



Timing and mechanism of formation of selected talc deposits in the Ruby Range, southwestern Montana
by Dale Lewis Anderson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Earth Sciences
Montana State University
© Copyright by Dale Lewis Anderson (1987)

Abstract:

The mechanism of formation of talc deposits in Archean dolomitic marbles of southwestern Montana is not well understood. This study examines the mineralogy, chemistry, and structure of selected talc prospects with the purpose of developing a model for talc formation in these dolomitic marbles.

Detailed field mapping and petrography yields a paragenetic sequence with three periods of mineral formation, designated M1, M2, and M3. M1 is characterized by amphibolite-grade assemblages in calcitic marbles. M2 resulted in dolomitization and greenschist-grade silicate assemblages overprinting M1 assemblages. M3, the last step in the paragenetic sequence, resulted in formation of talc from dolomite and all greenschist-grade silicate minerals (with the exception of chlorite) present.

Structural control of talc formation is suggested by discontinuous occurrences of talc bodies. Layer-parallel fracturing is indicated by the orientation and morphology of talc bodies, and by the lack of cross-cutting structures which can be related to talc formation.

Geochemical analyses and mass balance calculations demonstrate that talc bodies did not form by isochemical alteration of high-grade or talc-bearing marbles. Infiltration of large quantities of SiO₂ and Mg⁺⁺ is indicated, with concomitant removal of Ca⁺⁺. Infiltration is supported by the absence of isobaric univariant mineral assemblages, indicating that mineral parageneses did not buffer the talc-forming reaction.

Preservation of millimeter-to centimeter-scale relict textures suggests constant volume replacement during talc formation. Mass balance calculations show that alteration of 1 m³ of dolomite to form talc, while conserving volume, requires addition of 1,764 kg of SiO₂ and 157 kg of Mg⁺⁺ to the system, with concomitant removal of 1,556 kg of calcite. A minimum fluid flux of 7.05 x 10⁵ liters is indicated for each cubic meter of dolomitic marble that was altered to talc.

Field and mineralogic relationships constrain timing of talc formation. A Proterozoic, post-greenschist, pre-Paleozoic age is indicated.

Field relationships, mineral parageneses, marble and talc geochemistry, mass balance determinations, and the tectonic history of the study area are all consistent with formation of talc in a near surface hot springs environment. Maximum temperature and P_{fluid} indicated is 450° C and 2 kbar.

TIMING AND MECHANISM OF FORMATION OF SELECTED TALC
DEPOSITS IN THE RUBY RANGE, SOUTHWESTERN MONTANA

by

Dale Lewis Anderson

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Earth Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

March, 1987

MAIN LIB.
N378
An 214
Cop. 2

ii

APPROVAL

of a thesis submitted by

Dale Lewis Anderson

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

3/24/87
Date

Dave W. Maple
Chairperson, Graduate Committee

Approved for the Major Department

3/24/87
Date

Stephen C. Coster
Head, Major Department

Approved for the College of Graduate Studies

March 30, 1987
Date

Henry L. Parsons
Graduate Dean

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his/her absence, by the Director of Libraries when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature Dale Anderson

Date March 24, 1987

ACKNOWLEDGEMENTS

I would like to thank David Mogk (Committee Chairman), John Childs, and David Lageson for suggestions and constructive criticism during preparation of the manuscript. Many thanks go to David Mogk and John Childs, who were particularly patient and helpful in the organization and inspection of the manuscript.

Funding for the study was provided by Cyprus Industrial Minerals Company (CIMC). CIMC also provided access to the prospects examined, and XRD analyses of selected samples. Howard Harlan of CIMC provided lodging during field work at the Metlan Annex in Dillon, Montana, as well as suggestions throughout much of the study. Andy Barth provided comments and insights during field work and early stages of the study. Michael Clark assisted with plane table mapping of the Sweetwater Mine. Rick Weeks and Robert Piniaskiewicz of Cyprus Minerals reviewed final drafts of the thesis. I thank Robert for bringing to my attention an error in the mass balance calculations, which had previously avoided detection.

Finally, I would like to thank my family, without whose support my education would not have been possible.

TABLE OF CONTENTS

	Page
LIST OF TABLES	viii
LIST OF FIGURES.....	ix
LIST OF PLATES.....	xi
ABSTRACT.....	xii
1. INTRODUCTION.....	1
Purpose and Scope.....	1
Background.....	2
Methods.....	3
Geologic Setting.....	5
2. FIELD RELATIONSHIPS AND PETROGRAPHY.....	9
Bosal Prospect.....	9
Introduction.....	9
High-Grade Marble.....	9
Talc-Bearing Marble.....	10
Dillon Gneiss.....	14
Structure.....	15
Summary.....	15
Ruby View Prospect.....	16
Introduction.....	16
High-Grade Marble.....	16
Serpentine-Bearing Marble.....	17
Talc-Bearing Marble.....	17
Summary.....	20
T.P. Prospect.....	20
Introduction.....	20
High-Grade Marble.....	21
Talc-Bearing Marble.....	22
Dillon Gneiss.....	24
Summary.....	25
Spring Creek Prospect.....	25
Introduction.....	25
High-Grade Marble.....	26
Talc-Bearing Marble.....	26
Structure.....	30
Summary.....	30

TABLE OF CONTENTS--Continued

	Page
Pope Prospect.....	31
Introduction.....	31
High-Grade Marble.....	31
Talc-Bearing Marble.....	32
Schists.....	34
Dillon Gneiss.....	35
Summary.....	35
Sweetwater Mine.....	36
Introduction.....	36
Marbles.....	36
High-Grade Marble.....	36
Talc-Bearing Marble.....	37
Gneisses.....	39
Introduction.....	39
Unaltered Gneiss.....	39
Slightly Chloritized Gneiss.....	39
Intensely Chloritized Gneiss.....	40
Structure.....	42
Discussion.....	42
Mineralogic and Textural Relationships.....	42
Structural Control of Talc Formation.....	44
Stratigraphic Controls on Talc Formation.....	45
3. WHOLE ROCK GEOCHEMISTRY.....	47
Introduction.....	47
Data.....	47
Discussion.....	48
Geochemistry of Gneisses.....	51
4. MASS BALANCE.....	53
Introduction.....	53
Isochemical Talc Formation.....	54
Metasomatism and Talc Formation.....	57
Estimates on Fluid Flux During Talc Formation.....	61
Discussion.....	61
Implications of Mass Balance Calculations.....	62
Sources of Silica and Magnesium.....	63
5. RELATIVE AND ABSOLUTE AGES OF TALC FORMATION.....	65
Relative Age of Talc Formation.....	65
Absolute Age of Talc Formation.....	65
Summary.....	68

TABLE OF CONTENTS--Continued

	Page
6. PHYSICAL CONDITIONS OF TALC FORMATION.....	69
Introduction.....	69
Pressure of Talc Formation.....	69
Temperature of Talc Formation.....	70
Introduction.....	70
Talc Stability Field.....	72
Summary.....	73
7. CONCLUSIONS.....	74
Timing of Talc Formation.....	74
Physical Conditions of Talc Formation.....	75
Mechanism of Talc Formation.....	76
Significance of Study.....	77
REFERENCES CITED.....	79
APPENDIX.....	85
Whole rock geochemical analyses.....	86

LIST OF TABLES

Table	Page
1. Summary of replacement reactions and diablatic intergrowths observed during petrographic analysis.....	11
2. Balanced reactions corresponding to replacement reactions Listed in Table 1.....	12
3. Normative mineralogy of high-grade marble calculated in terms of talc, dolomite, and calcite.....	55
4. Normative mineralogy of talc-bearing marble calculated in terms of talc, dolomite, and calcite.....	56
5. Mass balance calculations holding Mg^{++} constant and introducing all SiO_2 and H_2O necessary to form talc from 1 m ³ of dolomitic marble.....	58
6. Calculations showing total mass of SiO_2 and Mg^{++} added to dolomitic marble to conserve volume while altering marble completely to talc.....	60
7. Whole rock geochemical analyses of high-grade marble.....	86
8. Whole rock geochemical analyses of talc-bearing marble....	87
9. Whole rock geochemical analyses of talc.....	89
10. Whole rock geochemical analyses of gneisses.....	90

LIST OF FIGURES

Figure	Page
1. Regional location map showing the study area and outcrops of similar lithologies in southwestern Montana.....	2
2. Location map showing the Ruby Range, with locations of prospects examined.....	4
3. Diagram showing the paragenetic sequence determined for the Bosal Prospect.....	13
4. Photomicrograph showing exsolution lamellae in carbonates (dolomite exsolving from calcite).....	13
5. Diagram showing the paragenetic sequence developed for the Ruby View Prospect.....	18
6. Diagram showing the paragenetic sequence for the T.P. Prospect.....	23
7. Photomicrograph showing talc pseudomorphs after serpentine.....	23
8. Diagram showing the paragenetic sequence for the Spring Creek Prospect.....	28
9. Photomicrograph showing quartz altering to talc.....	30
10. Diagram showing the paragenetic sequence for the Pope Prospect.....	33
11. Photomicrograph showing talc pseudomorphs after dolomite, defined by color bands in talc.....	34
12. Diagram showing the paragenetic sequence developed for marbles at the Sweetwater Mine.....	37
13. Photomicrograph showing relict quartz ribbons which have been altered to talc, surrounded by chloritized feldspar.....	41
14. Photograph of relict gneissic texture in which quartz ribbons preferentially altered to talc wrap around a chloritized feldspar porphyroblast.....	41

LIST OF FIGURES--Continued

Figure		Page
15.	CaO-MgO-SiO ₂ ternary diagram showing high-grade marbles, talc-bearing marbles, and talc.....	49
16.	CaO-MgO-SiO ₂ ternary diagram showing fields occupied by high-grade marble, talc-bearing marble, and talc.....	49
17.	Temperature-pressure diagram showing serpentine-talc relationships.....	66
18.	Isobaric temperature-X _{CO₂} diagram showing the stability field of talc at P _{fluid} = 2 kbar.....	71

LIST OF PLATES

Plate		Page
1.	Geology of the Bosal Prospect.....	In pocket
2.	Geology of the Ruby View Prospect.....	In pocket
3.	Geology of the T.P. Prospect.....	In pocket
4.	Geology of the Spring Creek Prospect.....	In pocket
5.	Geology of the Pope Prospect.....	In pocket
6.	Geology of the Sweetwater Mine.....	In pocket

ABSTRACT

The mechanism of formation of talc deposits in Archean dolomitic marbles of southwestern Montana is not well understood. This study examines the mineralogy, chemistry, and structure of selected talc prospects with the purpose of developing a model for talc formation in these dolomitic marbles.

Detailed field mapping and petrography yields a paragenetic sequence with three periods of mineral formation, designated M₁, M₂, and M₃. M₁ is characterized by amphibolite-grade assemblages in calcitic marbles. M₂ resulted in dolomitization and greenschist-grade silicate assemblages overprinting M₁ assemblages. M₃, the last step in the paragenetic sequence, resulted in formation of talc from dolomite and all greenschist-grade silicate minerals (with the exception of chlorite) present.

Structural control of talc formation is suggested by discontinuous occurrences of talc bodies. Layer-parallel fracturing is indicated by the orientation and morphology of talc bodies, and by the lack of cross-cutting structures which can be related to talc formation.

Geochemical analyses and mass balance calculations demonstrate that talc bodies did not form by isochemical alteration of high-grade or talc-bearing marbles. Infiltration of large quantities of SiO₂ and Mg⁺⁺ is indicated, with concomitant removal of Ca⁺⁺. Infiltration is supported by the absence of isobaric univariant mineral assemblages, indicating that mineral parageneses did not buffer the talc-forming reaction.

Preservation of millimeter-to centimeter-scale relict textures suggests constant volume replacement during talc formation. Mass balance calculations show that alteration of 1 m³ of dolomite to form talc, while conserving volume, requires addition of 1,764 kg of SiO₂ and 157 kg of Mg⁺⁺ to the system, with concomitant removal of 1,556 kg of calcite. A minimum fluid flux of 7.05 x 10⁵ liters is indicated for each cubic meter of dolomitic marble that was altered to talc.

Field and mineralogic relationships constrain timing of talc formation. A Proterozoic, post-greenschist, pre-Paleozoic age is indicated.

Field relationships, mineral parageneses, marble and talc geochemistry, mass balance determinations, and the tectonic history of the study area are all consistent with formation of talc in a near surface hot springs environment. Maximum temperature and P_{fluid} indicated is 450° C and 2 kbar.

CHAPTER 1

INTRODUCTION

Purpose and Scope

This study is part of ongoing research on the physical and chemical controls and timing of talc formation in the Ruby Range, southwestern Montana (Figure 1). The purpose of this study is to determine the mechanisms of formation of talc bodies of economic size, as well as to develop a physicochemical model for talc formation. Towards this end talc deposits have been examined in detail in the Ruby Range. Based on techniques presented below, this study will address the following points:

- 1) Physical characteristics of each prospect examined;
- 2) Talc forming reactions identified by means of petrographic analysis;
- 3) Geochemistry of marbles, with determination of the nature of bulk compositional changes during talc formation;
- 4) Mass balance calculations incorporating field and petrographic observations will demonstrate the nature of materials which may have been added to, or subtracted from, dolomitic marbles during talc formation;
- 5) Evidence for metasomatism, based on field relations, petrographic analysis, mass balance calculations and whole rock geochemistry;

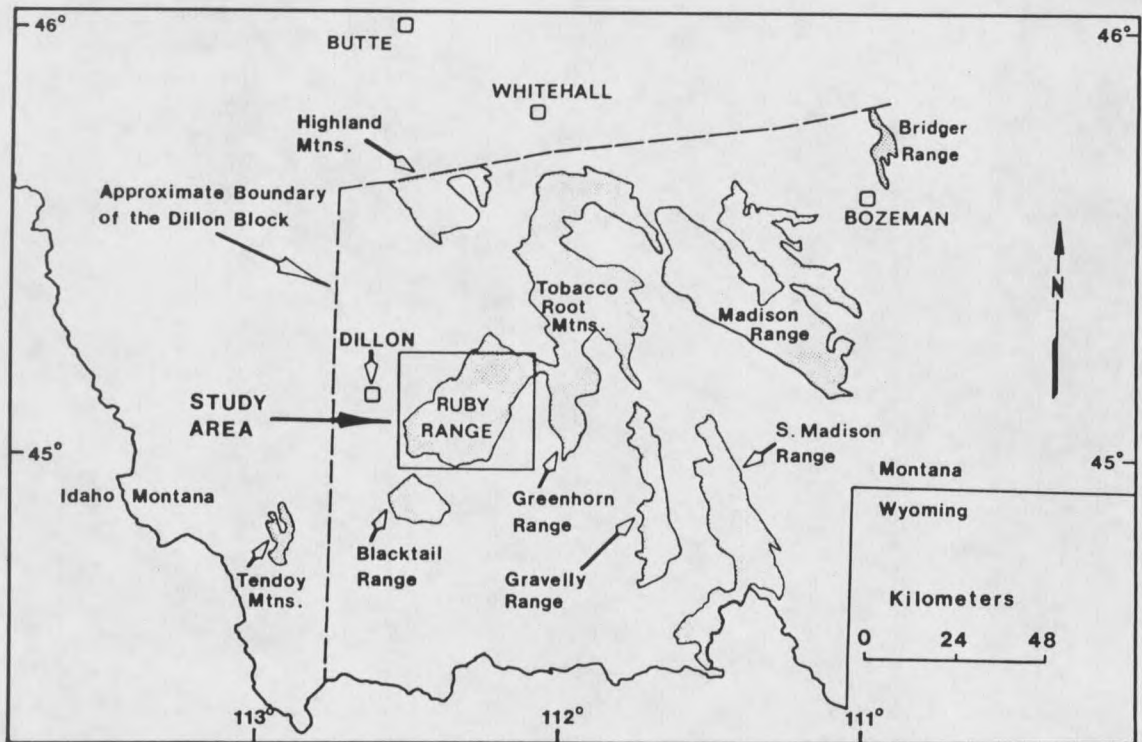


Figure 1. Regional location map showing the study area and outcrops of similar lithologies in southwestern Montana (modified from Bergantino and Clark, 1985).

- 6) Phase equilibria of the talc forming system and proposed temperatures of formation of talc;
- 7) Mechanism for formation of economic-sized talc bodies, and the inferred time of formation of such bodies.

Background

Formation of economically viable talc deposits is generally restricted to two geologic environments: 1) metamorphosed siliceous dolomitic carbonate rocks; and 2) altered ultramafic bodies. In the Ruby Range, metamorphosed dolomitic carbonate is known to be important

in talc formation; alteration of ultramafic bodies in the range has not been recognized as a mechanism for formation of minable talc bodies (Okuma, 1971; Desmarais, 1981).

Recognition of dolomitic marbles in the Ruby Range as the sole host rock for large talc deposits has resulted in several studies on the distribution and petrology of these units (Perry, 1948; Levinson, 1949; Heinrich and Rabbitt, 1960). Additional work has provided descriptions of many known talc deposits and prospects (Okuma, 1971; Garihan, 1973; Olson, 1976; Berg, 1979; Whitehead, 1979; Walton, 1981).

This study adds considerable information to this data base, including more detailed physical and petrographic descriptions of prospects studied. Also, this study results in the presentation of theories concerning talc formation which differ slightly from those developed in previous studies.

Methods

Field mapping on a scale of 1" = 5' or 1" = 10' of several talc-bearing prospects in the Ruby Range was carried out to determine mesoscopic controls on talc formation, such as compositional variations within host marbles, mineralogy, and structure. Prospects chosen for detailed examination provide three dimensional exposures of talc bodies and the relationships of talc bodies with surrounding marbles and gneisses. Also, these prospects were considered to be representative of areas with potential for talc formation of economic interest. The prospects examined during this study, shown in Figure 2, will be described in the following order: 1) Bosal Prospect; 2) Ruby View

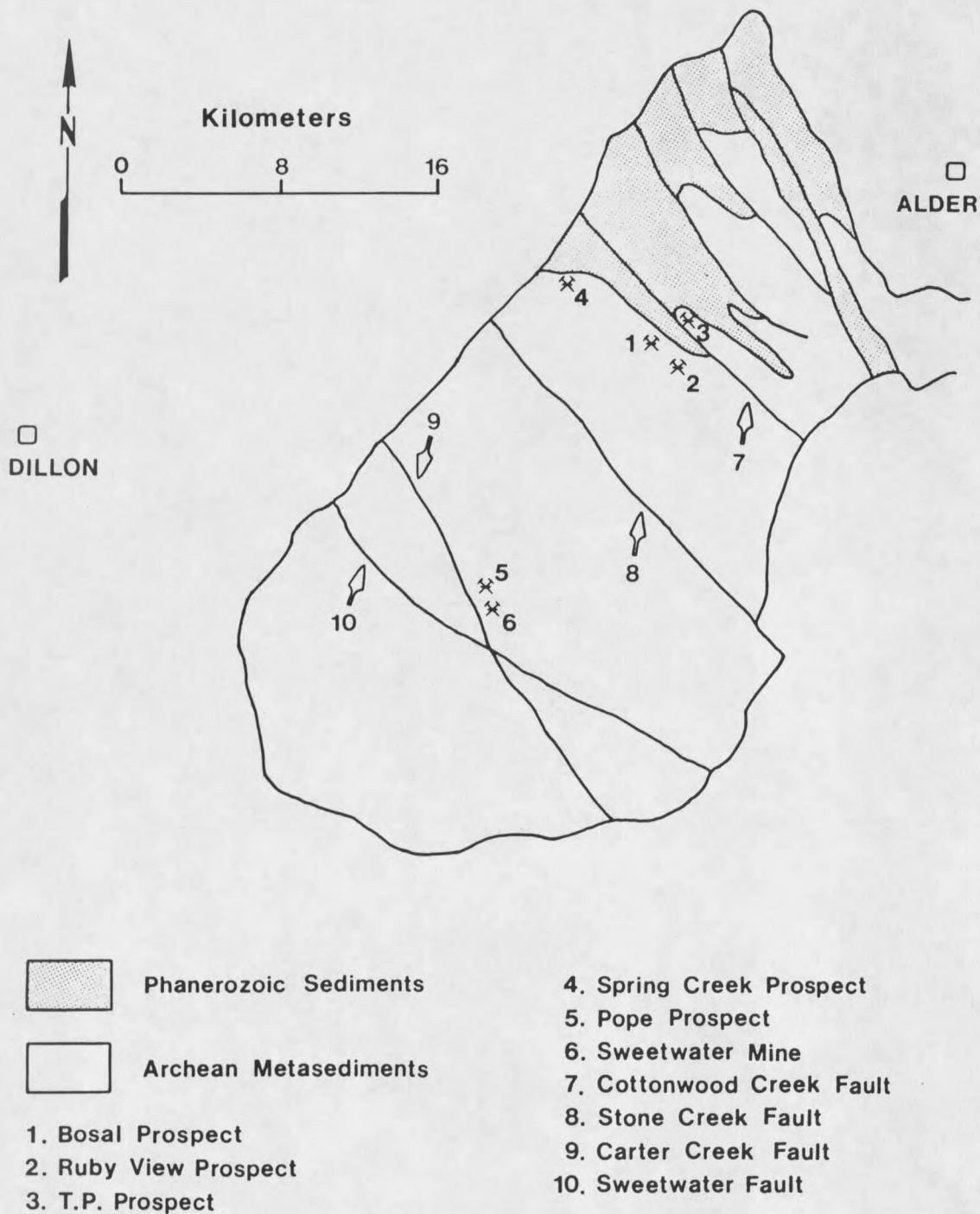


Figure 2. Location map showing the Ruby Range, with locations of prospects examined, and major northwest trending faults (modified from Schmidt and Garihan, 1986).

Prospect; 3) T.P. Prospect; 4) Spring Creek Prospect; 5) Pope Prospect; and 6) the Sweetwater Mine. All of the prospects examined are controlled by Cyprus Industrial Minerals Company (CIMC).

Samples collected during mapping were analyzed using standard petrographic techniques, as well as cathodoluminescence (CL) and ultraviolet (UV) microscopy, with two main goals: 1) determination of the talc-forming reactions; and 2) understanding the nature of talc-forming reactions within the context of the paragenetic sequence and thermal history of marbles being examined.

Samples were selected for whole rock geochemical analysis to determine chemical differences between talcose and non-talcose marbles. This information is necessary to evaluate the possible metasomatic processes which were active during talc formation.

Geologic Setting

In southwestern Montana, economically viable talc occurrences are restricted to Archean marbles exposed in late-Cretaceous-to Paleocene-aged block uplifts which have been modified by subsequent Basin and Range extension. Such lithologies occur in the Ruby, Tobacco Root, Gravelly, and Tendoy Ranges, among others (Berg, 1979) (Figure 1). All talc prospects examined during this study are located in marbles which have been correlated with the Cherry Creek Group (Heinrich and Rabbitt, 1960; Okuma, 1971; Garihan, 1973), as defined by Peale (1896), in the Gravelly Range, south of Ennis, Montana. This correlation has not been verified by geochronologic or geochemical data.

Previous investigators in the Ruby Range generally agree that the area underwent amphibolite-to granulite-grade, dynamothermal metamorphism (M_1), dated at approximately 2750 Ma. (Gilletti, 1966; Okuma, 1971; Garihan, 1973; James and Hedge, 1980). M_1 metamorphism produced the dominant foliation within the central and southern Ruby Range, which strikes northeast and dips to the northwest (Karasevich and others, 1981). Macroscopic folds associated with M_1 are isoclinal to tight, and axial surfaces strike northeast, and dip to the northwest. This style of folding is correlative with F_1 and F_2 folds of Okuma (1971) in the southern portion of the range, and F_1 and F_2 folds of Garihan (1973) in the central portion of the range. Deformation of isolated quartz pods and development of boudinage in gneiss and schist lenses within marble described herein is interpreted as having formed under these conditions. Timing of Okuma's F_3 event with respect to metamorphic conditions is unclear, but it is thought to have occurred under amphibolite-grade conditions due to a poorly developed axial planar cleavage (?) defined by alignment of hornblende and biotite in F_3 folds (Okuma, 1971).

A Proterozoic retrograde regional thermal event (M_2) resulted in overprinting of the amphibolite-grade assemblages by greenschist facies assemblages. No penetrative deformational features are associated with this thermal event. K-Ar dates place the timing of M_2 at about 1600 Ma. (Gilletti, 1966; Okuma, 1971; Garihan, 1973; Dahl, 1979; Desmarais, 1981).

Talc formation (M_3) occurred very late-to post-retrograde greenschist mineralization (M_2). It is important to point out that the

M₃ event may not represent a separate orogenic cycle; rather it may represent the final stage of M₂ recrystallization.

The major faults in the Ruby Range strike northwest (Figure 2), and have undergone recurrent movement since Proterozoic time (Schmidt and Garihan, 1983, 1986). Previous workers have suggested that talc formation is the result of fluid movement along these structures during the Proterozoic greenschist thermal event (Okuma, 1971; Garihan, 1973; Olson, 1976; Berg, 1979).

Contemporaneous with, and possibly prior to incipient rifting of the Belt Basin (1700 - 1500 Ma.), several generations of northwest trending mafic dikes intruded the area, probably along pre-existing fracture zones (Wooden and others, 1978). It has been postulated that these dikes may have been the source of heat and fluids for talc formation (Wooden and others, 1978). However, no apparent spatial relationship between mafic dikes and talc-bearing marble was documented during this study.

The Ruby Range and surrounding area (termed the Dillon Block by Harrison and others (1974))(Figure 1), has been interpreted as a positive tectonic feature during middle-to late-Proterozoic time, acting as the source area for clasts of Archean marble, gneiss and amphibolite in the LaHood Formation, which was deposited on the southern margin of the Belt Basin (McMannis, 1963; Boyce, 1975). Deposition of the LaHood Formation has been interpreted as marking incipient rifting of the Belt Basin (McMannis, 1963).

The northern-most portion of the Ruby Range is underlain by Phanerozoic sediments which have been subjected to Laramide style

deformation (Tysdal, 1976; Schimdt and Garihan, 1983). Most recently Basin and Range style extension has overprinted Laramide style deformation.

CHAPTER 2

FIELD RELATIONSHIPS AND PETROGRAPHY

Bosal ProspectIntroduction

The Bosal Prospect, controlled by CIMC, (Figure 2, SE 1/4 Sec.11 T7S R6W) is an isolated talc occurrence within a continuous marble band up to 20 meters thick. This marble band probably forms one limb of a tight to isoclinal fold, whose axial surface strikes northeast and dips steeply northwest. Compositional layering is defined in high-grade marbles by bands rich in Mg silicates, striking N 50-70° E and dipping 50-60° northwest. Centimeter-scale open folds and warps in layering are common. The geology of the prospect is shown in Plate 1.

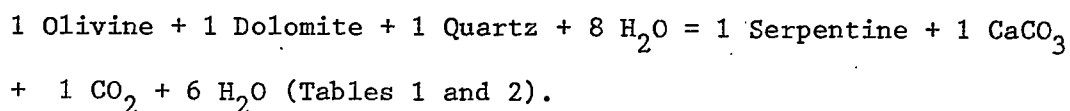
High-Grade Marble

High-grade marbles (includes those marbles with mineral assemblages indicative of high metamorphic grade) tend to be more calcitic than talc-bearing marbles, and contain the assemblage calcite-olivine-phlogopite +/- dolomite.

In thin section, carbonate grains display irregular to rounded boundaries and patchy extinction, undulose extinction is rare. Twinning in carbonate grains is present but not abundant. A complex recrystallization history is indicated by calcite grains which exhibit

homogeneous rims of calcite surrounding well developed exsolution (dolomite from calcite) lamellae.

On a microscopic scale retrograde serpentine occurs dominantly as a replacement of olivine, often with small growths of serpentine into surrounding dolomite grains. Small rounded calcite grains are common in serpentine that has replaced olivine grains, possibly a by-product of the recrystallization of olivine and dolomite to form serpentine by the reaction:



Quartz present in high-grade marbles occurs as deformed lenses and as rare isolated, secondary grains within marble.

Talc-Bearing Marble

Talc-bearing marbles contain the assemblage dolomite-calcite-talc-chlorite. Serpentine, tremolite and relict phlogopite are also present but are not in equilibrium. Graphite, pyrite, manganese oxide, and rare quartz are present as accessory minerals. Textures indicating the presence of a stable mineral assemblage are not present. Figure 3 shows the paragenetic sequence determined for the Bosal Prospect.

A complex recrystallization history is indicated by carbonate textures. These textures also indicate that the main period of dolomite formation post-dates high-grade metamorphism, in that all exsolution textures observed involved dolomite exsolving from calcite (Figure 4).

The dominant carbonate in talc-bearing marble is dolomite, which varies in color from light-orange to brown to white. Grains are subhedral to anhedral and range in size from 1 millimeter (mm) to 1 centimeter (cm), averaging 1 mm to 2 mm. Average grain size varies between layers.

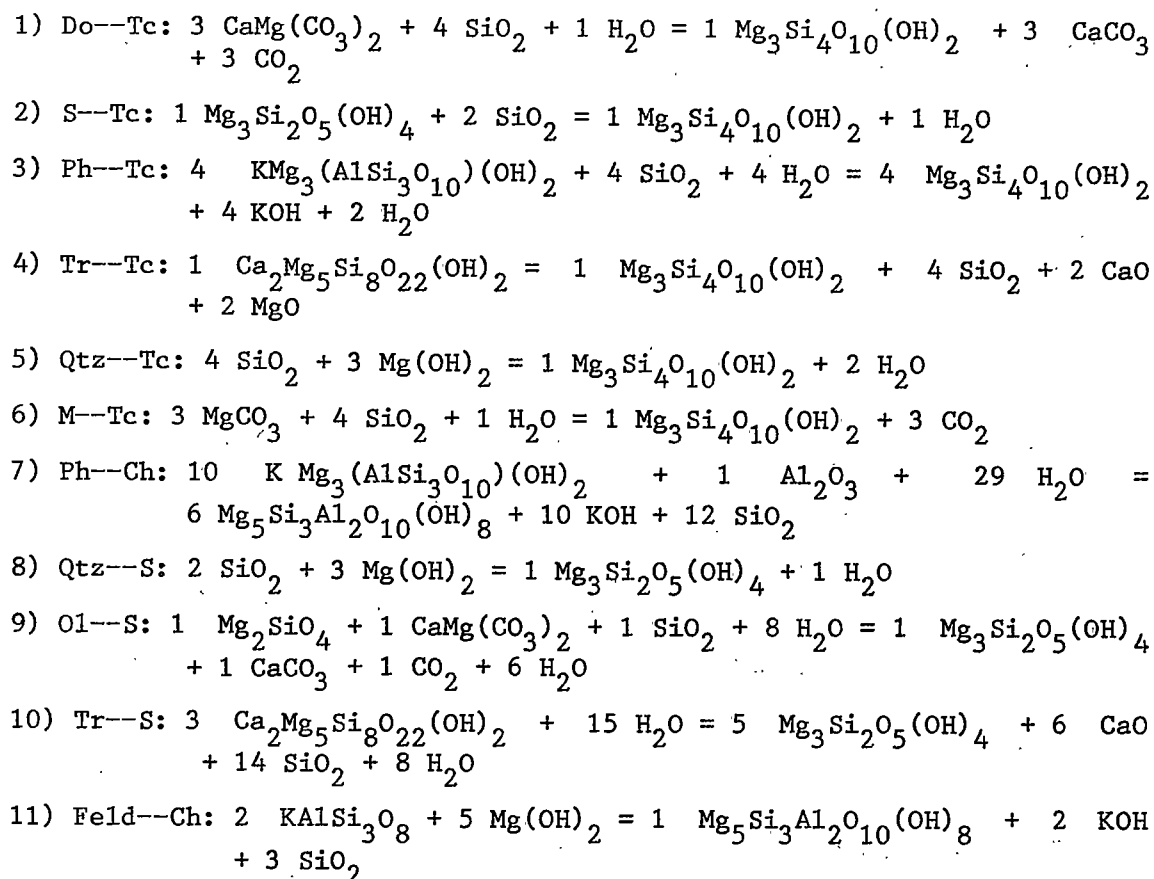
Table 1. Summary of replacement reactions and diablastic intergrowths observed during petrographic analysis, and the prospects in which they occur. Abbreviations used here are used in all following diagrams. R.V. (Ruby View), S. Creek (Spring Creek), Do (dolomite), Tc (talc), S (serpentine), Ch (chlorite), Tr (tremolite), Feld (feldspar), Qtz (quartz), Ph (phlogopite), Cc (calcite), Ol (olivine).

Prospect:	Bosal	R. V.	T.P.	S. Creek	Pope	Sweetwater
Observed Replacement						
1) Do -- Tc	X	X	X	X		
2) S -- Tc	X	X	X	X	X	
3) Ph -- Tc	X	X	X	X		
4) Tr -- Tc	X	X		X	X	
5) Qtz -- Tc				X		X
6) M -- Tc						X
7) Ph -- Ch	X			X		
8) Qtz -- S		X				
9) Ol -- S	X		X		X	
10) Tr -- S					X	
11) Feld -- Ch						X

Diablastic Intergrowths

1) Ch -- Tc	X	X	X	X	X
2) Do -- Ch		X		X	X
3) Do -- S	X				
4) Ch -- S		X	X	X	
5) Cc -- Tc					X

Table 2. Balanced reactions corresponding to replacement reactions presented in Table 1.



Talc occurs in several forms including: 1) a large layer-parallel body which is locally discordant; 2) centimeter-scale irregularly shaped talc pods which do not appear to be controlled by layering or fracturing; 3) scattered veinlets parallel to layering; and 4) disseminated talc grains which in many cases exhibit pseudomorphs after dolomite and tremolite.

The main talc body is a layer-parallel unit 2.5 to 3.5 meters (m) thick. Incomplete alteration of marble to talc within the body is indicated by inclusions of relict marble blocks.

