DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-979, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey for talc in part of the Ruby Mountains Wilderness Study Area (MT-076-001), Madison County, Montana.

INTRODUCTION

This report concerns the mineral resource potential for talc within the Bureau of Land Management administered Ruby Mountains Wilderness Study Area (MT-076-001). The study area lies at the north end of the Ruby Range, in Madison County, Montana (fig. 1). The study involved detailed examination of Archean metamorphic rocks with potential for talc and was carried out by R. B. Berg of the Montana Bureau of Mines and Geology under a contract with the U.S. Geological Survey. A summary of the data presented here was incorporated into a report by Tysdal and others (1987) on the mineral resources of the Ruby Mountains Wilderness Study Area.

Montana is one of the leading talc-producing states with estimated production of 283,000 metric tons for 1980, the most recent year for which a published figure is available (Krempasky, Bingler, and Lawson, 1982, p. 318). In 1985 Montana was the leading state in the volume of talc produced (Clifton, 1986, p. 196). Since the mid 1970's increased exploration for new talc deposits in southwestern Montana has been focused on the Ruby Range, where most of the known talc deposits occur. As of 1979 twenty deposits were known in the Ruby Range as compared to ten in the Greenhorn Range (10 to 15 km east of the Ruby Range) and seven in the Gravelly Range (20 to 30 km east of the Ruby Range) (Berg, 1979; Olson, 1976) (fig. 1). Two major open-pit mines (the Treasure and the Beaverhead) are situated about 10 km south of the wilderness study area and are in host rock types also exposed in the wilderness study area. According to Howard Harlan, Supervisor-Exploration, Cyprus Industrial Minerals Company (written commun., October 5, 1984), in 1984 a mining company was negotiating for mineral leases on private land near the wilderness study area and had staked claims on talc discoveries in parts of sections 19, 20, 29, and 30, T. 6 S., R. 5 W. and sections 11 and 12, T. 6 S., R. 6 W. just to the south of the wilderness study area.

GEOLOGIC SETTING

The Ruby Range are almost entirely underlain by rocks metasorphosed to the amphibolite facies during the Archean. Predominately metasedimentary units referred to as Cherry Creek-type lithologies are exposed in the northwestern third of the range. These units include marble, quartzite, schist, banded iron formation, amphibolite, and hornblende gneiss. Talc deposits in the Ruby Range are confined to dolomitic marble within this largely metasedimentary sequence. The Dillon Granite Gneiss, a large mass of locally pegmatitic quartzofeldspathic gneiss, is exposed to the southeast. Rb-Sr dating showed that these rocks originally were metamorphsed about 2,750 m.y. ago (James and Hedge, 1980), and K-Ar dating showed that a later thermal event occurred about 1,600 m.y. ago (Giletti, 1966). In the northern part of the range, Mesozoic and Paleozoic sedimentary rocks overlie the Archean rocks (Tysdal, 1976a, b). In the wilderness study area, only about 13 km^2 of metamorphic rocks are exposed, representing about 20 percent of the wilderness study area. Marble, the potential host for talc, is exposed over about 5 km^2 (7.5 percent) of the wilderness study area.

DEPOSIT MODEL FOR TALC

Method of formation

All known talc deposits in southwestern Montana are replacement bodies in dolomitic marble of Archean age (Olson, 1976; Berg, 1979). The most likely reaction for the formation of most of this talc is as follows:

$$3 \text{ dolomite} + 4 \text{ quartz} + H_2O = \text{talc} + 3 \text{ calcite} + 3\ CO_2$$

The occurrence at several localities within the study area of quartz boudins in dolomitic marble surrounded by talc rinds less than 1 cm thick is best explained by the above reaction. Further evidence for the formation of talc by this reaction is the occurrence of talcose layers in dolomitic marble where the talcose layer consists of a mixture of talc and calcite. Because quartz is a minor constituent of dolomitic marble in southwestern Montana, only rarely approaching the 32 volume percent required for this reaction, both H_2O and SiO_2 must have been added to the dolomitic marble to produce talc. Talc was formed after the metamorphism of carbonate sedimentary rocks to dolomitic marble. This is shown by the alteration of metamorphic minerals such as forsterite to serpentine, tremolite to talc, sillimanite to sericite, and feldspars to sericite in rocks adjacent to talc deposits. Because talc formed after amphibolite-grade metamorphism that affected the quartzofeldspathic gneiss, the protolith of this gneiss, if igneous, must have crystallized before the reaction of silica-bearing fluids with dolomitic marble to form talc and thus could not have been a source of these fluids as was suggested by Olson (1976, p. 113). The gneiss may have been the source of at least some of the silica required to form talc. Perhaps meteoric water, heated during its movement through the sequence of metamorphic rocks, dissolved silica from these rocks and then reacted with the dolomitic marble to form talc.

Many of the talc deposits in southwestern Montana are situated close to the contact between dolomitic marble and either quartzofeldspathic gneiss or schist. Adjacent to such deposits feldspar in the quartzofeldspathic gneiss was altered to sericite, more rarely to chlorite, and where sillimanite was present this mineral was altered to sericite. At some deposits intense alteration of the quartzofeldspathic gneiss formed rock that is mainly chlorite. Magnesium required in the replacement of quartzofeldspathic gneiss by chlorite could have been derived from the dolomitic marble.

A minor amount of talc in southwestern Montana has been formed by the replacement of tremolite as inferred by the occurrence of talc pseudomorphs after tremolite at several localities (Berg, 1979, p. 11). Some tremolite within the study area has been replaced by coarse-grained talc which appears silvery in bright sunlight. Several possible reactions can be suggested for this replacement, a likely possibility is the following:

$$\text{tremolite} + \text{dolomite} + H_2O + CO_2 = 2 \text{ talc} + 3 \text{ calcite}$$

Lithologic control

Host rock composition is the only recognized control on the occurrence of talc within the boundaries of the wilderness study area. Talc occurrences are limited to Archean marble of which three varieties have been recognized in the wilderness study area. The unique characteristics of each type are shown in table 1. Talc is most abundant in dolomitic marble designated Type III. Talc is less commonly found in Type II marble, which contains both dolomite and calcite; talc was not found in Type I marble, which lacks dolomite. South of the wilderness study area, in the central part of the Ruby Mountains, Garihan (1973a, p. 185) concluded that, with one exception, all talc occurrences are in one specific marble layer. In other areas of southwestern Montana individual marble units have not been traced over significant distances and thus talc occurrences cannot be correlated with specific units.

Structural control

No evidence of structural control of talc occurrences was found in the study area. The general strike of compositional layering in the Ruby Peak belt of marble is northwest to west with a steep northerly dip. This orientation is consistent within the Ruby Peak marble unit and also throughout the quartzofeldspathic gneiss exposed to the northeast and southwest. The best exposures of the marble are at Ruby Peak and along the ridges surrounding the peak. On a smaller scale, quartz layers and boudins in the Ruby Peak marble unit up to several tens of centimeters thick have been deformed locally into folds ranging from open to isoclinal, with the axial surfaces of the isoclinal folds subparallel to compositional layering of the enclosing marble. Folds are generally confined to individual compositional layers several meters thick within the marble. Within the wilderness study area talc concentrations were not found to be controlled by these folds. This contrasts with Garihan's (1973a, p. 188) observation in the central part of the Ruby Range, where he concluded that talc is associated with tight folds.

Concentrations of talc were not found near the high-angle faults that juxtapose Paleozoic sedimentary rocks against the Archean metamorphic units. On a ridge in the NW1/4 SE1/4 SE 1/4 sec. 8, T. 6 S., R. 5 W. (pl. 1), the marble has been brecciated and is veined with chalcedony, presumably along a fault. Talc was not found in the brecciated marble nor along the chalcedony veinlets. Examination of aerial photos failed to show linears that could be related to talc concentrations. This also contrasts with observations of Garihan (1973b, p. 164) in the central part of the range where he concluded that talc is concentrated along faults.

Age

Talc is unknown in the dolomitic formations of Paleozoic age in southwestern Montana, which suggests that the talc formed during the Precambrian, after the metamorphic event of 2,700 m.y. ago. Garihan (1973b) suggested that talc formation can be correlated with the 1,600-m.y.-old thermal event that affected the metamorphic rocks of southwestern Montana.

TALC OCCURRENCES

An estimated 80 percent of the observed talc occurrences are within Type III marble. Unlike the discolored talc chips found in the soil and scree, talc exposed in outcrop is pale green and waxy. Based on size and shape, the talc occurrences can be divided into three categories; veinlets, small pods, and conformable layers of talcose marble.

Table 1. Comparison of the three compositional varieties of marble

	Type I	Type II	Type III
Talc host rock	no	rarely	most commonly
Estimated relative abundance of this type	20%	50%	30%
Nature of outcrop	rounded	irregular with solution along joints	slabby and angular
Weathered surface	somewhat crumbly white to light gray	very crumbly brown to very dark brown	tan
Color on fresh surface	white	tan - calcite white; dolomite honey	white
Texture	granular	dolomite porphyroblasts surrounded by white calcite	granular
Grain size	2-10 mm	2-5 mm	2-7 mm
Layering	rarely recognizable	caused by variation in the abundance of dolomite from 25% to 95%; these layers 1 cm to 1 m thick some quartz layers and pods a few cm thick	quartz layers and boudins 10% of marble locally-overall quartz content <1%
Mineralogy	calcite	calcite (white) dolomite (honey) quartz graphite phlogopite (tan to pale green) diopside (green to white) forsterite (white) tremolite (colorless) spinel (green) grossularite (pale pink) apatite (aquamarine color) anthophyllite (brown to white) biotite (in quartz only) K-feldspar	dolomite (white) quartz graphite
Alteration	none	forsterite to serpentine rare chrysotile veinlets a few mm thick rare talc after tremolite very rare talc pods a few cm long Mn minerals coat quartz and calc-silicate layers	numerous talc veinlets and pods typically <30 cm thick

Veinlets range up to 1 cm thick and are scattered throughout the marble. At no locality was a concentration of veinlets found, but rather an individual veinlet would be found at one outcrop and then perhaps at another outcrop 0.5 km distant another veinlet would be found. Numerous blocks of marble in talus that contain a several millimeter-thick layer of talc on one side give evidence of numerous veinlets not seen in outcrop. Blebs or pods less than several centimeters long are also found scattered throughout Type III marble. These pods are not found in any significant concentration, except in the talcose layers described below.

Talcose pods or layers concordant to foliation of the marble contain most of the talc found in the wilderness study area. More than 50 percent, and perhaps as much as 70 percent, of all of the talc seen is in these layers, which are confined to Type III marble. Eight of these layers were found and two are described in more detail below. All eight have several features in common. With the exception of one occurrence (locality 2, described below) they are traceable for no more than 2 m along strike, typically pinching out at both ends. Thickness ranges from 3 to 60 cm and estimated talc content ranges from 5 to 90 percent. Most of these layers contain calcite and less abundant dolomite. In one occurrence quartz and calcite are mixed with talc. Transparent, coarse-grained dolomite with individual grains 10 to 15 mm across forms the core of one talcose pod. A large pod of talcose marble is exposed in the cliffs on the south side of the ridge in the SW1/4 SE1/4 SW1/4 sec. 8, T. 6 S., R. 5 W. (pl. 1). This pod is 4 by 4 by 2 m and is estimated to contain 5 to 10 percent talc in dolomitic marble.

Locality #1

A very shallow prospect pit (locality 1, pl. 1) 30 cm deep by 1 m by 0.5 m was excavated in a saddle on the ridge south of Ruby Peak. This pit is at an elevation of 2820 m (9,240 ft) in the NW1/4 NW1/4 SW1/4 sec. 16, T. 6 S., R. 5 W. (This section is state owned). Bedrock is not exposed in this pit, but abundant pieces of talc 5 to 20 cm long indicate a concentration of talc in the marble. The talc weathers bluish green. Within a distance of several meters to the south, many small talc pods (less than 10 cm long) occur within an exposure of Type III marble. The attitude of the compositional layering in this marble is N 50° W, 40° NE. A conformable layer about 1 m thick of a mixture of talc, chlorite, and quartz is exposed approximately 2 m along strike to the northwest from the prospect. This layer is covered at the southeast end and pinches out at the northwest end. Talc float is abundant for several tens of meters on the slope to the northwest. A rock consisting of a mixture of chalcedony, dolomite, and talc, some with the texture of weathered bone, also was found in float approximately 50 m northwest of the concentration of talc. On the basis of the abundance of talc float in this area it is surmised that there are abundant talc pods or layers within the dolomitic marble in this saddle.

Locality #2

At Locality #2 (pl. 1) a poorly exposed talcose layer occurs on the west slope of Ruby Peak. It is at an elevation of 2650 m (8,700 ft) in an area of scattered trees in the NW1/4 SE1/4 NE1/4 sec. 17, T. 6 S., R. 5 W. Types II and III marble are interlayered and strike N 68° W, and dip 45° NE. The conformable talcose layer, which is 2 m thick and extends for approximately 25 m along strike, is in Type III marble. Barren marble of Type III is exposed northeast of the pods and soil covers the layer to the northwest. The sequence surrounding this occurrence (from southwest to northeast) is Type III marble; Type II marble poorly exposed for several meters; talc layer in Type III marble; Type II marble layer 0.5 m thick; and finally Type III marble. Talc was not found in the Type III marble exposed either above or below the talc-bearing layer. On the basis of loose blocks of talc, this 2 by 25 m area either is a single body of talc or, more likely, an area in which the dolomitic marble has been largely replaced by talc. As is typical in southwestern Montana, frost action has caused the fracturing of talc to form small chips, thus the talc is not as well exposed as the surrounding marble.

ASSESSMENT CRITERIA

Exposures of marble were examined for talc; soil, scree, and talus were also searched for chips of talc and fragments of talc-bearing marble. Total traverse distance within areas underlain by marble was 30 km for a traverse density of 6 km/km^2 of marble. Talc fragments can be readily recognized in the scree below steep cliffs, which themselves could not be examined directly for talc. In several places where talc chips were unusually abundant, the concentration of talc could be traced uphill to a source vein or pod. Although talc fragments are typically dark colored because of a coating of iron and manganese minerals, they are easily recognizable by their smooth surface and ease with which they can be scratched with the fingernail. The amount of discoloration of the talc fragments gives a crude indication of the distance that the talc has traveled from its source. In general talc fragments less than several meters from their source are pale green and free of discoloration.

Searching for talc float on north-facing slopes is much less effective because of sparse outcrops, thick soil, and vegetation. Game trails and the soil disturbed by uprooted trees offered the best opportunities for recognizing talc pieces in these areas. Only talc fragments greater than 2 cm could generally be identified in the soil on the north-facing slopes, in contrast to fragments less than 1 cm across that are easily recognized on open slopes below cliffs.

Contacts of the marble with quartzofeldspathic gneiss were examined for talc and talc float, because at both the Beaverhead and Treasure Mines (10 km southwest of the wilderness study area) talc occurs in dolomitic marble adjacent to its contact with gneiss or schist. Talc float was not found in any significant concentration along these contacts in the wilderness study area.

Areas of silicification were examined because of the possible reaction of silica with dolomitic marble to produce talc. Chalcedony veinlets occur in the NW1/4 SE1/4 SE1/4 sec. 8, T. 6 S., R. 5 W. (pl. 1), where marble was brecciated, but were only rarely found elsewhere. With the exception of locality #1, no talc was found closely associated with these veinlets. At this locality a concentration of chalcedony float was found 50 m northwest of the talc occurrence.

Igneous intrusives offer another possible source of silica-bearing fluids. The only indisputable igneous intrusive in the wilderness study area is a diabase dike, of probable Precambrian age. The dike intruded both quartzofeldspathic gneiss and marble near the western contact between Archean metamorphic rocks and Paleozoic sedimentary rocks. Talc float was found in the vicinity of the dike, but there is no evidence of an increase in concentration of talc adjacent to the dike. The precursors of the quartzofeldpathic gneiss and amphibolite within this area are not known.

Geochemical methods have not met with success in talc exploration in southwestern Montana and were not attempted in this study. A preliminary investigation of the possibility of using the fine-size fraction of stream sediments as a method of reconnaissance talc exploration has met with limited success (Berg, 1979, p. 15, 16). In southeastern Pennsylvania, Blount and Spohn (1982) showed that the concentration of talc in the fine-size fraction of residual soil could be correlated with a known talc deposit. No published account of the application of this method to talc exploration in the northern Rocky Mountains is available and the method was not used in the wilderness study area.

ASSESSMENT OF TALC POTENTIAL

A concentration of talc occurrences may give indication of an area that has possibilities for a minable deposit. In the Greenhorn Range, 20 km southeast of the wilderness study area, talc occurrences are much more abundant in the southern half of the range where the only talc mine (now inactive) in the range is situated. Berg (1979, sheets 2 and 3) showed 43 talc occurrences in the range, most of which are talc chips in the soil. Although talc is exposed throughout the range, 33 of the 43 talc occurrences are in the southern part of the range. The density of talc occurrences in the southern part of the range is 5.8/km^2 of marble whereas in the northern part of the range it is 1.8/km^2. For the wilderness study area of the Ruby Range, no density concentrations were calculated. However, in the parts of the wilderness study area rated as having high mineral resource potential for talc, the density concentrations for talc occurrences are much greater than 5.8/km^2.

In the wilderness study area of the Ruby Range, the mineral resource potential for talc (classified according to the system of Goudarzi, 1984) ranges from low to high. High potential with level C of certainty (available information gives a good indication) is applied to three areas: (1) surrounding Ruby Peak (part of sec. 16, T. 6 S., R. 5 W.); (2) west of Ruby Peak (SE1/4 NE1/4 sec. 17, T. 6 S., R. 5 W.); and (3) a small area in the S1/2 of section 8, T. 6 S., R. 5 W. Because of sparse vegetation in all of these areas, they could be searched effectively for talc and on the basis of the aforementioned comparison to the Greenhorn Range, an area with similar bedrock, the concentration of talc occurrences in both of these areas must be considered anomalous.

The remainder of the large area underlain by marble in the belt of marble extending from Ruby Peak is rated to have moderate mineral resource potential with a level C certainty. The area is underlain by marble, in part dolomitic, and there are scattered occurrences of talc float. Bedrock is generally well exposed over much of this area.

The two isolated areas underlain by marble in the NE1/4 sec. 7 and NW1/4 sec. 8, T. 6 S., R. 5 W. (pl. 1) are rated to have moderate talc potential with level B of certainty (available information is suggestive) because they are underlain by marble that is poorly exposed. The ridge underlain by marble at the western boundary of the wilderness study area in the SW1/4 sec. 12, T. 6 S., R. 6 W. (pl. 1) is rated to have moderate potential with C level of certainty. The marble is well exposed and although talc float was not found within the wilderness study area, a small amount of talc float was found along this same layer 250 m west of the wilderness study area. Marble is exposed at the southeastern corner of the wilderness study area in the SE1/4 sec. 23 and SW1/4 sec. 24, T. 6 S., R. 5 W. (pl. 1). Because the area is underlain by marble, some of which is dolomitic, it is considered to have moderate mineral resource potential for talc; exposures of bedrock in this area are good and the level of certainty is judged to be C.

The remaining portion of the wilderness study area that is not covered by Mesozoic and Paleozoic strata is considered to have low mineral resource potential for talc because of lack of exposed Archean marble. The level of certainty for this judgment is C. Detailed mapping of the metamorphic rocks (Karasevich, 1981) failed to reveal other marble units within the wilderness study area, although poor exposures in some areas could conceal small bodies of marble, which may contain some talc.

The resource potential assigned to the individual areas of the exposed metamorphic rocks are based on geologic parameters that are useful only for rocks at or near the surface. Neither these parameters, nor geochemical and geophysical parameters, were considered useful to assess the likelihood of the occurrence of concealed talc resources. Hence, the favorability and certainty ratings apply only to those metamorphic rocks at or near the surface; the mineral resource potential for talc at depth in these areas may be lower or higher than that determined for exposed metamorphic rocks.

The mineral resource potential for talc in metamorphic rocks concealed beneath Mesozoic and Paleozoic strata is unknown, and the certainty is rated A: available information is not adequate for determination of the level of mineral resource potential. The existence and extent of marble beneath the cover of Mesozoic and Paleozoic strata are unknown, and the geologic parameters used to determine the mineral resource potential for talc are not useful in areas that are covered.

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DESCRIPTION OF MAP UNITS

Qu **Sediments (undivided) (Quaternary)**—Alluvium, colluvium, landslide deposits, and glacial deposits

Tb **Bozeman Group (Tertiary)**—Upper part of unit is conglomerate, present along both flanks of the Ruby Mountains; lower part is olive tuffaceous mudstone, siltstone, and sandstone

Tv **Volcanic rocks (Tertiary)**—Andesitic tuff breccia, lapilli tuff, and agglomerate; present only in one place on western flank of range

MzPz **Sedimentary rocks (Mesozoic and Paleozoic)**—Uppermost unit is conglomerate of the Cretaceous Beaverhead Group, present only locally along the western flank of the mountains; as much as a few hundred feet thick. Remainder of the sequence is about 5,000 ft thick and consists largely of limestone and dolomite, and minor clay shale. In descending order, the formations are the Mississippian Kibbey(?) Formation, Mission Canyon Limestone, Lodgepole Limestone; Mississippian and Devonian Three Forks Formation; Devonian Jefferson Formation; Cambrian Red Lion Formation, Pilgrim Dolomite, Park Shale, Meagher Limestone, Wolsey Shale, Flathead Sandstone

Agn **Metamorphic rocks (Archean)**—Largely biotite- and hornblende-quartzofeldspathic gneiss; includes local units of amphibolite gneiss; microcline-quartz Dillon Granite Gneiss; and, in the southeasternmost part of the map, magnetite banded iron-formation and associated ultramafic rocks

Am **Marble (Archean)**—White to pale-brown fine- to coarse-grained calcitic and dolomitic marble

CORRELATION OF MAP UNITS

Qu — QUATERNARY

unconformity

Tb, Tv — TERTIARY

unconformity

MzPz — MESOZOIC AND PALEOZOIC

unconformity

Am, Agn — ARCHEAN

CONTACT

U/D FAULT—U, upthrown side; D, downthrown side; dotted where concealed

ANTICLINE—Showing trace of axial plane, direction of dip of limbs, and plunge of axis

SYNCLINE—Showing trace of axial plane, direction of dip of limbs, and plunge of axis

OVERTURNED ANTICLINE—Showing trace of axial plane, direction of dip, and plunge of axis

OVERTURNED SYNCLINE—Showing trace of axial plane, direction of dip, and plunge of axis

45/ STRIKE AND DIP OF BEDDING

65/ STRIKE AND DIP OF FOLIATION

2× TALC LOCALITY DISCUSSED IN TEXT

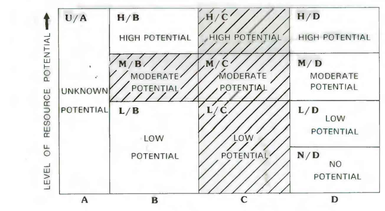
• LOCALITY OF TALC FLOAT OR MINOR OCCURRENCE OF TALC

EXPLANATION OF MINERAL RESOURCE POTENTIAL

Geologic terrane having high resource potential (talc, certainty level C)

Geologic terrane having moderate resource potential (talc, certainty levels C and B)

L/C **Geologic terrane having low resource potential for talc in Archean rocks**—Applies to entire study area except as shown above



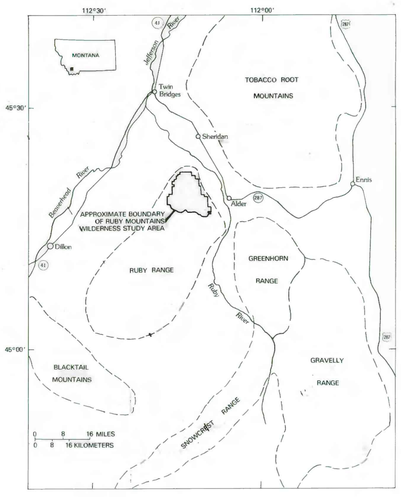
LEVELS OF RESOURCE POTENTIAL

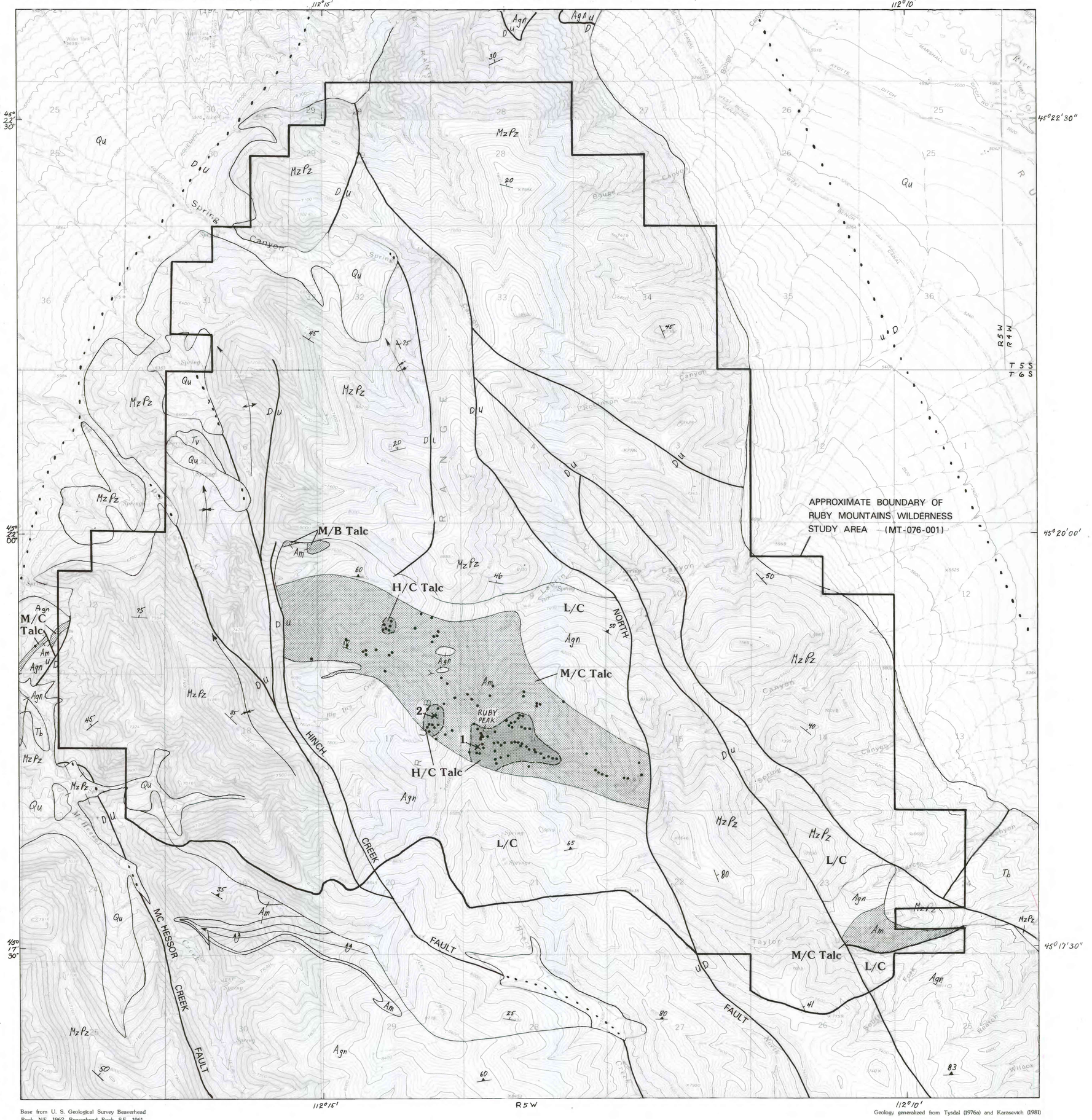
H High mineral resource potential
M Moderate mineral resource potential
L Low mineral resource potential
U Unknown mineral resource potential
N No known mineral resource potential

LEVELS OF CERTAINTY

A Available data not adequate
B Data indicate geologic environment and suggest level of resource potential
C Data indicate geologic environment, give good indication of level of resource potential, but do not establish activity of resource-forming processes
D Data clearly define geologic environment and level of resource potential and indicate activity of resource-forming processes in all or part of the area

Diagram showing relationships between levels of mineral resource potential and levels of certainty. Shading shows levels that apply to this study area





Base from U. S. Geological Survey Beaverhead Rock, NE., 1962, Beaverhead Rock, S.E., 1961, Laurin Canyon and Sheridan, 1963

Geology generalized from Tysdal (1976a) and Karasevich (1981)

SCALE 1:24 000

1 ½ 0 1 MILE

1 .5 0 1 KILOMETER

POTENTIAL FOR TALC DEPOSITS WITHIN THE BLM WILDERNESS STUDY AREA OF THE NORTHERN PART OF THE RUBY RANGE MADISON COUNTY, MONTANA

By

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1987

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.