

THE CHEMISTRY AND METASOMATIC ORIGIN OF THE TALC DEPOSITS OF THE RUBY RANGE, SOUTHWESTERN MONTANA

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INTRODUCTION

The Archean marbles of southwestern Montana have been the primary domestic source of steatite grade talc for many years (Berg, 1979). Many studies have been completed over the past several decades in order to better understand the geology and, more specifically, the talc mineralization of this area (Garihan, 1973; Berg, 1979; Anderson and others, 1990). Despite the considerable amount of work on these deposits, very little has been published about the chemistry of the talc and the subsequent metasomatic fluids. Therefore, my project centered on the collection and analysis of talc and marble specimens from seven mines and prospects in the Ruby Range (Figure 1). The primary goals of the chemical analyses were to characterize the chemical homogeneity of the talc deposits and the chemical make up of the metasomatic fluids.

OBSERVATIONS AND TECHNIQUES

Specimen Collection, Petrography and X-ray

Over one hundred specimens of talc and carbonate were collected from the Crescent Ranch Mine (1), the Smith-Dillon Mine (2), the Sweetwater Mine (3), the American Chemet Mine (4), the Regal-Keystone Mine (5), the Cottonwood Creek prospect (6), and the MP prospect (7) (Figure 1). The talc and unaltered carbonate specimens were collected in close association with each other to bracket the chemistry of the metasomatic fluids. Petrographic analysis of several talc and marble specimens was undertaken to effectively correlate collected chemical data with specific mineral assemblages. The thin sections studied were principally talc and carbonate. The majority of the carbonate is dolomite; however, the mineralogy varies from calcite to magnesite. Graphite is also common in both the talc and marble. Many of the specimens also contained sparse amounts of iron oxide and pyrite. X-ray diffraction of some of the samples was required to discern the individual mineral components of some cryptocrystalline talc specimens. Chlorite and a ten-angstrom mica, possibly phlogopite, were identified in the x-ray analysis.

Microprobe

Several different methods have been employed in the analysis of mine and prospect samples. The electron microprobe at Texas A+M University was used to obtain chemical traverses on several thin sections of talc and carbonate. The traverses across the microscopic boundary between the talc and carbonate indicated no consistent chemical patterns. The boundary was occasionally observed as a well defined, jagged segregation (Figure 2), but typically as a zone of gradation over a distance of fifteen microns. Many of the same relationships that were evident in petrographic thin section were also encountered during microprobe analysis. The chemistry of the talc was similar throughout the several thin sections sampled (Figure 3). The talc is relatively pure $Mg_3Si_4O_{10}(OH)_2$ with minor amounts of Al, Fe, and Mn. The talc also contained trace amounts of F but virtually no Cl. Anderson and others (1990) proposed sea water (saline solutions) as the source of the metasomatic fluids in the Ruby Range. Oxygen isotope data collected by Amy Larson and Angela Vasquez support this theory. However, the very low halide concentrations found in the talc contest the involvement of saline solutions.

A few dolomite remnants found in a talc matrix did exhibit slightly higher Ca/Mg ratios, evidence of a depletion of Mg in the marble during the talcification process. Back-scatter electron images of the carbonate also exhibited high concentrations of Fe, locally up to 3 wt.%. However, this observation was rare and the Fe concentration apparently did not alter the chemistry of the adjacent talc.

A series of reddish cryptocrystalline talc specimens collected at the Sweetwater Mine were found to contain significant amounts of K and Al with minor levels of Mn. Based on stoichiometry, the levels of K and Al indicated the presence of the mineral muscovite or sericite. Analysis of a blue cryptocrystalline mineral collected from the same location indicated the presence of Ca and P which stoichiometrically indicates the existence of apatite. The occurrence of the reddish mineral is common only to the Sweetwater Mine and might represent altered gneiss. Apatite is commonly found in several mines and prospects, in

to clarify much of the microcrystalline and altered minerals present within the thin sections. This work is currently in progress, but some clarification has already been achieved. Cathodoluminescent petrography was utilized on a reconnaissance scale in the hope that it would reveal primary textures that were not noticeable otherwise. This type of analysis proved most useful in accenting or highlighting features already revealed by the staining and standard petrographic analysis.

Discussion

Two broad distinctions have been noted so far in the composition of the marbles. In general, the marbles associated with the talc bodies are dominantly composed of dolomite, with minor calcite, talc, phlogopite, and graphite. The calcite which is observed in the dolomite occurs as tiny disseminated grains throughout the dolomite matrix. In many cases, the disseminated calcite is so fine that it only manifests itself in the form of a pinkish stain in the otherwise clear or bluish-stained dolomite. The assumption that the pinkish stains represent finely dispersed calcite within large dolomite crystals has been initially verified with an EDAX-equipped scanning electron microscope at Amherst College. This type of texture has been interpreted as unmixing of dolomite with excess calcium at temperatures above the normal stability of dolomite. As the dolomite reformed, it incorporated this excess calcium in the form of tiny disseminated calcite grains into its structure. Reaction rims of calcite around talc blebs in the dolomitic talc-marbles were also noted. This indicates that as the talc formed within the dolomite, the Mg^{++} was removed, leaving a reaction rim of calcite. This was also observed in the field at the Regal-Keystone Mine, where a talc body tens of meters across was separated from the surrounding dolomite by a calcitic, phlogopite-rich layer of marble approximately one meter thick.

The other general type of marble which was observed in thin-section was a calcite-rich marble with phlogopite, dolomite, forsterite, tremolite and apatite (distinguished by cathodoluminescence). Many examples of coarse exsolution lamellae of dolomite within the calcite crystals were observed, indicating unmixing from a higher grade mineral assemblage. This was also observed by Anderson, et al. (1990), who also noted that the higher grade calcite marbles were usually unaltered marbles not directly associated with the talc deposits. They interpreted these marbles to be the original Archean carbonate which was later dolomitized and selectively replaced by talc. However, most of the unaltered, non-talc-associated marble which I collected in the field proved to be mainly dolomite with only minor calcite scattered throughout it, as described previously. This was determined both by the staining of the thin sections, as well as by the X-ray diffraction analysis which has been performed so far.

Much of the mineralogy, particularly the silicates, within the marbles is so fine-grained that identification by petrographic means is difficult to impossible. This is particularly true in the differentiation of talc, serpentine, and chlorite. Thus, work is currently in progress to dissolve the carbonate out of some of these samples in order to identify the silicate minerals with X-ray diffraction. Until the precise silicate mineralogy is known, interpretation of the history of dolomitization will be uncertain at best. However, initial results indicate the likelihood of Archean dolomite, and thus a more complicated story than put forth by Anderson, et al. (1990).

References

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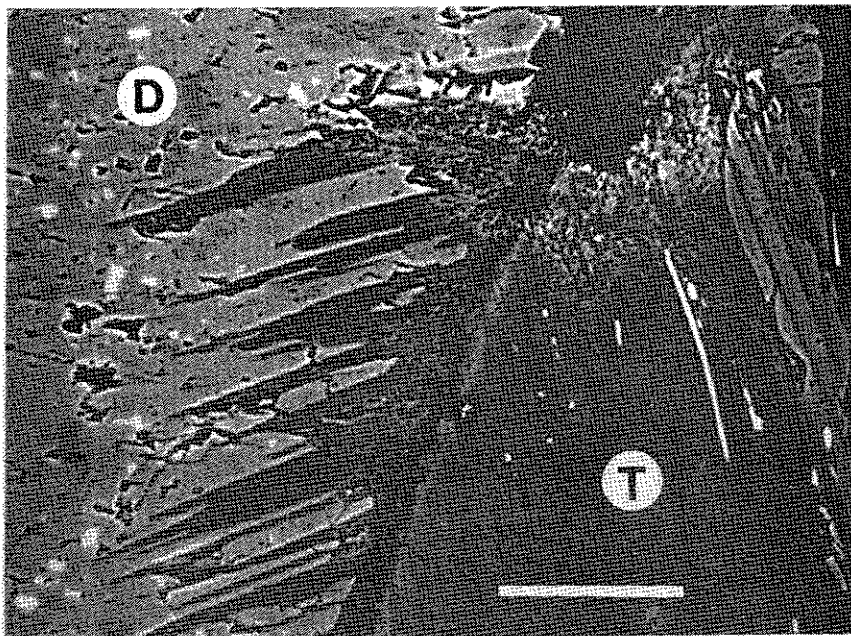
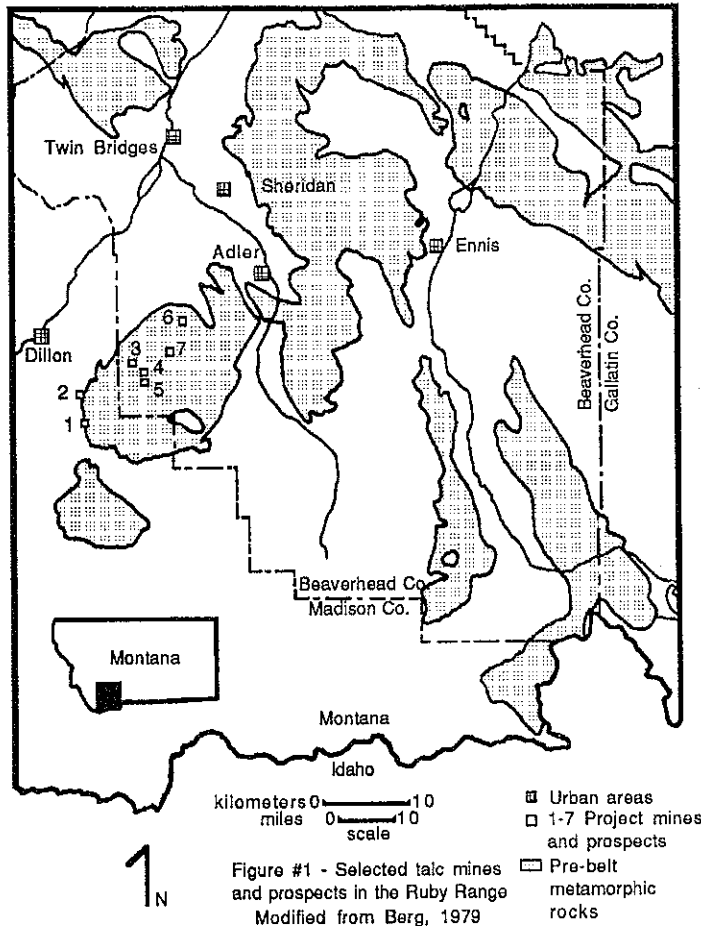


Figure 2
 Jagged separation of talc and dolomite from American Chemet Mine-21
 T=talc D=dolomite
 bar scale equals 50 microns

Carbonate	Mg	Ca	Mn	Fe					Total*
#1	43.3	53.1	0.5	1.7					98.6
#2	42.4	54.2	0.5	1.6					98.7
#3	43.3	53.2	0.5	1.5					98.5
Talc	Mg	Ca	Mn	Fe	Al	Si	F	Cl	
#1	31.2	0.1	0.0	0.2	0.5	62.0	0.2	0.0	94.2
#2	31.4	0.1	0.0	0.3	0.3	62.9	0.1	0.0	95.1
#3	31.2	0.0	0.0	0.3	0.3	62.1	0.1	0.0	94.0

Figure 3
 Microprobe chemical data from American Chemet Mine-20
 Talc data in wt% oxide (except F and Cl) and Carbonate data in wt% CO₃
 * values do not include H₂O

Specimens	Cr	Be	Ce*	Ni	Sr	V	Zr
Carbonate							
CC-Avg	8	1.8	12	13	42	6	7
MP-19	9	1.7	12	10	44	7	9
AC-Avg	8	1.6	16	8	26	4	0
Talc							
CC-Avg	3	1.7	9	19	5	5	5
MP-9	10	1.6	4	48	2	10	22
AC-Avg	14	1.9	20	24	2	10	31
AC-16	2	4.3	50	21	3	19	60
SW-Avg	3	1.6	2	12	2	6	48
SD-2B	4	1.7	6	25	2	7	9

Figure 4
 Talc and carbonate trace element data (ppm)
 * Chondrite normalized

both the unaltered marble and talc rock. However, the Sweetwater mine contains the only large amounts of apatite found in the specimens collected.

ICAP

Major and trace element data for thirty-three talc and carbonate specimens was collected using Beloit College's Inductively Coupled Argon Plasma spectrometer. Initial attempts to obtain major element data with the ICAP proved unsuccessful due to improper calibration of the machine. However, the trace element data obtained were very accurate. The abundance of all the trace elements analyzed was low but aid significantly in understanding the chemistry and origin of the metasomatic fluids involved in the talcification process. Many of the trace elements analyzed showed obvious changes in concentrations between the marble and talc specimens (Figure 4). The addition of Zr, Ce, and V to the marble in the process of making talc must have occurred, either by contamination from the interlayered gneiss or primary fluids, since the increase is beyond that which might be expected from a concentration during a volume change following complete metasomatic alteration. The densities of dolomite and talc are very similar (2.85 g/cm³ and 2.7-2.8 g/cm³ respectively). This similarity in densities limits the concentration of trace elements possible during metasomatism. The concentration of Be in both the marble and talc specimens remained relatively constant in the mines and prospects sampled. This data represent the best chemical confirmation that no large volume change occurred between the marble and talc during metasomatism. The lack of expansion fractures or voids during petrographic analysis of the partially altered marbles has also confirmed that a large volume modification as a result of the metasomatic process did not transpire.

A series of Archean gneisses is commonly found interlayered with the Archean marble of the Ruby Range (Anderson and others, 1990). The dark-green chloritic-talcs found in close proximity to many talcified marbles is thought to be the altered remnants of the interlayered gneiss. The American Chemet Mine has several of these altered gneiss units present. Chemical analysis of the altered gneiss reveals high trace element concentrations (Figure 4 AC-16). Pure talc samples from the American Chemet Mine similarly exhibit a relatively high concentration of some trace elements compared to the pure talcs specimens from the Ruby Range (Figure 4 AC-Avg). One explanation for the high trace element concentrations in the talc of the American Chemet Mine is the presence of the altered gneiss.

CONCLUSION

The composition of the fluids are important if the metamorphic history of the area is to be attained. Without major element data, it is difficult to ascertain the exact composition and mass-transfer capabilities of the system. However, the trace element data suggest several important possibilities that must be considered. First, the F and Cl concentrations in the talc are low enough to challenge whether the metasomatic fluids were saline, which is the predominate theory (Anderson and others, 1990). Second, the comparison of trace element concentration between the talc and the unaltered marble indicates a substantial difference, thus reflecting the trace element chemistry of the fluids. The high concentration of Cr, Ce, and Zr in talc specimens from the American Chemet Mine suggests a plausible contribution from the altered gneiss closely associated with the talc. The consistent concentration of Be throughout the Ruby Range in both marble and talc samples is chemical evidence that no large volume change occurred during the talcification process.

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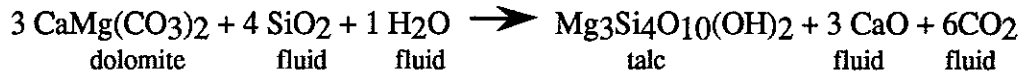
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TALC FORMATION IN THE REGAL-KEYSTONE MINE OF THE RUBY RANGE, DILLON, MONTANA

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Introduction:

Proterozoic talc deposits have been reported across the Ruby Range of southwestern Montana in dolomitic marbles of Archean age. The dominate process governing talc formation is the replacement of dolomite by talc. James (1990) postulates that the addition of silica in solution, under correct pressure and temperature, to a dolomitic marble produces talc, calcium oxide, and carbon dioxide. The process can be described by the following reaction:



Previous studies suggest hydrothermal fluids to be the agent of this talc forming process (Berg, 1979; Anderson, Mogk, and Childs, 1990; James, 1990).

The purpose of this study is to learn as much as possible about the Regal-Keystone talc mine in order to constrain possible models of talc forming processes at this site. Understanding the formation of the talc bodies in the Regal-Keystone mine may offer insight into the formation of other talc deposits across the Ruby Range.

Description of Study Area:

The Regal-Keystone talc mine, owned by Pfizer, Inc., is located approximately 11 miles southeast of Dillon, MT on the Christensen Ranch quadrangle (NW1/4, NE1/4, and NE1/4, NW1/4, sec. 2, T. 8S., R.7W) of the Ruby Range (Olson, 1976). Structurally, the mine is located in a synformal marble unit, the axis of which is oriented northeast/southwest with its nose to the southwest. The mine area consists of an open-pit mine, approximately 150 meters long and 15 to 35 meters wide, and twenty trenches that range in length from about 15 to 50 meters (Figure 1)

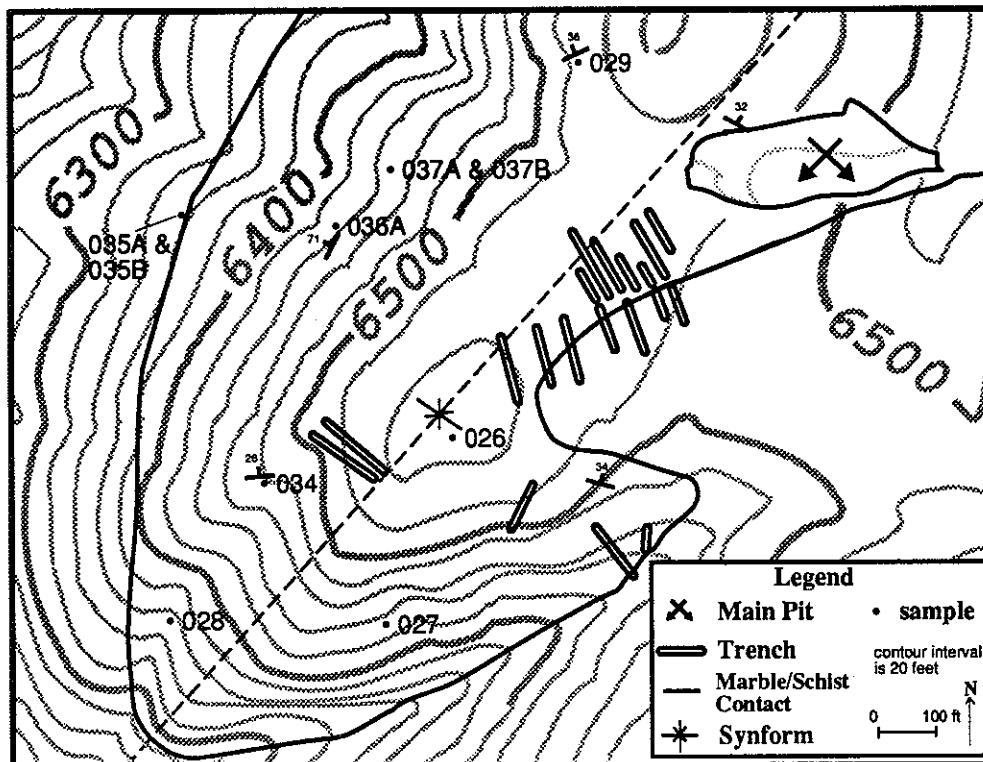


Figure 1: Topographic sketch map of Regal-Keystone Mine study area with pit and trenches (adapted from James, 1990).