diopside, and sphene are always present.
- p€sk - skarn-like rocks; pink to brownish green, fine- to coarse-grained, massive to crudely layered, calcite-garnet-diopside-epidote rich rocks.

p€ms — MAFIC SERIES
Diverse sequence of dark colored, fine- to coarse-grained moderately to strongly foliated, amphibole-biotite rich schists and gneisses.

MAP SYMBOLS

CONTACT
Most contacts shown as solid lines since they are predominately only approximately located, gradational, or inferred. Dashed between Precambrian and post-Precambrian units. Dotted where strongly gradational.

60 57 — 70 62
STRIKE AND DIP OF FOLIATION WITH BEARING AND PLUNGE OF LINEATION
Lineation includes biotite, muscovite, and chlorite streaks; oriented amphibole grains; quartz rods; Mn and Fe oxide smears; and a few small folds and crenulations, designated by c.

SHEAR ZONE

VERTICAL SHAFT

FAULT
Dashed where inferred

PORTAL OF TUNNEL OR ADIT

THRUST FAULT
Dashed where inferred. Sawteeth on upper plate

SMALL PROSPECT PIT

70 — Inclined; Vertical
STRIKE AND DIP OF FOLIATION

Au Ag
TYPE OF MINERALIZATION

60 — Inclined; Vertical
STRIKE AND DIP OF STRONGLY CATACLASTIC FOLIATION IN SHEAR ZONES

107
LOCATION AND NUMBER OF ASSAYED SAMPLES

1000 0 1000 2000 3000 4000
FEET