

HYDROTHERMAL ALTERATION AND MINERALIZATION  
IN THE CLIMAX MOLYBDENUM DEPOSIT  
CLIMAX, COLORADO

Charles E. Sears, Jr.

ProQuest Number: 10795941

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



ProQuest 10795941

Published by ProQuest LLC (2019). Copyright of the Dissertation is held by the Author.

All rights reserved.

This work is protected against unauthorized copying under Title 17, United States Code  
Microform Edition © ProQuest LLC.

ProQuest LLC.  
789 East Eisenhower Parkway  
P.O. Box 1346  
Ann Arbor, MI 48106 – 1346

A thesis submitted to the Faculty and Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Doctor of Science.

Signed: Charles E. Sears, Jr.  
Charles E. Sears, Jr.

Approved: F. M. Van Tuyl  
F. M. Van Tuyl

Golden, Colorado

Date:

Approved: Truman H. Kuhn  
Truman H. Kuhn

Approved: Warren R. Wagner  
Warren R. Wagner

1914, vol. 1, p. 111

Dept. of the University

## TABLE OF CONTENTS

	Page
<b>ABSTRACT</b>	
<b>INTRODUCTION</b> -----	1
Location of Area-----	1
Purpose-----	1
Procedure-----	1
Previous Work-----	2
History-----	4
Maps and Plates-----	4
Acknowledgments-----	5
<b>GEOLOGY</b> -----	6
Geomorphology-----	6
Geology of the Bedrock-----	6
Pre-Cambrian Rocks-----	7
Idaho Springs formation-----	7
Silver Plume granite-----	8
Pegmatites-----	9
Paleozoic Sedimentary Rocks-----	9
Tertiary Intrusive Rocks-----	9
Lincoln Porphyry-----	10
Early Porphyry-----	10
Structure-----	10
Folds-----	13
Faults and Fissures-----	13
Mosquito fault-----	13
Major fault-----	14

	Page
Fissures-----	14
West Shear zone-----	15
Petrology and Petrography-----	15
Highly Silicified Rocks-----	16
Moderately Silicified Granite-----	16
Moderately Silicified Schist-----	17
Slightly Silicified Granite-----	17
Slightly Silicified Schist-----	18
Early Porphyry-----	18
Origin of the Early Porphyry-----	21
ORE DEPOSITS-----	22
Geology of the Molybdenite Deposit-----	22
Form of the Ore Body-----	24
Mineralization-----	25
Molybdenite-----	25
Pyrite-----	28
Cassiterite-----	29
Monazite-----	30
Wolframite-----	34
Titanium Minerals-----	35
Topaz-----	35
Fluorite-----	36
Apatite-----	36
Chalcopyrite-----	36
Galena-----	37
Sphalerite-----	37
Sillimanite-----	37

	Page
Orthoclase-----	37
Microcline-----	38
Plagioclase Feldspars-----	38
Rhodochrosite-----	38
Magnetite-----	38
Xenotime-----	39
Zircon-----	39
Sphene-----	39
Koehlinite-----	39
Secondary Minerals of the Climax Molybdenum Deposit-----	40
Jarosite-----	40
Limonite-----	40
Ferrimolybdate-----	40
Relationships and Control of Mineralization-----	40
Molybdenite-----	41
Wolframite-----	41
Cassiterite and Monazite-----	41
Topaz-----	41
Pyrite-----	42
ALTERATION-----	42
Introduction-----	42
Hydrothermal Alteration at Climax-----	43
Argillization-----	44
Allophane-----	44
Montmorillonite-----	44
Kaolinite-----	44
General Features-----	45

	Page
Age Relationships-----	45
Silicification-----	45
High Temperature Phase-----	46
Colloidal Phase-----	47
Third Phase of Silicification-----	48
Sericitization-----	48
Topazization-----	48
Granitization an Alternate Explanation-----	49
Summary of Alteration at Climax-----	50
CONCLUSIONS-----	50
RECOMMENDATIONS FOR FURTHER INVESTIGATION-----	52
REFERENCES CITED-----	54

#### ILLUSTRATIONS

##### Figure

1. Photomicrograph of the Lincoln porphyry-----	11
2. Photomicrograph of the Early porphyry-----	11
3. Photomicrograph of the Early porphyry-----	12
4. Photomicrograph of the Lincoln porphyry-----	12
5. Moderately silicified granite with molybdenite veinlets. Sterke Level.-----	19
6. Moderately silicified Early porphyry with schist inclusions. Phillipson Level. -----	19
7. Moderately silicified Early Porphyry with schist inclusions-----	20
8. Photomicrograph of Allophane-----	20
9. Paragenesis Chart-----	26
10. Photomicrograph showing cassiterite in sericite. From DD 118-900-	27

	Page
11. Photomicrograph showing cassiterite in sericite. From DD 118-99-----	27
12. Sketch showing the relationships between wolframite and molybdenite-----	31
13. Sketch showing the relationships between wolframite and molybdenite-----	31
14. Sketch showing the relationships between wolframite, molybdenite, and chalcopyrite-----	31
15. Sketch showing the relationships between wolframite, molybdenite, and pyrite-----	31
16. Sketch showing the relationships between wolframite, molybdenite, and chalcopyrite-----	32
17. Sketch showing the relationships between wolframite and molybdenite-----	32
18. Sketch showing the relationships between pyrite, molybdenite, and chalcopyrite-----	32
19. Sketch showing the relationships between pyrite and molybdenite-----	32
20. Sketch showing the relationships between pyrite, topaz, and molybdenite-----	33
21. Sketch showing the relationships between pyrite and topaz-----	33
22. Sketch showing the relationships between wolframite, pyrite, and topaz-----	33



Plates

- I Map showing the location of area. Facing page 2.
- II Geologic Map of the Climax District. In pocket.
- II-A General stratigraphic section of the Pennsylvanian and Permian(?) rocks of the Kokomo District, Colorado. Facing page 9.
- III Block diagram showing location of sections and levels, with explanation of symbols. Facing page 52 and in the pocket attached to each plate.
- IV Expanded block diagram of the Climax molybdenum deposit showing Sections 380, 300, 180, and 240. The 500 level is also shown. In pocket.
- V Expanded block diagram of the Climax molybdenum deposits showing Sections 24, 16, and 8. The Phillipson Level is also shown. In pocket.
- VI Grizzly Level. In pocket.
- VII Phillipson Level. In pocket.
- VIII Storke Level. In pocket.
- IX 500 Level. In pocket.
- X Section 380. In pocket.
- XI Section 300. In pocket.
- XII Section 180. In pocket.
- XIII Section 240. In pocket.
- XIV Section 24. In pocket.
- XV Section 16. In pocket.
- XVI Section 13. In pocket.
- XVII Section 8. In pocket.

## A B S T R A C T

The Climax molybdenum deposit is located high in the Front Range at Climax in northeastern Lake County, Colorado. Active operations were started by the Climax Molybdenum Company in 1918. Daily production has increased from 250 tons of 1.0 percent molybdenite to 15,000 to 20,000 tons of 0.4 percent molybdenite at the present time. Molybdenite is the principal ore mineral and, until recently, the only mineral recovered; but now wolframite, cassiterite, pyrite, monazite, topaz, and a concentrate containing titanium and rare earth bearing minerals are also recovered.

The purpose of this investigation was to study the distribution of the ore minerals and to determine the relationship of hydrothermal alteration to mineralization and ore localization.

The ore body is bounded on the west and east by normal faults: the Mosquito and Major faults, respectively. The Mosquito fault parallels the Mosquito Range and separates the Pre-Cambrian granite and schist from the Paleozoic sediments which lie to the west of the Mosquito Range. The Major fault branches from the Mosquito fault to the north of Climax and passes through the eastern side of the ore body. The relationship of the Mosquito fault to the ore body is not clear, although movement has occurred along it since deposition of molybdenite. Molybdenite mineralization does not extend west of the Mosquito fault. Tertiary dikes and sills, which intrude both the pre-Cambrian and Paleozoic rocks, have been displaced by the Mosquito fault.

The form of the ore body, as shown by development and exploration, seems to indicate a domed structure. The highly silicified, or fine grained quartz, zones are domal in form and are underlain and overlain by granite

containing large schist inclusions. The ore zone lies within the granite and laps over and under the quartz zones.

In the ore zone closely spaced quartz veinlets, which carry molybdenite as finely disseminated particles, small hexagonal plates, and leaf-like flakes, cut Early porphyry, pre-Cambrian granite, and schist. The quartz and molybdenite are believed to have been transported and deposited as colloids and immediately crystallized to quartz and molybdenite.

The accessory ore minerals, wolframite, cassiterite, and monazite, are thought to be, at least in part, older than molybdenite. Pyrite is both older and later than molybdenite, and topaz is later than molybdenite.

Hydrothermal alteration extends throughout the Climax ore body. The granite, schist, and Early porphyry show successive alteration effects of argillization, silicification, sericitization, and topazization, in the order given.

Argillization is most conspicuous in the areas of granitic rocks. Allophane is the most pervasive of the argillic minerals although montmorillonite and kaolinite are present along fractures and finely disseminated in the feldspars.

Three phases of silicification exist: (1) a high temperature phase resulting in the highly silicified zone which grades laterally into the moderately silicified zone; (2) a colloidal phase occurring as fissure filling related to the deposition of molybdenite; and (3) minor silicification, accompanying the topaz phase, which resulted in the formation of quartz-topaz veinlets. These cut earlier mineral veins.

Sericitization affects mainly the mica minerals, although the feldspars also are altered. The sericitic alteration apparently is related to the quartz-molybdenite phase of mineralization. Presumably this alteration just preceded, or was contemporaneous with, the deposition of the quartz-

molybdenite veinlets. There are indications that some sericitic alteration may have taken place after the deposition of molybdenite.

Molybdenite occurs most frequently in the moderately silicified and highly fractured zones. The quantity of molybdenite present is dependent upon the degree of fracturing. Mineable ore is restricted to the highly fractured zones.

Wolframite is found most frequently in the more silicified parts of the ore body. It occurs in early quartz-pyrite veins which are cut by molybdenite veinlets and in late quartz-topaz veinlets which cut molybdenite veinlets. Some wolframite is associated with quartz veins in the schist and also as finely divided grains between biotite plates in the unaltered to slightly altered schist.

Cassiterite and monazite, which occur in the granite and schist, are abundant where there is copious sericite. The cassiterite in the granite is reddish brown in color and larger grained than that in the schist. The cassiterite in the schist occurs as small rounded bleb-like grains, usually dark straw-yellow in color. The difference between the cassiterite that occurs in the granite and that which occurs in the schist is attributed to different periods of mineralization.

The Early porphyry is composed of altered feldspars and rounded quartz eyes. The feldspars are partially albitized and altered, and only faint remnants of their original character remain. The eyes of quartz consist of several irregular quartz grains with diverse optical orientation. The Early porphyry is considered to be the product of partial assimilation and alteration of the Silver Plume granite by ascending hydrothermal solutions of Tertiary age resulting in a rock with a porphyroblastic texture.

This investigation indicates the need for a more detailed X-ray, spectro-chemical, and chemical study of the Climax molybdenum deposit.

Such a detailed study would help to determine more accurately: (1) the amount and types of the several clay minerals present; (2) the relationship and importance of argillic and sericitic alteration; (3) the age relationships of wolframite, cassiterite, and monazite; (4) the relationship of  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ , and  $\text{CaO}$  to alteration and mineralization; and (5) the occurrence and association of the radioactive and titanium-bearing minerals.

The original material for this dissertation includes a significant number of oversized pages. The full text can be viewed by accessing the supplement file.

