Lateral Zonation Within a Talc-Chlorite Replacement Body,—Ruby Mountains, Madison County, Montana

A Thesis

Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science

By

Gary M. Newman

The Ohio State University
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Approved by

Russell O. Utgard

Department of Geology and Mineralogy

Douglas Pride

Department of Geology and Mineralogy

DRILLING OPERATIONS IN THE RUBY
RANGE WITH THE BEAVERHEAD MINE
IN REAR.

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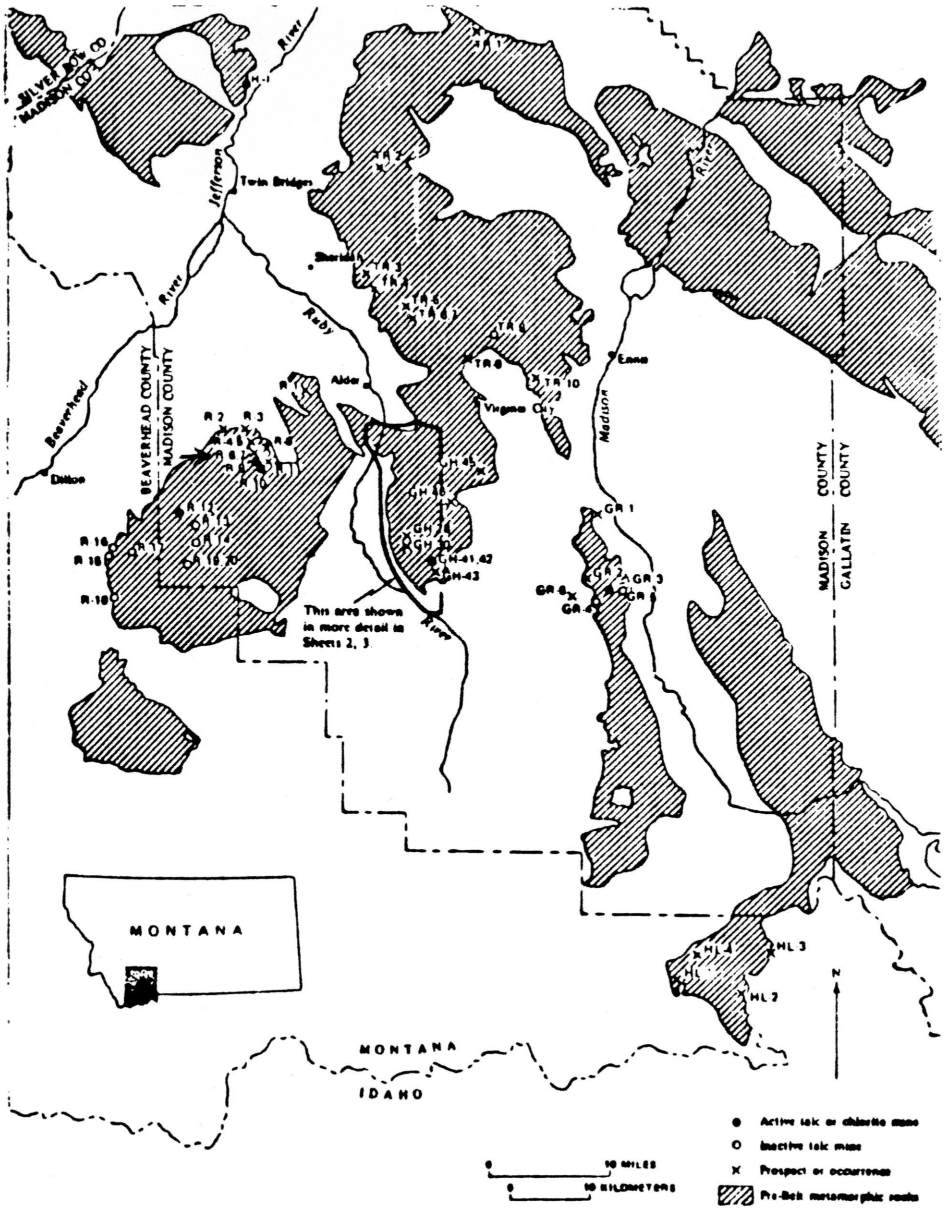
Introduction

The objective of this thesis was to determine the lateral zonation of minerals that led to the formation of talc by replacement of marble in the Ruby Range of southwestern Montana. Data was accumulated through the study of hand samples taken during the summer of 1982 from an exposed outcrop, and from thin sections made from the hand samples 9 through 23. This led to an understanding of mineral zonation present in the outcrop.

The hand samples were taken from a prospect northeast of Treasure Mine (Fig. 2). The prospect is located in the SE 1/4, Sec. 11, T7S, R.6W, Madison County, Montana, in the Mine Gulch quadrangle. About 40 feet of talc is exposed in an outcrop with a total width of about 120 feet. Rock samples were taken about every three feet along the face of the outcrop, and about one foot beneath the exposed surface. Samples 13 and 18 probably were from transported overburden.

The samples were studied as hand specimens and in thin sections, with most of the effort spent in thin section study. Particular attention was paid to the replacement of minerals and the types of metamorphism that they underwent.

The section on the exploration of talc may be of interest to the reader. During the summer of 1982, the writer was involved in the testing of a new geophysical technique with the intention of extending the existing ore bodies into the open ground. Because open ground was unavailable, a parallel anomaly on available ground was isolated using sampling grids. The technique may be of interest in the future.



TALC OCCURRENCES
R-7 PROSPECT NE OF TREASURE MINE
R-9 TREASURE MINE

Figure 2 - Talc and chlorite occurrences in southwestern Montana.

(BERG, 1979)

Talc

A) Chemical and Physical Properties

Talc is a hydrated magnesium silicate with the theoretical formula:

$$Mg_6\ Si_8\ O_{20}\ (OH)_4$$

The chemical composition of natural talc, however, is variable. It is an extremely soft mineral and is No.1 on Mohs scale of hardness. It varies in color from snow white to greenish gray and various shades of green. The specific gravity ranges from 2.58 to 2.83. Talc usually is derived as a secondary mineral by alteration of other magnesium silicates such as serpentine and pyroxene.

Talc is a sheet silicate mineral. It has a trioctahedal structure with the octahedal sites in the layers or "sheets" occupied by magnesium. Chemically, pure talc rarely is found in nature in commerical quantities. Practically all of the talc produced is an impure product. Even hand-sorted selectively mined cosmetic talc contains extraneous minerals. Only a very small percentage of the world reserves are "pure" talc. When impure talc products are repressed by froth floation or similiar selective separatory methods, very high purity talc can be produced. Talc is called "pure" if it contains about 95 percent $Mg_6\ Si_8\ O_{20}\ (OH)_4$.

Differential thermal analysis (DTA) and X-Ray Diffraction (XRD) (Berg, 1979, p.13) both provide good analytical methods for identification of talc and many of the impurities within talc. A large endothermic peak at 965°C is typical of talc mineral analyzed by the DTA method, that is less than 95 percent pure.

B) <u>Commerical Properties and Uses</u>

Talc deposits can be classified into four catagories (Berg, 1979, p.3):

(1) <u>Steatite</u>: Compact, massive, cryptocrystalline, can be sawed, drilled, or machined to required shapes. Steatite converts on firing at 1800°F for six hours to interlocking crystals of clinoenstatite. This product has good electrical insulating properties.

(2) <u>Soft Platy Talc</u>: Alteration product of sedimentary magnesium carbonate rocks. Chlorite is commonly associated with this talc. This is the most important type of talc. It possibly has more uses than any other talcose material.

(3) <u>Tremolite Talc</u>: Sometimes called "hard" talc. It is massive or laminated rock composed of varying percentages of tremolite, anthophllite, calcite, dolomite, and serpentine. It is characterized by calcium oxide contents of 6 to 10 percent.

(4) <u>Mixed Talc Ores</u>: Includes the so called "soft talc", a friable, white schistose rock composed of platy talc, dolomite, calcite, serpentine, and small amounts of many other minerals. A mixture of talc, chlorite, and dolomite are common in some low-grade deposits.

Because of its physical properties, talc has many uses. The largest consumer of talc for domestic use is the ceramics industry. Ceramics is followed by paint, paper, plastics, roofing, cosmetics, insecticides, rubber, and a number of minor uses. Talc is used for ceramics because of properties that include high specific heat, resistance to acids, magnesia content fluxing agent, and low firing shrinkage. High grade steatite is used for electrical, chemical, and refractory purposes.

Talc also is used as an inert extender and filler in paints. The addition of talc slows the settling rate of paint, promotes durability and smooth flow, and aids in the dispersion of pigments. Talc replaces some of the more expensive pigments such as titanium dioxide.

Talc is utilized as a lubricant in paper manufacture to control pitch that would bond to the equipment and produce brown spots in the finished paper. Finally ground talc of steatite grade or near steatite grade is used in the paper industry as fillers in the highest grades of paper, and it is used in face powders and pharmaceuticals.

Intermediate to lower grade talc is used as an insecticide carrier, asphalt filler, and dusting agent and filler in the rubber industry. It increases the physical stability and resistance to weathering of roofing materials and it is used as a filler to reduce the cost of finished plastics and rubber products.

C) Mining, Processing and Exploration

Talc is mined by conventional methods of underground and open pit mining. In open pit mines, the overburden is removed and closely spaced holes are drilled to sample the ore body. Data taken from the samples is used in planning a mining sequence for the various grades of talc. Blending of the different grades is used to produce the maximum amount of mineable material.

The primary processing methods are benefication and pulverization. The purity of the ore will dictate the methods of benefication. Froth flotation is supplemented by high-intensity magnetic separation on some talc ores. Pulverization is used to produce talc of high brightness* and of extremely fine grain size. After initial pulverization in roller mills, the talc is

*Brightness is a measure of the reflectivity of the talc compared to an MgO standard.

FED INTO A FLUID-ENERGY MILL, WHERE IT IS PULVERIZED BY ATTRITION IN A CIRCULAR CHAMBER IN WHICH EITHER COMPRESSED AIR OR STEAM PROPELS THE TALC PARTICLES THROUGH A CIRCULAR PATH. A CENTRAL PORT IN THE CHAMBER ALLOWS THE FINER PARTICLES TO LEAVE AS THE COARSER PARTICLES TRAVEL AROUND THE PERIPHERY OF THE CHAMBER.

AFTER GEOLOGIC INVESTIGATION, EXPLORATION FOR TALC IS DONE BY DRILLING. MARBLE OUTCROPS ARE EXAMINED FOR TALC VEINS AND PODS. AREAS WHERE THE MARBLE HAS BEEN FOLDED OR WHERE FAULTS ARE ABUNDANT ARE GOOD AREAS FOR TALC OCCURRENCES. DRILLING IS USED TO PINPOINT THE AREA FOR MINING. STREAM SAMPLING OF THE SEDIMENTS FOR TALC IS USED IN AREAS OF THICK FOREST COVER.

A NEW ABOVE-GROUND GEOPHYSICAL METHOD THAT HAS PROVEN VERY EFFECTIVE IN TEXAS IS AN ELECTROMAGNETIC PROSPECTING DEVICE. ITS PURPOSE IS TO MEASURE THE ELECTRICAL RESISTIVITY OF THE TALC AND THE SURROUNDING ROCKS. A CURRENT IS INDUCED IN THE EARTH BY AN ALTERNATING MAGNETIC FIELD TRANSMITTED THROUGH AN ANTENNA. A SECOND RECEIVING ANTENNA MEASURES BOTH THE FIELD RECEIVED DIRECTLY FROM THE TRANSMITTER FIELD AND THE RESISTIVITY DISTRIBUTION IN THE EARTH. COMPARISON OF THE AMPLITUDE AND THE PHASE DIFFERENCES OF THESE TWO FIELDS ALLOWS CALCULATION OF THE ELECTRICAL RESISTIVITY OF THE EARTH BENEATH THE TRANSMITTER-RECEIVER PAIR.

ALTHOUGH THE GEOPHYSICAL METHOD LED TO THE DISCOVERY OF SOME 10 MILLION TONS OF TALC IN TEXAS, IT HAS NOT BEEN AS EFFECTIVE IN MONTANA. THE REASONS FOR THIS INCLUDE THE LACK OF EXPERIMENTATION IN AREAS OF DIFFERING GEOLOGY, AND, UNDERSTANDING OF THE EQUIPMENT. WITH FUTHER TESTING, THE INSTRUMENT MAY PROVE AS EFFECTIVE IN MONTANA AS IN TEXAS.

OTHER GEOPHYSICAL TECHNIQUES THAT HAVE BEEN TESTED WITH SOME RELIABLE RESULTS ARE SELF POTENTIAL (SP) AND RESISTIVITY METHODS. THE SP METHOD MEASURES THE NATURAL, STEADY-STATE ELECTRICAL FIELD AT THE SURFACE OF THE EARTH. VARIATIONS OF THIS FIELD ARE CAUSED BY THE PRESENCE OF BURIED METALLIC MINERALS, BY SUBSURFACE HEAT OR FLUID FLOW, AND BY CHANGES IN ROCK AND SOIL CHEMISTRY ACROSS FAULTS OR CONTACTS. ELECTRICAL RESISTIVITY MEASURES THE RESISTIVITY OF A GIVEN ROCK, RESISTIVITY THAT IS CONTROLLED BY THE POROSITY OF THE ROCK AND THE SALINITY OF ANY PORE FLUID. HIGHER POROSITY AND SALINITY YIELDS LOWER RESISTIVITY VALUES. THE AMOUNT OF EQUIPMENT AND THE EXPENSE OF THESE TWO GEOPHYSICAL METHODS DO NOT ALLOW COVERAGE OF LARGE AREAS.

Other Talc Mining Districts (Fig.3)

There are five major talc districts in the United States, excluding Montana: (1) California-Nevada, (2) North Carolina-Georgia-Alabama, (3) New York, (4) Vermont, and (5) Texas. There are many similarities and differences among the talc-bearing areas. Some similarities include talc bodies that are tabular and concordant; that generally occur in Precambrian rock units, with a few in rock units no younger than Early Paleozoic; and that the talc is a secondary mineral formed "in situ" from pre-existing rocks or from introduced material, or both.

California-Nevada

Talc is found in three prominent areas in southwestern California: the Inyo Panamint Range, Death Valley-Kingston Range, and the Silver Lake-Yucca Grove area. The Inyo Panamint area talc is found along fractured and sheared zones, in steeply dipping metadolomites and quartzites of Ordovician and Silurian ages. Dolomite-quartzite contacts contain talcose zones due to replacement by talc.

In the Death Valley-Kingston Range, talc is found in the middle of the Precambrian Crystal Spring, metadolomite. The deposits are associated with a thick diabase sill that intruded mildly metamorphosed sedimentary rocks.

The Silver Lake-Yucca Grove area talc occurs in a feldspar-diopside hornfels with Precambrian metasedimentary rocks. The talc occurs as an alteration of carbonate rock, most likely dolomite.

North Carolina-Georgia-Alabama

In North Carolina, the talc is mined in the Murphy talc district. It is found in metasedimentary rocks and is associated with ultramafic bodies. The host rock is the Murphy Marble.

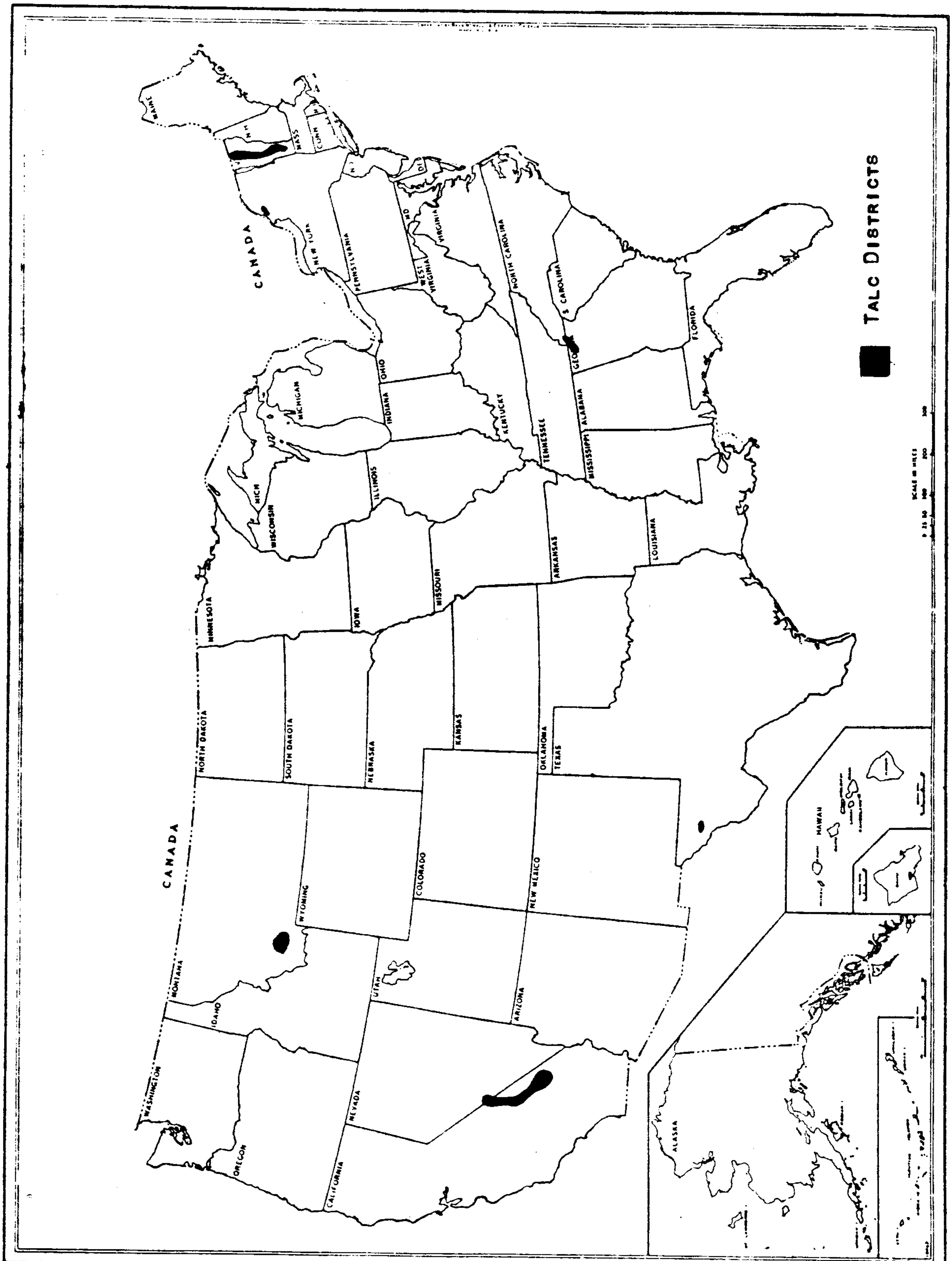


Fig. 3 —Major talc-mining districts of United States.

The deposits in Georgia are located in Murray County. The talc is believed to have formed by the alteration of dolomitic portions of the Cohutta Schist of Precambrian age (Olson,1976,p.106).

The mining of talc in Alabama is done in Talladega County. The deposits occur in a carbonate sequence that likely was Cambro-Ordovician in age.

New York

The talc-bearing strata are part of the Grenville Series, which is an impure silicated metadolomite. High hydrothermal solutions charged with silica replaced the carbonate. Talc formed during retrograde metamorphism, at which time magnesium was available in solution. More than half of the New York talc ore is tremolite that was not replaced by the talc.

Vermont

The talc district in Vermont runs through the central part of the state. Most of the original peridotite or pyroxenite bodies have been completely serpentinized and in part altered to talc.

Texas

Talc is present in the central part of the state, in the Llano district, and in the westernmost part in the Allamoore district. Today the Allamoore district is the only area of importance in Texas. The talc there occurs in Precambrian rocks of the Allamoore formation. The formation consists of interlayered limestone and volcanic rocks. The origin of the talc is from an alteration of dolomitic marl or magnesium rich tuff.

Geology of Montana Talc

Almost all of the known talc in Montana occurs in Precambrian dolomitic marble, in the "Cherry Creek beds". These metamorphic rocks, along with Archean gneiss, are known as the pre-Belt metamorphic rocks. They are termed pre-Belt because they are overlain by sedimentary rocks of the Belt supergroup. The Archean gneiss is overlain by the Cherry Creek rocks. In some classifications, the Archean gneiss is included in the Pony Series, for exposures in the vicinity of the town of Pony, in the Tobacco Root Mountains. The Cherry Creek rocks, which include marble, mica schist, quartzite, and gneiss, were named for exposures between Cherry Creek and Wigwam Creek, in the Gravelly Range.

Age relations and rock distinction are difficult between beds of the pre-Belt metamorphic rocks. Some separation can be done based on an aggregate of rock types present in a thick exposure. It is difficult to put together a stratigraphic section, or to correlate units from range to range, due to the isoclinal folding in the area.

Talc usually occurs as lenses and stringers in the marble. It is associated with tight folds, fractures, marble breccia zones, bedding planes, and faults. These, as well as compositional and chemical factors, are important to the formation and the localization of the talc.

Origin of Talc in Montana

The dolomitic marble does not contain sufficient quartz for the complete replacement of dolomite by talc. The quartz is a minor constituent of the marble. However, meteoric water is thought to have dissolved silica from overlying rocks during its downward movement. Hydrothermal fluids from Precambrian plutons and post-metamorphic pegmatite dikes also have been suggested (Olson,1976,p.113) as sources for the SiO_2-bearing waters. However, Precambrian plutons crystallized after both the talc and chlorite formed, and thus could not have been the source. The post-metamorphic dikes occur only rarely in marble and are not found in the vicinity of talc deposits, making them also unlikely sources for the silica.

Experiments conducted by Slaughter, Kerrick, and Wall(1975) involved the replacement of tremolite by talc. Of the three possible reactions between tremolite and talc it was determined that the temperature range was from 400° to 575°C, and the range of fluid pressure was from 1kb to 5kb. For the reaction, dolomite to talc, the temperature range is somewhere between 400° and 460°C. So, overall, it is estimated that the talc in the Montana deposits formed between 400° to 500°C and at fluid pressure less than 5kb.

Talc is believed to have formed during a period of regional metamorphism. The metamorphism was to greenschist grade, which apparently postdated an amphibolite period of metamorphism and pre-dated the intrusion of the diabase dikes. Talc is considered to have formed during retrograde metamorphism (Berg,1979,p.14) as it (talc) is of a lower temperature assemblage and would have been converted to a higher assemblage during the amphibolite-grade metamorphism.

The talc formed in dolomitic marble of pre-Beltian age because the marble layers do not contain SiO_2, or interbeds of metaquartzite, it is believed that the SiO_2 was introduced. Talc in southwestern Montana is believed to have formed under the following reaction:

$$3CaMg(CO_3)_2 + 4SiO_2 + H_2O = Mg_3Si_4O_{10}(OH)_2 + 3CaCO_3 + 3CO_2$$

For a complete replacement of dolomite by talc in this reaction, 32 volume percent of quartz is necessary. Because dolomite is present at the different talc localities, quartz becomes a limiting factor in the replacement of marble. The lack of calcite in close association with the talc may mean that it was "flushed" from the system by the hydrothermal fluids (Berg,1979, p.12). The talc apparently formed by the action of hydrothermal fluids containing silica during metamorphism of dolomite. The presence of hydrous minerals such as chlorite, sericite, and serpentine, found near the talc bodies suggests that water pennatrated the rocks beyond the boundaries of the talc bodies.

Chlorite is closely associated with the talc, and is considered to have formed at the same time as the talc. Chlorite may have formed from the quartzofeldspathic gneiss by the addition of magnesium from the dolomite.

The metasomatism of dolomite to talc has been dated at 1600 m.y. (Berg, 1979,p.14). No talc has been found in dolomitic formation of Cambrian, Ordovician, and Devonian age.

Ruby Range Geology

The Ruby Range (Fig.4) is an uplifted block of pre-Belt metamorphic rocks trending N40E, with a width of 10 to 15 miles (Olson,1976,p.115). The Ruby Range has a westward dip of 30 to 70 degrees (Perry,1948,p.4). It is surrounded by intermountaine basins partially filled with Tertiary sediments. The pre-Belt rocks were subjected to multiple periods of Precambrian deformation, which produced isoclinal folds and a mineral assemblage of amphibolite facies. Paleozoic and younger sedimentary rocks are exposed in the northern part of the Ruby Range where they flank the Precambrian core.

The pre-Belt rocks of the Ruby Range are of three major units (Fig.5): the Cherry Creek Series, the Dillion Granite Gneiss and the pre-Cherry Creek rocks. The Dillion Granite Gneiss is exposed in the middle of the Ruby Range and separates the Cherry Creek rocks from the pre-Cherry Creek rocks. The Cherry Creek rocks are the most important as they host the talc deposits.

The Cherry Creek Series is an intensely metamorphosed series of early Precambrian schists, phyllites, light and dark-colored gneiss, amphibolites, schistose quartzite, containing kyanite, and sillmanite. The series strikes northeast parallel to the northwest flank of the Ruby Range, and is truncated to the northwest by range front faults. The thickness of the series is four to six thousand feet. The series is of sedimentary origin, and it has been intruded by dikes and sills, some of which are metamorphosed. Isoclinal and overturned folds and crumpled beds are evident. The marble layers are well-bedded, individual layers that are light gray in color and generally well exposed. Individual quartzite layers in the Cherry Creek Series range from 15 to 180 feet (Olson,1976,p.118) in thickness and make good unit markers. Amphibolite and hornblende gneiss vary in thickness from 6 inches

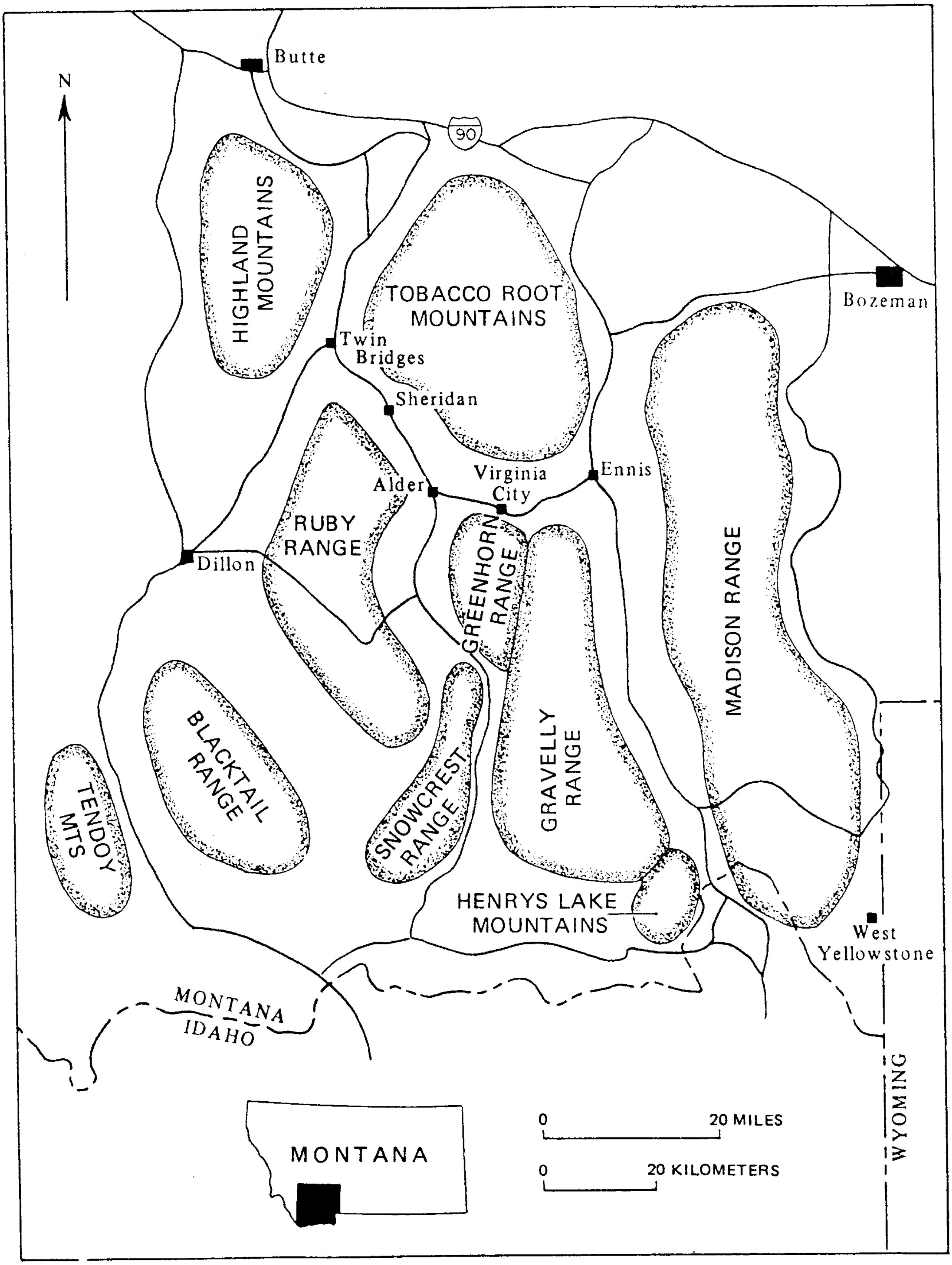


Figure 4 – Mountain ranges and major roads in area of talc and chlorite occurrences in southwestern Montana.

METAMORPHIC SUBDIVISION	MAJOR ROCK TYPES	PROTOLITH	THICKNESS	LOCAL EXPOSURE AREA	TYPE AREA / REGIONAL DISTRIBUTION
CHERRY CREEK GROUP	A) *marble* (locally talcose) and *calc-silicate gneiss* (the latter more abundant to the south).	A) limestone/dolomite, shaly-quartose carbonate rocks.	A) < 1m to about 1 km. Mostly a few tens to hundreds of meters.	A) a 3-5 km wide belt along the western range flank, southwest of Spring Cr. area east of Kephart fault across Ruby dam into Greenhorn Rg. Examples: Ruby Peak marble, "Regal" marble.	Cherry Creek type locality is east flank of Gravelly Rg. The Group occurs also in the Tobacco Root, Highland, Greenhorn, Madison, Tendoy (?) Ranges. (Big Snowy block has Archean marbles.)
	B) *metaquartzite*.	B) orthoquartzite, impure sandstone.	B) <10 m in the north to 60m in the south		
	C) *amphibolite*.	C) basic sills (flows?) and dikes mafic pyroclastics (?)	C) <1m to a few hundred meters. 500m to south.		
	D) *sillimanite - biotite gneiss* and *schist mica schist*. retrograde *chlorite schist*.	D) pelites.	D) variable	D) discontinuous sillimanite interlayers in biotite gneiss to the north. schist belts a few hundred meters wide near Spring Cr. and along Mine Gulch.	
	E) *iron formation (quartz-magnetite-iron silicate schist)*.	E) ferrugenous sediments. (shallow marine - brackish water?).	E) few meters to tens of meters. Carter Cr. deposit is 100-155m thick (folded).	E) Kelly and Carter Cr. deposits. thin units at northern range tip and between Trout Cr. and the Dillon synform.	E) Copper Mtn. area, S. Tobacco Rt. Mts. and Ruby Cr. area, E. Gravelly Rg. also have iron deposits.
	F) *anthophyllite schist*.	F) ultrabasic intrusions? anatexis of metasedimentary rk?	F) 0.5 to 20(?) m	F) scattered lenses, thin layers associated with amphibolite. relict kyanite and staurolite along Stone Cr. large lens at Hinch Cr.	F) Tobacco Rt. Mts. occurrences, see Vitaliano and others, 1979.
DILLON QUARTZO-FELDSPATHIC GNEISS	*hornblende - biotite - garnet - microcline gneiss* (leucocratic to mafic varieties).	quartz - illite (?) siltstone and granitic derivitives.	9 km thick, with substantial folding and interlayered amphibolite.	underlies 325 km^2 along range crest.	Type locality is in Blacktail Rg near Jake Cr. Found also in Tendoy Rg., area north of Armstead. similar quartz-feldspar gneiss near Pony and in the southern Madison and Tobacco Rt. Mts.
PRE-CHERRY CREEK ROCKS	*biotite - hornblende - garnet gneisses* and *schists*. *augen gneiss*. *amphibolite*. *anthophyllite schist*. *migmatite*.	pelites, impure sandstone. basic dikes, sills. volcaniclastics? *(hornblende gneiss)*.	unknown. (400m minimum in southern range).	6 km long belt between Sage and Mormon Crks. 25 km^2 area centered on Moose Cr. not present northern range. best exposed north of Cottonwood Cr.	eastern Blacktail, southern Madison Ranges.
ULTRAMAFIC ROCKS	*metaperidotite*, *metapyroxenite*, *serpentinite*.	peridotite, pyroxenite	variable.	scattered pods, lenses, boudins.	found throughout southwest Montana pre-Belt exposure area.
DIABASE	several petrologic varieties.	tholeiitic basalt.	dikes up to 6 km long and 100 m wide.	not abundant to the north. elsewhere intruded along northwest - trending weakness directions and faults.	

to 1500 feet in the individual units (Olson,1976,p.118) and are important in terms of the total volume of rocks present.

The Dillion Granite Gneiss began as a large tabular intrusive body of batholithic proportion. The Gneiss consists mainly of quartzofeldspathic gneiss, but contains pegmatite and aplite. It separates the Cherry Creek rocks to the northwest from the pre-Cherry Creek rocks to the southwest. The Gneiss is conformable with those metasedimentary rocks that it intruded. Granitization and isochemical metamorphism also have been considered as alternatives for the formation of the Dillion Granite Gneiss.

The pre-Cherry Creek rocks lie southwest of the Dillion Granite Gneiss. The units are biotite-quartz-feldspar gneiss, hornblende gneiss, amphibolite, sillimanite gneiss and chlorite gneiss. These rocks are considered to be older than the Cherry Creek rocks because they lie stratigraphically below them. Their origin is believed to have been as mafic sills and intrusives because of the discontinuous nature of some of the amphibolite bodies. The pre-Cherry Creek rocks are coarse grained and banded.

Other rock bodies in the area that are worth mentioning include ultramafic rocks, granulites, and diabase dikes. They are present throughout the Ruby Range. The ultramafic rocks intrude the pre-Cherry Creek, the Cherry Creek Group, and the Dillion Granite Gneiss in the southwestern part of the Ruby Range. All of the pre-Belt rocks play host to the ultramafic rock bodies in the middle of the Ruby Range. The three major types of ultramafic rocks are metamorphosed peridotite, pyroxenite, and serpentinite. The granulites usually are found in terranes underlain by the Dillion Granite Gneiss. It is these locations, near two talc-bearing marble units, that makes the granulites of interest.

Diabase dikes are common along the southern two-thirds of the western flank of the Ruby Range. Except for the marble, the country rocks were basically uneffected by the intrusion of the dikes and have been metamorphosed to the greenschist facies. The diabase dikes are the youngest Precambrian unit in the range. They were emplaced later than the phases of shearing and recrystallization that are associated with the ultramafic rocks and the other pre-Beltian rocks.

Hand Sample Analysis

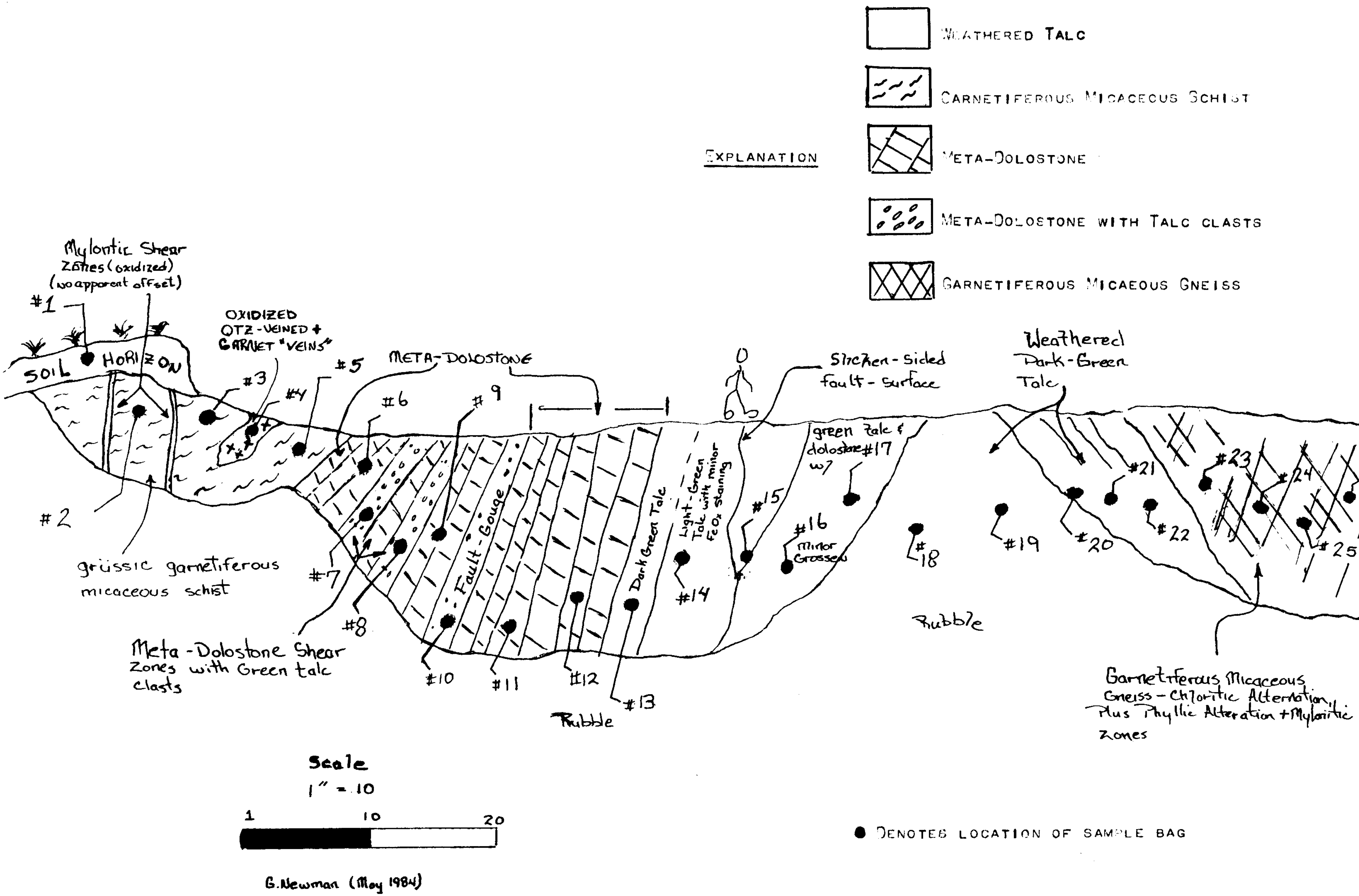
Hand samples 9 through 23, shown in the cross section (Fig.6), were studied to identify the rocks and their minerals. A pie-diagram (Fig.10) shows the overall composition of the hand samples. The lateral sequence, that the samples followed in the outcrop, was a micaeous schist with quartz viens followed by dolomitic marble and talc and a micaeous gneiss with chloritic alteration.

The samples 9, 10, 11, and 12, contained an average of 75.5 percent dolomite and 23.5 percent talc. Minor constituents consist of .08 percent graphite and .02 percent calcite. The graphite formed long after the talc and is of no significance in the formation of talc. Some of the samples showed minor FeOx staining.

In samples 13 through 20, talc was the primary mineral. Talc averaged 90.8 percent with dolomite showing 5.4 percent. The minor constituents are 1.5 percent of limonite, and 1.3 percent of graphite. Small traces of gypsum (sample 15) and calcite also were visible.

The last samples, 21 through 23, contained little talc and dolomite. Chlorite was present, but was hard to distinguish from the talc in these samples. The major constituent was quartz at 45 percent. Other minerals present included, 30 percent chlorite, 10 percent plagioclase and minor amounts of muscovite, magnesite, graphite, and garnet.

Samples 1 through 8 showed garnetiferous micaeous schist and some metadolostone. Samples 24 through 27 showed phyllic alteration and mylonitic zones. These 12 samples were not used, because any significant changes that had taken place in the formation of talc would be noticeable in the samples 9 through 23.



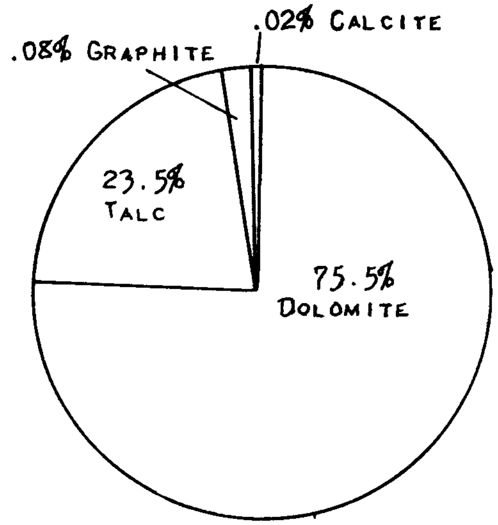
(FIG. 6) CROSS-SECTION OF PROSPECT NORTHEAST OF TREASURE MINE


17
19
18

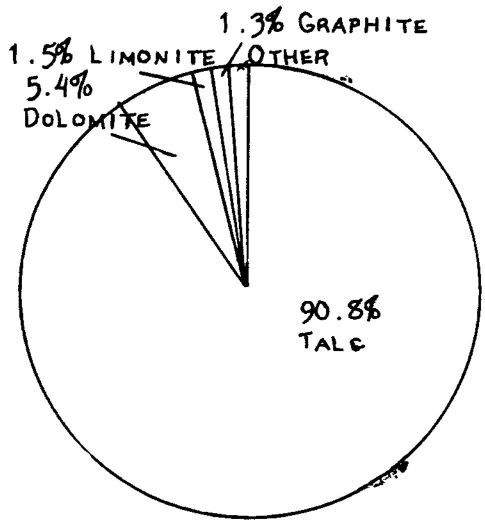
E) SAMPLE BAGS 18 THROUGH 27

F) SAMPLE BAGS 23 THROUGH 27

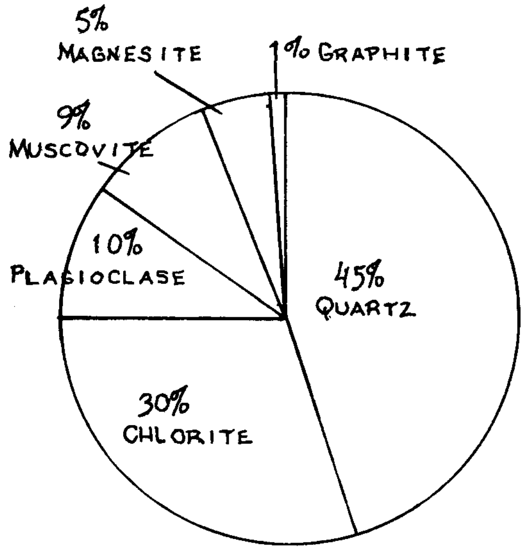
(FIG.9) PHOTOGRAPHS SHOWING SECTIONS OF THE OUTCROP WITH SAMPLES 18 THROUGH 27 IN PLACE.



Samples 9 through 12



Samples 13 through 20



Samples 21 through 24

(Fig. 10) Pie diagram analysis of hand samples

Thin Section Analysis

In thin sections 9 through 11, dolomite was the major constituent. It occurs in subhedral crystal form and varies in size from .5 to 3mm. The talc in these thin sections occurs as fine aggregates, showing replacement of the dolomitic marble. Minor amounts of graphite also were noticeable.

Talc is the primary mineral in the thin sections 12 through 20. It occurs as fine aggregates, replacing the subhedral, dolomite grains. Chlorite, in the form of clinochlore was visible in scattered amounts in thin sections 14 through 17. The clinochlore grains varied in size from .5 to 1.5mm. Minor amounts of graphite, and limonite also were visible.

In thin sections 21 through 23, a garnetiferous micaeous gneiss was recognized with major amounts of chlorite and quartz. The quartz occurred as rounded anhedral grains in various sizes with some of the grains showing deformation due to stress. Chlorite occurred as the groundmass. The formation of the chlorite was due to the magnesium being added to the quartzofeldspathic gneiss. The movement of magnesium from the dolomite to the gneiss was, probably, due to hydrous solutions. Smaller amounts of feldspar, biotite, and garnet were visible. The accessory minerals visible included epidote, zircon, graphite, sericite, and muscovite. Sericite occurred as an alteration product of the plagioclase.

Minerals forming from higher temperatures, such as tremolite and serpentine, were not found in the thin sections. Evidence of the higher temperature forming minerals would have been helpful in the understanding of the type of metamorphism that the talc underwent.

Summary

Generalizations can be made on the zonational changes that occurred in the formation of talc from the hand samples and the thin section analysis. The generalizations apply only for the outcrop from which these samples were taken. The analysis of the rock samples in the hand specimens and thin sections led to the conclusion that the talc has replaced the quartz-free magnesite-bearing marble. This does not mean that the only place talc will be found is in the dolomitic marble. However, it does mean the talc can be found in the marble.

The formation of talc was dependent on factors, such as parent rock, presence of quartz, water, and temperature. In terms of temperature, it would be likely the formation of talc would have taken place under low temperatures of 500°C. Dolomite is stable under a range of temperatures. It will not react in the absence of quartz until the temperature reaches an excess of 700°C. With the presence of quartz, dolomite will react to form talc at a lower temperature. Because it is understood that quartz was introduced into the dolomite by hydrous solutions, a low forming temperature would be likely. Also, no higher temperature minerals were found, making the formation of talc under a lower temperature possible.

Although a number of reactions are possible for the talc formation, the following reaction seems the most likely:

$$3CaMg(CO_3)_2 + 4SiO_2 + H_2O = Mg_3Si_4O_{10}(OH)_2 + 3CaCO_3 + 3CO_2$$

Even though a large amount of calcite was formed in the reaction, little was visible in the thin sections or hand samples. This evidence may support the theory that the calcite was flushed downward by hydrothermal solutions.

The chlorite found in the thin sections probably formed by the replacement of the quartzofeldspathic gneiss within which it is found. The hydrous solutions moved quartz into the dolomite for the formation of talc, and at the same time allowed for the movement of magnesium from the dolomite to the quartzofeldspathic gneiss for the formation of chlorite.

The question remains as to the type of metamorphism that the talc underwent. If the talc had undergone a retrograde metamorphism, traces of higher temperature minerals probably would have remained in the thin sections. A complete replacement of the higher temperature minerals such as tremolite by talc is not likely. A possibility is that, water and CO_2-bearing gases could have been introduced along fractures and shear zones after the temperatures of retrograde metamorphism had subsided, allowing for the talc to form. Talc does occur along such zones in southwestern Montana.

Because higher temperature minerals are not evident, a prograde metamorphic event seems to be the best possibility for the talc formation. With the temperatures probably proceeding from low to high, the talc would have occurred in hte greenschist facies during regional metamorphism. The theory of talc forming during the period of regional metamorphism of the greenschist grade, which postdated the amphibolite and predated the intrusion of the diabase dikes (Olson,1976,p.112), would seem to explain the type of metamorphism that led to the formation of talc. The formation of talc in other districts in the United States is by retrograde metamorphism.

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Appendix I

Detailed Description of Rock Samples and Thin Sections

SAMPLE NO. 9

HAND SPECIMEN DESCRIPTION:

MASSIVE, MEDIUM-GRAINED YELLOW-GREEN DOLOMITE CONTAINING FROM 30 TO 40% TALC AND .5 TO 1.5% GRAPHITE.

THIN SECTION STUDY-SUMMARY

DOLOMITE GRAINS SHOW ANHEDRAL FORM. TALC IS SUBHEDRAL AND CAN BE SEEN REPLACING THE DOLOMITE. ALSO, THERE IS A SMALL AMOUNT OF GRAPHITE.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

DOLOMITE (60%) SUBHEDRAL GRAINS AVERAGING FROM .5MM TO 2.5MM IN SIZE.

TALC (35%) SUBHEDRAL GRAINS RANGING FROM VERY SMALL TO 1.5MM.

ACCESSORIES (5%)
GRAPHITE

WEATHERING AND ALTERATION PRODUCTS:

INTRODUCED (SECONDARY) PRODUCTS

ROCK NAME

DESCRIPTION OF ROCK SPECIMEN.

SAMPLE No. 10

HAND SPECMEN DESCRIPTION:

MASSIVE, MEDIUM-GRAINED YELLOWISH-GREEN DOLOMITE WITH 10 TO 15% TALC AND SOME MINOR TRACES OF CALCITE. THE CALCITE WAS ONLY FOUND ON ONE OF THE ROCK SPECIMENS IN THIS SAMPLE BAG. UNTIL THE THIN SECTION IS LOOKED AT, IT MAY HAVE NO BEARING IN THIS SAMPLE.

THIN SECTION STUDY-SUMMARY:

DOLOMITE GRAINS SHOWING SUBHRDRAL FORM AND REPLACEMENT BY TALC. TALC IS OCCURRING AS AGGREGATES. THE GRAPHITE IS AGAIN PRESENT IN A SMALL AMOUNT.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

TALC (70%) AGGREGATE STRUCTURE. TALC IS REPLACING THE DOLOMITE.

DOLOMITE (25%) SUBHEDRAL CRYSTAL FORM. THE GRAINS VARY IN SIZE FROM .5MM TO 2.0MM.

ACCESSORIES (5%)
GRAPHITE

WEATHERING AND ALTERATION PRODUCTS:

INTRODUCED (SECONDARY) PRODUCTS

ROCK NAME

DESCRIPTION OF ROCK SPECIMEN.

SAMPLE NO. 11

HAND SPECIMEN DESCRIPTION:

MASSIVE, MEDIUM-GRAINED YELLOWISH-GREEN DOLOMITE WITH 25 TO 30% TALC.

THIN SECTION STUDY-SUMMARY:

DOLOMITE GRAINS SHOWING ANHEDRAL AND SUBHEDRAL CRYSTAL FORM. TALC OCCURRING IN FINE AGGREGATES. GRAPHITE IS VISIBLE IN SMALL AMOUNTS.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

DOLOMITE (70%) SUBHEDRAL GRAINS WITH THE GRAIN SIZE RANGING FROM .5 TO 2.0MM.

TALC (25%) AGGREGATE STRUCTURE

ACCESSORIES (5%)
GRAPHITE

WEATHERING AND ALTERATION PRODUCTS:

INTRODUCED (SECONDARY) PRODUCTS

ROCK NAME

DESCRIPTION OF ROCK SPECIMEN.

SAMPLE NO. 12

HAND SPECIMEN DESCRIPTION:

MASSIVE, MEDIUM-GRAINED LIGHT-GREEN DOLOMITE WITH 30 TO 35% TALC.

THIN SECTION STUDY-SUMMARY:

THE TALC OCCURS AS FINE AGGREGATES THAT HAVE SOME TYPE OF PARALLEL ORIENTATION. DOLOMITE SHOWS SUBHEDRAL FORM WITH THE TALC REPLACING THE DOLOMITE. THE OUTLINES OF THE DOLOMITE CAN BE SEEN AS THE TALC REPLACES IT. GRAPHITE AND CHLORITE ARE ALSO VISIBLE.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

TALC (65%) AGGREGATE STRUCTURE

DOLOMITE (25%) SUBHEDRAL GRAINS VARYING FROM .5 TO 2.0MM IN SIZE.

CHLORITE (5%) CLINOCHLORE IS THE TYPE OF CHLORITE VISIBLE. IT OCCURS AS TABULAR AND ELONGATED GRAINS. THE SIZE VARIES FROM .5MM TO 1.5MM.

ACCESSORIES (5%)
GRAPHITE

WEATHERING AND ALTERATION PRODUCTS:

INTRODUCED (SECONDARY) PRODUCTS

ROCK NAME

Description of Rock Specimen

Sample No. __13____

Hand Specimen Description:

Massive, fine grained, light-green talc with 5 to 10% dolomite, 1.0 to 2.0% graphite and some minor FeO_x staining.

Thin Section Study-Summary:

The thin section is mostly talc replacing the dolomite. The dolomite grains are sections of subhedral grains that have not been completely replaced by talc. Some graphite is also present.

Thin Section Study-Mineralogy, Texture, Grain Shapes:

Talc (90%) Aggregate structure having replaced the dolomite

Dolomite (8%) Parts of the subhedral grains have not been replaced by the talc

Accessories (2%)
Graphite

Weathering and Alteration Products:

Introduced (secondary) products

Rock Name ________________________________

DESCRIPTION OF ROCK SPECIMEN.

SAMPLE NO. 14

HAND SPECIMEN DESCRIPTION:

MASSIVE, FINE GRAINED, LIGHT-GREEN TALC WITH 10 TO 15% DOLOMITE, AND 1.0 TO 2.0% LIMONITE.

THIN SECTION STUDY-SUMMARY:

THE TALC OCCURS AS FINE AGGREGATES, WHICH REPLACED THE DOLOMITE. THE DOLOMITE VARIES IN SIZE FROM .5MM TO 1.5MM AND OCCURS AS SUBHEDRAL GRAINS. CHLORITE SHOWS TABULAR STRUCTURE WITH GRAIN SIZE FROM .5 TO 1.5MM. LIMONITE IS MINOR.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

TALC (80%) FINE AGGREGATE STRUCTURE THAT HAS REPLACED THE DOLOMITE.

DOLOMITE (10%) SUBHEDRAL GRAINS THAT HAVE BEEN PARTIALLY REPLACED BY TALC.

CHLORITE (5%) IT SHOWS TABULAR FORM WITH THE SIZE VARYING FROM .5MM TO 1.5MM. IT IS OF THE VARIETY, CLINOCHLORE.

ACCESSORIES (5%)

LIMONITE-GRAIN SIZE VARIES FROM .2MM TO .5MM.

WEATHERING AND ALTERATION PRODUCTS:

INTRODUCED (SECONDARY) PRODUCTS

ROCK NAME

Description of Rock Specimen.

Sample No. 15

Hand Specimen Description:

Massive, fine grained, light-green talc with 2 to 4% graphite, 1 to 2% graphite, 3 to 5% gypsum, and 2 to 3% calcite.

Thin Section Study-Summary:

The thin section shows slick and slide fault gouges. There is a variety of high birefringence colors. Outlines of subhedral grains of dolomite that have been partiality or completely replaced by talc are visible. Chlorite and limonite are also visible.

Thin Section Study-Mineralogy, Texture, Grain Shapes:

Talc (90%) Occurs as fine aggregates and a replacement for the dolomite.

Dolomite (5%) Parts of the grains with subhedral outlines show replacement by talc.

Chlorite (3%) Clinochlore is present. It varies in size from .5mm to 1mm.

Accessories (3%)

Graphite-average size of grains is .2mm.

Limonite-grains vary from .2mm to .5mm.

Weathering and Alteration Products:

Introduced(secondary)products

Rock Name ____________________

DESCRIPTION OF ROCK SPECIMEN.

SAMPLE NO. 16

HAND SPECIMEN DESCRIPTION:

MASSIVE, FINE GRAINED, GREEN TALC WITH 3 TO 5% GRAPHITE AND 1 TO 2% LIMONITE.

THIN SECTION STUDY-SUMMARY:

TALC OCCURS AS FINE AGGREGATES. CHLORITE IS PRESENT IN SMALL AMOUNTS IN TABULAR AND ELONGATED GRAINS. THERE IS ALSO A SMALL AMOUNT OF LIMONITE AND GRAPHITE PRESENT.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

TALC (90%) OCCURS AS FINE AGGREGATES

CHLORITE (5%) CLINOCHLORE IS PRESENT IN TABULAR AND ELONGATED GRAINS RANGING IN SIZE FROM .2MM TO 1MM.

ACCESSORIES (5%)
GRAPHITE-GRAIN SIZE FROM .2MM TO .3MM.
LIMONITE-GRAIN SIZE VARIES FROM .5MM TO 1.0MM.

WEATHERING AND ALTERATION PRODUCTS:

INTRODUCED(SECONDARY)PRODUCTS

ROCK NAME ______________________

DESCRIPTION OF ROCK SPECIMEN.

SAMPLE NO. 17

HAND SPECIMEN DESCRIPTION:

MASSIVE, FINE GRAINED, GREEN TALC WITH 3 TO 5% DOLOMITE AND 1 TO 2% LIMONITE.

THIN SECTION STUDY-SUMMARY:

TALC IS THE MAJOR CONSTITUENT OCCURRING AS FINE AGGREGATES. CHLORITE IS PRESENT IN SMALL AMOUNTS. LIMONITE IS ALSO VISIBLE IN THE THIN SECTION IN SMALL AMOUNTS.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

TALC (92%) OCCURS AS FINE AGGREGATES.

CHLORITE (5%) SIZE VARIATION FROM .5MM TO 1MM. OCCURS AS CLINOCHLORE. GRAINS ARE TABULAR IN FORM.

ACCESSORIES (3%)
LIMONITE-SIZE RANGE FROM .2MM TO .5MM OF GRAINS.

WEATHERING AND ALTERATION PRODUCTS:

INTRODUCED (SECONDARY) PRODUCTS

ROCK NAME ______________________

DESCRIPTION OF ROCK SPECIMEN.

SAMPLE NO. 18

HAND SPECIMEN DESCRIPTION:

MASSIVE, FINE GRAINED, LIGHT GREEN TALC WITH 2 TO 4% LIMONITE AND 2 TO 4% GRAPHITE. SOME DOLOMITE WAS VISIBLE, BUT THE PIECES OF ROCK CONTAINING THESE SMALL AMOUNTS OF DOLOMITE COULD HAVE BEEN OUT OF PLACE.

THIN SECTION STUDY-SUMMARY:

TALC OCCURS AS FINE AGGREGATES. SMALL AMOUNTS OF DOLOMITE THAT ARE VISIBLE AND SHOW REPLACEMENT BY TALC. SOME GRAPHITE AND LIMONITE ARE VISIBLE.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

TALC (90%) OCCURS AS FINE AGGREGATES. REPLACES THE DOLOMITE.

DOLOMITE (5%) RANGES IN SIZE FROM .5MM TO 2.5MM. SUBHEDRAL GRAINS HAVE BEEN PARTIALLY REPLACED BY TALC. SOME GRAPHITE AND LIMONITE ARE VISIBLE.

ACCESSORIES (5%)

LIMONITE-.2 TO .3MM IN GRAIN SIZE

GRAPHITE-.2MM IN AVERAGE GRAIN SIZE

WEATHERING AND ALTERATION PRODUCTS:

INTRODUCED(SECONDARY)PRODUCTS

ROCK NAME ______________________

DESCRIPTION OF ROCK SPECIMEN.

SAMPLE NO. 19

HAND SPECIMEN DESCRIPTION:

MASSIVE, FINE GRAINED, LIGHT-GREEN TALC WITH 10 TO 15% DOLOMITE.

THIN SECTION STUDY-SUMMARY:

TALC OCCURS AS FINE AGGREGATES. DOLOMITE ALSO IS VISIBLE WITH THE GRAINS VARYING IN SIZE FROM .5MM TO 1.5MM.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

TALC (90%) OCCURS AS FINE AGGREGATES.

DOLOMITE (10%) GRAIN SIZE FROM .5 TO 1.5MM. OUTLINES OF SUBHEDRAL GRAINS ARE VISIBLE.

WEATHERING AND ALTERATION PRODUCTS:

INTRODUCED (SECONDARY) PRODUCTS

ROCK NAME ____________________

DESCRIPTION OF ROCK SPECIMEN.

SAMPLE NO. 20

HAND SPECIMEN DESCRIPTION:

MASSIVE, FINE GRAINED, LIGHT-GREEN TALC WITH 5 TO 10% DOLOMITE, 2 TO 3% GRAPHITE, AND 1 TO 2% LIMONITE.

THIN SECTION STUDY-SUMMARY:

TALC OCCURS AS FINE AGGREGATES. PLATES OF CARBONATES SHOW CLOSE ASSOCIATION WITH QUARTZ GRAINS. THE CARBONATE GRAINS ARE DOLOMITE. SOME LIMONITE AND GRAPHITE ARE ALSO VISIBLE.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

TALC (85%) OCCURS AS FINE AGGREGATES.

DOLOMITE (5%) GRAINS RANGE IN SIZE FROM .5MM TO 1.5MM. SOME SUBHEDRAL GRAIN OUTLINES CAN BE SEEN.

QUARTZ (5%) GRAINS ARE ANHEDRAL IN CRYSTAL FORM. THE GRAINS AVERAGE 1MM IN SIZE.

ACCESSORIES (5%)

GRAPHITE-SIZE RANGE FROM .2MM TO .3MM.
LIMONITE-GRAINS VARY FROM .3MM TO .5MM.

WEATHERING AND ALTERATION PRODUCTS:

INTRODUCED(SECONDARY)PRODUCTS

ROCK NAME ____________________

DESCRIPTION OF ROCK SPECIMEN.

SAMPLE NO. 21

HAND SPECIMEN DESCRIPTION:

MEDIUM-GRAINED DARK GRAY OR GREEN CHLORITE CONTAINING 20 TO 25% QUARTZ, 5 TO 10% FELDSPARS AND UP TO 3% GRAPHITE.

THIN SECTION STUDY-SUMMARY:

LARGE ANHEDRAL QUARTZ GRAINS ARE VISIBLE. THE FELDSPARS ARE HIGHLY ALTERED. BIOTITE IS SUBHEDRAL WITH NO SPECIFIC ORIENTATION.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

BIOTITE (5%) SUBHEDRAL GRAINS RANGING IN SIZE FROM .5MM TO 1MM.

FELDSPAR (10%) SUBHEDRAL GRAINS VARYING FROM .1 TO 2MM IN GRAIN SIZE.

CHLORITE (50%) GROUNDMASS

QUARTZ (30%) ROUNDED ANHEDRAL GRAINS BETWEEN .5 TO 1MM IN SIZE.

ACCESSORIES (5%)

GRAPHITE-.2 TO .5MM IN GRAIN SIZE
ZIRCON-TRACES OF GRAINS .1 TO .2MM IN SIZE
EPIDOTE-.1 TO .2MM IN GRAIN SIZE. VISIBLE IN SOME OF THE QUARTZ GRAINS.

WEATHERING AND ALTERATION PRODUCTS:

INTRODUCED (SECONDARY) PRODUCTS

ROCK NAME ____________________

Description of Rock Specimen.

Sample No. 22

Hand Specimen Description:

Medium grained, dark gray micaeous gneiss with 20 to 25% quartz.

Thin Section Study-Summary:

Quartz grains are elongated. Biotite shows preferred orientation, parallel to the quartz. Plagioclase, which shows lamellae, are anhedral and some sericite alteration can be seen.

Thin Section Study-Mineralogy, Texture, Grain Shapes:

Biotite (12%) Grains show preferred orientation. They are anhedral to subhedral in crystal form. Grain size varies from .5 to 1mm.

Garnet (15%) Grains are anhedral with some inclusions. The average size is 1mm. The grains are poikioblasically, enclosing the quartz.

Plagioclase (8%) Grains are anhedral with some sericite alteration. The grain size varies from .5 to 1mm.

Quartz (32%) Various grain sizes. Grains are anhedral in form.

Chlorite (27%) Aggregated groundmass

Accessories (6%)
- Muscovite-small grain sizes
- Zircon-.1 to .2mm in grain size
- Sericite-alteration of plagioclase

Weathering and Alteration Products: Sericite altered from plagioclase

Introduced (secondary) products

Rock Name Mica Gneiss

DESCRIPTION OF ROCK SPECIMEN.

SAMPLE NO. 23

HAND SPECIMEN DESCRIPTION:

MEDIUM GRAINED, MICACEOUS GNEISS WITH 45 TO 50% QUARTZ, 5 TO 10% BIOTITE, AND 2 TO 5% GRAPHITE.

THIN SECTION STUDY-SUMMARY:

POLYCRYSTALLINE QUARTZ GRAINS ARE ROUNDED. SOME OF THE PLAGIOCLASE SHOW TWIN LAMELLAE WHICH HAVE BEEN DESTROYED. BIOTITE IS SUBHEDRAL SHOWING NO SPECIFIC ORIENTATION. THE GROUNDMASS IS CHLORITE.

THIN SECTION STUDY-MINERALOGY, TEXTURE, GRAIN SHAPES:

BIOTITE (10%) AVERAGE GRAIN SIZE .5 TO 1MM. GRAINS ARE MOSTLY SUBHEDRAL.

PLAGIOCLASE (20%) MOST GRAINS ARE BETWEEN .5 AND 1MM IN SIZE. GRAINS ARE MOSTLY ANHEDRAL.

QUARTZ (30%) ANHEDRAL GRAINS WITH VARIOUS SIZES RANGING FROM .4MM TO 1.5MM. SOME GRAINS SHOW DEFORMATION DUE TO STRESS.

CHLORITE (25%) AGGREGATED GROUNDMASS

GARNET (10%) EQUANT, ANHEDRAL GRAINS WITH INCLUSIONS. VARIATION IN GRAIN SIZES.

ACCESSORIES (5%)
MUSCOVITE
SERICITE-ALTERATION OF PLAGIOCLASE

WEATHERING AND ALTERATION PRODUCTS: SERITIZATION OF PLAGIOCLASE

INTRODUCED(SECONDARY)PRODUCTS

ROCK NAME MICA GNEISS

APPENDIX II

GUIDES TO THE OCCURRENCES OF MONTANA TALC

Guides to the Occurrence of Talc

For a good understanding of the occurrence of talc in Montana, the following points are important. These guidelines were quoted to Olson (Olson, 1976, p.139) by A. Okuma (1971).

"a) All of the commerical talc deposits are intimately associated with the marble units. Dolomite marbles seem to be a prequisite for the formation of high quality talc in the Ruby Range.

b) The talc generally occurs in areas of structural weakness, such areas being marked by faulting, brecciation, silicification, and in many cases, recrystallization.

c) The talc deposits are related to the presence of intrusive rocks, probably of granitic or other composition, from which they obtained their supply of hydrothermal solutions. To some degree the nearness to the Dillion Granite Gneiss especially of the olive-gray variety may be a useful guideline for prospecting.

d) Areas of retrograde metamorphism may be of special significance in talc prospecting."