MOLYBDENITE ORES OF THE UNITED STATES AND CANADA.

37

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MOLYBDENITE ORES OF THE UNITED STATES AND CANADA.

Molybdenum attained a new importance during the war, and the necessity of providing sources for the required amount caused many hitherto untouched deposits to be developed. Because of this, opportunity has been given for a more detailed study of the various types of occurrences. It has long been noted that molybdenite, the sulphide of molybdenum, is associated with acid igneous intrusions, but beyond that, information is meager.

The following are statements pertaining to molybdenum:

"Molybdenite occurs in quartz veins, pegmatites, granites, metamorphic rocks, and contact metamorphic deposits, and is generally associated with acid igneous rodks."[1]

"Molybdenite is a constituent of some igneous rocks, especially granites."[2]

"Molybdenite is not infrequently found in tin and wolfram lodes. In addition it occurs now and then with pyrite in separate quartz veins in close connection with granite."[3]

"Molybdenite is an accessory mineral in certain granites. It is common in many veins of the deep seated class, more or less closely connected with pegmatites. It is also of

1. Ries, H., Economic Geology, p.793.
2. Emmons, S.F., Principles of Economic Geology, p.530.
3. Beyschlag, Vogt, and Krusch, Ore Deposits, p.449.

frequent occurrence in contact-metamorphic deposits and in ordinary fissure veins". [4]

"Molybdenite occurs principally in association with granitic rocks, -- in pegmatite dikes, in veins, and in contact metamorphic deposits, -- in all of which associations, its origin is traced to hot solutions from the magma." [5]

Special articles on molybdenum deposits have appeared from time to time. Chief among these are:

Bulletin 761, U.S.G.S. Molybdenum Deposits, A Short Review, by Frank L. Hess. Herein are discussed the larger molybdenum deposits of the world. Included among them are the developements at Climax, Colorado, at the Leviathan mine, Hualpai Mts,, Arizona, and at Quyon, Quebec, all of which shall be discussed presently.

Canadian Dept. of Mines, Memoir 136, by M.E.Wilson. The associations and genesis of deposits at Quyon, and Squaw Lake are treated and the occurrence at Breckenridge, Quebec, is described, besides numerous other Canadian localities.

U.S.Bureau of Mines Bulletin 111, Molybdenum, Its Ores and Their Concentration.

Colorado Geological Survey, Bulletin 14, by P. G. Worcester. Molybdenum Deposits of Colorado. Worcester has compiled a list of all molybdenum deposits reported to the Survey, and has described the larger deposits.

4 Lindgren, W., Mineral Deposits, p.897.

5. Leith, C.K., Economic Aspects of Geology, p.186.

The statements made in these publications are considerably more informative concerning the general relationships of molybdenum than those in the text books.

Hess mentions the occurrence of molybdenite in quartz veins, either as an original constituent, or as a later filling; in pegmatite though probably always deposited in the dikes after their solidification; in those deposits formed by the replacement of granitic rocks that resemble pegmatites and take the form of pipes or more tabular masses; in greisen; in granite, but probably not as an original constituent; in regionally metamorphosed rocks; and in contact metamorphic deposits."[1]

This is the fullest statement of the kind found in the literature.

A list of the types of occurrence of molybdenite suggested in the various writings is as follows:

Magmatic segregation
Contact metamorphic
Pegmatites and aplites
Quartz veins (deep seated)
Pipes resembling pegmatites
Quartz pipes
In granite
In greisen.

[1] loc. cit. p.2.

It shall be the purpose of this investigation to study more than twenty molybdenite deposits of the United States and Canada, with the view of determining if the aforementioned classification is valid and complete. Each deposit will first be discussed in relation to the opinions which have been advanced by previous investigators, if there are any. The views of the writer induced by megascopic examination of specimens and microscopic examination of the corresponding thin sections, will then be presented. If they are not similar to the views already maintained concerning the deposit, or if no previously mentioned occurrence is applicable, another one will be suggested and the reasons for such a suggestion will be presented.

The geographical location of the deposits is varied as likewise is the geological setting. In Canada, four properties are in the Province of Quebec, and one in Nova Scotia. In the United States five properties are located in Arizona, seven in California, five in Colorado, one in Washington, and one in Utah.

Biotite granite is the prevailing country rock, but syenite, gneiss, muscovite granite, monzonite, and diorite are also found in this capacity.

The deposits will be discussed under the general type of occurrence which they seem to represent upon cursory examination.

Magmatic Segregation.(?)

The deposits at Quyon Quebec are characterized by certain features which might tend to suggest magmatic segregation as the origin, Wilson advocates this manner of origin,7 while Thomson believes in aneentirely different mode of origin which will shortly be described.8

The deposits occur in the region south of the Eardley Escarpment which parallels the north bank of the Ottawa River. There are numerous out-liers of the pink Onslow Syenite and the gray porphyritic syenite which it intrudes. It is in one of these out-liers forming an east-west trending ridge that the more important of the molybdenite deposits occur. There are five principal ore bodies in which pits have been sunk. No.1 Pit, the largest, is in a dome shaped ore body in the Onslow Syenite which trends roughly north and south. The ore rock consists of quartz, microcline, plagioclase, fluorite, molybdenite, pyrite, and magnetite, and is of a more basic character than the surrounding rock. Occasionally there is rutile, augite, tourmaline, apatite, and biotite. At the southwest corner of the pit is a pegmatite dike, sixteen feet wide, with flakes of molybdenite throughout. In some places the deposit is similar to the surrounding rock in appearance, being of granular texture. In other places the texture is coarse and pegmatitic. Fracturing has taken place but is observed as being of later age than the mineral deposition.

7 Wilson, M.E., Canadian Dept. of Mines Memoir, p.74.
8. Thomson, E., Economic Geology, Vol. 13, p.303.

The unusual occurrence of molybdenite in connection with rock of a relatively basic type has caused considerable speculation as to its origin and at least two theories of origin have been upheld. Thomson discusses this locality and maintains that the mineral deposition was effected by pegmatitic solutions in fractures in the previously formed body of segregated rock.[9] In support of this he puts forward the evidence of the pegmatite dike present on the property, and points out that the presence of fluorite and tourmaline indicate a pegmatitic origin.

Wilson, however, is very stronglyin favor of the magmatic segregation theory.[10] In support of this he points out that:

1. There is a close relationship, chemically and mineralogically between the molybdenite ore masses and the Onslow syenite in which they occur.

2. The Onslow syenite contains small aggregates of molybdenite which are not connected with the main ore body and which therefore must have developed from the syenite by segregation.

3. There is a complete gradation from the syenite wall rock in to the ore masses.

4. The presence of minerals, such as biotite, augite, normally characteristic of igneous rocks, shows that the ore is very closely related to the quartz syenite in origin.

9. Thomson, E., Economic Geology, Vol. 13, p.303.

10. Wilson, M.E., Canadian Dept. of Mines Memoir, 136.

The writer's microscopic study of the ore has tended to demonstrate that the magmatic segregation theory is not entirely feasible. There is some replacement of albite by quartz, and the magnetite shows evidence of having crystallized later than albite, which would not be so if the ore represented an ordinary igneous rock. The mere presence of so much magnetite suggests possible magmatic segregation but on the other hand magnetite is not an unusual constituent of pegmatites. The pegmatitic texture of the deposit is significant, and should not be underestimated. In other words the whole ore body or at least a large part of it might be a pegmatitic replacement in the Onslow syenite, such as are the "pegmatite pipes" which constitute molybdenite deposits in Australia.[1] In order to confirm this a careful study would have to be made of the contact relationships.

1. Andrews, E.C., S.S.Wales G.S., Bureau of Mines, Min. Res., no. 24, 1916. p.22.

CONTACT METAMORPHIC.

Squaw Lake, Quebec.

The Squaw Lake molybdenum deposits are situated in the northern part of Huddersfield township, Pontiac county, Quebec. The ore occurs in connection with lenses in granite and syenite gneiss. The ore mineral molybdenite is associated with the contact minerals formed by the interaction of the gneissoid magma with limestone, remnants of which exist in the lenses. These minerals constitute a rock which ranges all the way from a pure gneiss to a pyroxenite composed entirely of diopside. Diopside, scapolite, calcite, hornblende, biotite, titanite, orthoclase, pyrite, and pyrrhotite accompany the molybdenite. The titanite is especially abundant occurring in envelope-shaped crystals, and indicating an assimilation of calcium and silica by rutile contained in the gneiss.

The ore is obviously of a contact metamorphic nature and the deposition of the molybdenite was induced by the action of siliceous solutions on the limestone. Pyroxenic pegmatites are found in the locality. There are no pegmatitic outcrpos of great size near the deposits but the diamond drill passed through pegmatite bodies twenty five feet thick. Thomson advocated a pegmatitic origin for the ore on the following basis:[12]

"From the invariable association of the molybdenite with the pyroxene, the conclusion is inevitable that the deposition of the ore is closely connected with the process of silicification resulting from the contact between the acid

12. A Pegmatitic origin for Mb. ores. Economic Geology, Vol.13.

igneous magma and the limestone lenses of the Grenville series."

J.E.Spurr cites an occurrence of molybdenite in Renfrew county which mineralogically is an exact counterpart of the Squaw Lake deposits but which differs in the larger amount of pegmatite exposed in conjunction with the ore. He states:

"This pyroxenic rim at the contact of the pegmatite and limestones as described, seems to me plainly a case of the modifying of a pegmatitic magma before crystallization by mixture of lime and magnesia from the probably dolomitic limestone. The quartz element of the pegmatite, by adding lime and magnesia crystallized as diopside, and the albite which occurs in the pegmatite, mixed with microcline, by mixture with the lime became scapolite, while the microcline crystallized as such since there is no lime-potash-alumina silicate." [13]

This suggestion is practically the same as Thomson's in regard to the extraction of the silica content of the pegmatite magma.

Microscopic examination shows outlining of the diopside crystals by the sulphides.

In other cases these crystals are surrounded by a ground mass of calcite fragments. The molybdenite occurs as needles and shows evidence of being the last sulphide to crystallize. The pyrite and pyrrhotite are generally associated in banded and concentric structures with pyrrhotite forming the core. One specimen from the property consists entirely of glassy quartz and the corresponding section shows a very small

13. Spurr, J.E., "The Ore Magmas", p.583.

amount of microcline and pyrrhotite, indicating the pegmatitic character of at least a part of the rocks associated with the deposit.

It is the writer's belief that we may reasonably assume these deposits to have occurred in connection with the interaction of a siliceous magma and probably a pegmatitic magma with limestone.

Breckenridge, Quebec.

The molybdenite deposits north of the village of Breckenridge, Ottawa County, Quebec occur in association with pyroxene gneiss and metaporphic pyroxenite. The gneiss is composed of diopside, quartz, orthoclase, plagioclase and microcline. Pyrite is closely associated with the molybdenite.

The second type of deposit occurs to the northwest of the first and consists of pyroxenite in which masses of pyroxene pegmatite are included. A brecciated zone of pink calcite intersects the pyroxenite.[14] Scattered throughout this zone and through the pyroxenite is the molybdenite in seams and disseminated flakes.

This deposit is clearly of a close similarity with the Squaw Lake properties and the origin is considered to be the same.

14, Memoir 136, Canadian Geol. Survey.

Contact Metamorphic Deposits.

Table of minerals.

	Squaw Lake	Breckenridge.
No. of sections	(9)	(1)
quartz	1	
orthoclase	3	1
plagioclase		
microcline	2	1
scapolite	3	
muscovite		
biotite	3	
hornblende	2	
augite	1	
diopside	7	1
epidote		
chlorite		
titanite	3	
fluorite		
apatite		
zircon		
spinel		
hematite		
molybdenite	3	
pyrite		
pyrrhotite		
chalcopyrite		
magnetite	1	
bornite		
ilmenite		

	Squaw Lake	Breckenridge
molybdite		
calcite	3	

Pegmatites and Aplites.

New Ross, Nova Scotia.

At New Ross, Luneburg County, Nova Scotia, there is an interesting occurrence of molybdenite associated with pegmatites. The region is covered with glacial drift and no outcrops of ore are present although boulders of molybdenite bearing rock are prevalent in the drift. The country rock of the district is a muscovite granite which has been intruded by aplite dikes and later by pegmatites.[15]

The pegmatite consists of salmon colored orthoclase and quartz. One specimen shows clearly the nature of the sharp contact of the aplite and pegmatite and also inclusions of the aplite in the pegmatite indicating the latter to be the younger. Frequently wherever molybdenite occurs, sericitization has been an accompanying action. The molybdenite occasionally is oriented along cleavage planes in the orthoclase.

Microscopic examination shows the pegmatite to contain besides orthoclase and quartz, muscovite, biotite, plagioclase, fluorite, apatite, spinel and tourmaline. The muscovite is largely in the form of sericite. The biotite and plagioclase are much altered and may represent original constituents of the granite. Tourmaline, the black variety, occurs with sericite in vugs in the pegmatite. The iron spinel is visible in one specimen as a green mineral occurring in rounded grains.

The molybdenite here has clearly been one of the last if not the last mineral to be deposited. It was brought in by

15. Cook, C.W., "Molybdenite Deposits Near New Ross, Nova Scotia."

solutions accompanying the end phase of a siliceous magma, represented in its initial activity by the aplite.

An interesting observation was made by Cook in relation to the association of the molybdenite and sericite:

"The removal of the water from the already highly concentrated solution (and perhaps in part a falling temperature) brought about the crystallization of the molybdenite, generally in close association with the orthoclase and sericite, and to a less extent in fractures in the quartz. This function of the sericite in bringing about the precipitation of molybdenite, (as well as other metallic sulphides), with which it is not infrequently associated, has not, in so far as the writer is aware, been suggested before."[16]

Gibson, California.

At the Woodworth property near Gibson, Shasta county, California. molybdenite occurs in boulders of aplite which have not been traced to their location in place. Molybdenite with pyrite occurs in crystals evenly disseminated through the aplite. The pyrite shows a perfect cubic shape in many instances and the molybdenite occurs as needles with sharp, clear outlines. Molybdite is present and the rare mineral ilsemannite, a hydrated oxide of molybdenum.

Ramona, California.

Near Ramona, San Diego county, California, a molybdenite bearing aplite dike has been exposed in the gorge of Santa

16. Cook, C.W., Am.Journal of Science, Vol.IV, p.50.

Maria Creek. The country rock is a coarse grained biotite granite. The aplite consists of quartz, albite, microcline, and more than the usual amount of biotite.

The molybdenite occurs in aggregates and seams throughout the mass and is clearly an original constituent of the aplite.

Escondido, California.

The Haney property at Escondido resembles that at Ramona in that aplite constitutes the ore rock. The minerals are albite, microcline, orthoclase, quartz, biotite, apatite, ilmenite and leucoxene.

As at the Ramona occurrence the molybdenite is clearly an original constituent of the aplite.

Pegmatites and Aplites.

Table of Minerals.

	New Ross (4)	Gibson (2)	Ramona (1)	Escondido (1)
quartz	3	2	1	1
orthoclase	2	2	1	1
plagioclase	2	2	1	1
microcline				1
scapolite				
muscovite	4			
biotite	3		1	
hornblende				1
augite				
diopside				
epidote				
chlorite				
titanite		1		
fluorite	2			
apatite	1			
zircon	1			
spinel	1			
hematite				
molybdenite	1	2		
pyrite		1		
pyrrhotite				
chalcopyrite				
magnetite				
bornite				
ilmenite				1
molybdite				
calcite				

SERICITIZATION DEPOSITS.

Mojave, California.

Sericitization sometimes plays a major part in the deposition of molybdenite. Such an occurrence is observable on the Jawbone property in the Mojave Desert, about twenty miles north of Mojave, Kern County California. The country rock appears to have been a pink granite. Sericitization has been so intense that some specimens of the altered rock have the appearance of talc. The original plagioclase, orthoclase and quartz have all been subject to replacement by sericite. Fragments of muscovite crystals may possibly be original, but the greater part of this mineral occurs in the form of sericite.

A peculiar red mineral has been deposited between the altered crystals of the original rock which could not be identified. It is quite similar to cinnabar. Glassy quartz was deposited along with the sericite. One specimen consists entirely of quartz and sericite with vugs of molybdenite, which occurs in thin plates arranged normal to the wall. The molybdenite was evidently the last mineral to be deposited.

Since sericitization is so prominent a process in this type of deposition of molybdenite, the type will be given the classification of deep vein deposits accompanied by sericitization.

Jackman Property, Hualpai Mts., Arizona.

At the Jackman Property and the Telluride Chief mine in the Hualpai Mountains, Arizona, sericitization is again the most prominent mineralization in connection with molybdenite. The country rock in both cases is granite which has been invaded by solutions from which pyrite, chalcopyrite, and molybdenite have crystallized.

The microscope shows a very intimate mixture of sericite and molybdenite. An unusually large amount of fluorite is present. One feature of the Jackman Property is unusual. A section shows a large amount of limenite and leucoxene deposited simultaneously with pyrite, and therefore brought in bythe mineralizing solutions. This is certainly unusual for an acid deposit of this character. Pure quartz veins containing huebnerite also occur on this property.

The Telluride Chief ore is similar to that from the Jackman Property.

Copper Creek, Arizona.

Child's Property at Copper Creek, Arizona, near Mammoth is an interesting deposit. Here biotite granite has been subjected to sericitization accompanied by the deposition of molybdenite. Quartz was deposited preceding and following th the molybdenite and sericite. This is proved by the fact that beneath the molybdenite on the vein walls is a band of quartz, and quartz also occurs in cavities over molybdenite and untouched by the sericitization. Along with the quartz in this

latter instance, small rutile crystals and pink orthoclase was deposited. The replacement of the original quartz by sericite is well shown by the microscope. The ore rock consists of quartz, apatite, sericite, calcite, molybdenite and chalcopyrite. The biotite of the country rock has been altered to chlorite. The molybdenite occurs in small crystals.

Sericitization.
Table of Minerals.

	Jawbone (3)	Jackman (7)	Copper Creek (2)
quartz	3	6	2
orthoclase	2	1	
plagioclase	2		
microcline		1	
scapolite			
muscovite	3	5	2
biotite		1	1
hornblende			
augite			
diopside			
epidote			1
chlorite			1
titanite			
fluorite		3	
apatite		1	1
zircon			
spinel			
hematite			
molybdenite		4	1
pyrite		3	
pyrrhotite			
chalcopyrite			1
magnetite		1	
bornite			
ilmenite		1	
molybdite			
calcite	1		1

Silicification in Granite (?)

Climax, Colorado.

The largest producing deposit of molybdenum minerals in the world is located near the Continental Divide, fifteen miles northeast of Leadville, near the village of Climax, Lake County, Colorado. A glacial cirque had been cut into a ridge trending roughly north and south. Bartlett mountain on the northeast side of the cirque contains the ore body, which lies at an elevation of about twelve thousand feet. This mass of ore is intensely siliceous and has been intruded by rhyolite dikes.[17] The limits of the ore body are not definitely known, but outcrops of ore have been located on Ceresco Mountain on the opposite side of the cirque. If this ore is continuous underneath the debris with that known on Bartlett Mountain, of dimensions at least one thousand by fifteen hundred feet, the ore body is indeed of great magnitude. The greatest part of the developement and mining work has been done by the Climax Molybdenum Company.

Considering the size of the ore body the degree to which silicification has taken place is remarkable. The whole mass has been thoroughly crushed so that there is a maze of fractures throughout, which furnished channels along which the solutions operated. Typical specimens taken from the main tunnel show six to ten distinct fractures tothe square inch. The original nature of the rock which has been so altered is difficult to determine because of the extreme thoroughness of the silicification. Kaolinized feldspar is visible in small amounts, but

17. Hess, Frank L., U.S.G.S. Bulletin 761.

the predominant mineral is quartz. The molybdenite is finely crystalline and is almost powdery in appearance. Sericite is commonly seen in the ore and molybdite especially in the upper levels.

The rhyolite porphyry or "nevadite" intrusive into the country rock has itself been fractured and mineralized to some extent. It has been suggested that this intrusion brought with it the siliceous molybdenite bearing solutions.[18] As far as visible sources are concerned the rhyolite porphyry is the most likely prospect. The nature of the rock into which the porphyry was intruded, as stated before is difficult to determine. The original constituents have been largely replaced by quartz and altered to sericite. Hess does not advance any opinion as to the nature of the original rock. P.G.Worcester believes it to have been a white even grained granite poor in muscovite and the ferro magnesian minerals.[19] This is borne out by the megascopic characteristics of the ore but could not be confirmed by microscopic examination since all the sections had been prepared from ore so greatly silicified that the original constituents had been eradicated.

The rhyolite phase consists of quartz and orthoclase phenocrysts in a crystalline ground mass. Plagioclase phenocrysts are also present and have a decidedly resorbed appearance.

The ore consists usually of quartz, sericite and molybdenite. Molybdite is plentiful in the upper levels. Apatite

18. loc. cit. p.12

19. loc. cit. p.58

pyrite, fluorite, and magnetite are present occasionally, the latter perhaps as an original constituent. In ore from the upper levels large muscovite crystals with corroded borders exist. These have been largely replaced by quartz and to some extent by sericite. These crystals occurring as they do in the upper level may represent remnants of the original rock, and, if so, indicate it to be a granite.

However since the deposition of the molybdenite is the result of siliceous alteration of the country rock, it is preferred to classify this deposit as a silicification deposit of the deep vein zone.

Empire, Colorado.

About fourteen miles west of Empire Station, the granite country rock of biotite granite has been intruded by a light green rhyolite-porphyry which on a weathered surface exhibits rusty iron stains.

According to P.G. Worcester, who examined the property, the ore occurs in quartz veinlets, in the shattered granite and on the borders of the porphyry dikes:

"Many fissures occur nearly parallel to or at right angles to the direction of the dikes. Both the dike rock and the country rock are in places much brecciated, and the molybdenite occurs as fine separated grains or thick coatings with the quartz which fills the fractures."[20]

The ore consists of quartz, molybdenite, pyrite, and a little sericite and fluorite.

20. loc. cit. p. 48

Probably the quartz veinlets were here introduced as the later phase of the rhyolite intrusion, and thus a silicification process is represented.

Tonasket, Washington.

At Tonasket, Washington, Okanogan county, silicification of biotite granite has taken place. The unaltered granite is rather coarse grained and contains a large percentage of biotite. Molybdenite, associated with pyrite, has two principal modes of occurrence: as a fine dissemination throughout the country rock adjacent to quartz veinlets, and in the veinlets accompanied by quartz. The tenor of the ore is lower than at Climax which corresponds with the fact that silicification has been less intense here. Fracturing has not been carried on to the extent as at Climax. The biotite of the country rock has been altered to epidote.

Microscopic examination shows the ore rock to be exceedingly siliceous. The plagioclase has been altered and the biotite is corroded. In one section replacement of quartz by molybdenite and sericite has occurred. The structure of this replacement is radial,and so interlaced are the minerals that their contemporaneity is obvious. Sericitization here has followed silicification. The sericite may have functioned in causing the precipitation of the molybdenite as suggested in regard to the New Ross Deposits.

Leviathan Mine, Arizona.

The Leviathan mine on the eastern slope of the Hualpai Mountains, Arizona is interesting particularly because of the movement taking place when the molybdenite was deposited. The quartz which constitutes the gangue had been previously deposited in veins. In the last stages of vein formation, came movement in the veins which is indicated by pronounced polishing and grooving on several specimens. The molybdenite precipitated at this time was ground into a fine powder and such is its appearance in the quartz gangue.

Chalcopyrite, bornite, biotite, fluorite, calcite, and hornblende accompany the quartz and molybdenite.

A description of the Leviathan mine by F.W.Horton is as follows:

"The Leviathan properties consist of a group of six claims located on two approximately parallel veins known as the "Whale" and the "Copper Wonder". These veins traverse a granite country rock and consist of white quartz carrying molybdenite and chalcopyrite as the principal ore-forming minerals.

The molybdenite occurs in amorphous and finely crystalline form in thin veinlets and irregular masses throughout the quartz and as nuggets in vugs and cavities in the veins. Much of it is somewhat intimately associated with chalcopyrite, and in only a few places could the writer obtain specimens that were free from copper."[21]

21. Horton, F.W., U.S. Bureau of Mines, Bulletin 111, 1916, pp.86-88.

Selicification.
Table of Minerals.

	Climax, Col. (9)	Empire, Col. (2)	Tonasket, Wash. (2)	Leviathan, Ariz. (2)
quartz	9	2	2	4
orthoclase	2		2	
plagioclase			1	
microcline			2	
scapolite				
muscovite	8	2		2
biotite	1		2	1
hornblende				1
augite				
diopside				
epidote			1	
chlorite				
titanite				
fluorite	2	1		2
apatite	2		3	
zircon				
spinel				
hematite				
molybdenite	7	2	1	2
pyrite			2	2
pyrrhotite				
chalcopyrite			1	4
magnetite	2			
bornite				1
ilmenite				
molybdite	3	1		
calcite	3			1

QUARTZ VEIN.

Pitkin and Winfield, Colorado.

Near Pitkin, Gunnison county, Colorado are three properties on which occur quartz veins bearing molybdenite. At the first of these, the New Discovery Claim, the country rock is stated to be a quartz monzonite cut by a quartz vein having a width of from two to three feet. The molybdenite here has a tendency to occur in narrow bands which have been described as parallel to the dip of the vein. The ore minerals are quartz, molybdenite, molybdite, and pyrite.

The Bonton claim has been developed by two tunnels which cross several molybdenite-bearing quartz veins. The country rock is monzonite and granite. Pyrite and molybdenite are intimately associated and occur in a gangue of white quartz.

A group of several claims has been located on the north fork of Clear Creek about two miles south of Winfield, Chaffee county, and fourteen miles west of Granite. The country rock is a coarse gray biotite granite, cut by quartz veins shot through by streaks of molybdenite and pyrite. Molybdite is also present. 21

Roper Property, Mojave.

The Roper Property is situated in the New York Mountains, San Bernardino County, California, near the railway station of Ledge.

21. Worcester, P.G., Col. G.S. Bulletin 14, p.62.

The biotite granite country rock has been traversed by a quartz vein bearing molybdenite and chalcopyrite. The granite has been silicified near the contact and molybdenite is disseminated through the granite for a short distance. The orghoclase occurring in the rock near the silicified contact shows considerable alteration. Fluorite occurs extensively in the massive quartz of the vein.

Copper Hill, Arizona.

At Copper Hill in Copper Basin, east of Winkelman, Arizona, hydrothermal deposition has taken place along a shear zone in diorite. The solutions deposited drusy quartz, chalcopyrite, pyrite, molybdenite, and lastly sericite.

Azurite and malachite have resulted from the weathering of the chalcopyrite. The action of the ore depositing solutions can hardly be called silicification, since it occurred at a low temperature and the alteration of the country rock is markedly local.

Quartz Veins.

	Pitkin (3)	Roper (2)	Copper Hill (4)
quartz	3	2	4
orthoclase		1	
plagioclase			
microcline			
scapolite			
muscovite	2	2	3
biotite			1
hornblende			
augite			
diopside			
epidote			
chlorite			
titanite			
fluorite			
apatite			
zircon			
spinel			
hematite			
molybdenite	2	2	4
pyrite	1		3
pyrrhotite			
chalcopyrite		2	
magnetite			
bornite			
ilmenite			
molybdite	1		
calcite			3

FISSURE VEIN.

Brown Canyon, Colorado.

At Brown Canyon, Colorado, diorite has been cut by two parallel quartz veins which contain molybdenite and a large amount of beryl.

The large beryl crystals occur in interlocking masses with the molybdenite in vugs throughout the quartz and beryl.

This represents the open vein type of precipitation, and illustrates what a wide range it is possible for molybdenum to occupy.

IN GRANITES.

San Diego, California.

Near San Diego, molybdenite occurs as a dissemination in biotite granite. The granite consists of microcline, plagioclase, orthoclase, quartz, biotite, titanite. There is also ilmenite and leucoxene generally occurring in biotite crystals. Pyrite accompanies the molybdenite and has been deposited as a fine network in cracks throughout the granite. Large crystals of molybdenite occur in the granite, with no alteration visible except an enveloping impregnation of pyrite which has resulted in a red iron stain around the border.

This lack of alteration might lead one to believe that the origin of the deposit was magnatic segregation, but the pyrite and molybdenite have been deposited in such a manner as to preclude this. They have been precipitated in cracks in the feldspars and quartz and in one case a large quartz crystal had been entirely surrounded by molybdenite. Since the molybdenite was not deposited at the time of the formation of the granite and since there is no deposition in fractures, it is reasonable to believe that deposition was by replacement by pneumatolytic solutions accompanying an igneous intrusion perhaps deep below the zone of deposition.

Campo, California.

Near Campo, San Diego County, California, there is a molybdenite deposit exposed in a railroad cut which exhibits some unusual features. Granite has been faulted and invaded by

solutions which have altered the rock extensively. The granite is composed of orthoclase, albite, oligoclase, quartz, biotite, green hornblende, apatite, and zircon.

Examination of the altered rock reveals pyrite and magnetite deposited in concentric bands enclosing orthoclase crystals. The biotite exhibits corrosion.

The molybdenite occurs in disseminated crystals, some large, in the altered granite. A ring of finely crystalline pyrite occasionally surrounds the molybdenite discoloring the rock in a way similar to the occurrence on the Woodworth property, San Diego, and a similar origin is suggested.

Little Cottonwood Canyon, Utah.

At Pitts' property, Utah, molybdenite is disseminated in muscovite granite and is also found with pyrite in quartz veins. The molybdenite occurs in a film up to a quarter of an inch thick on the wall rock, with quartz filling the center of the veins. Considerable sericitization of the country rock has taken place.

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	Quyon, Quebec	Contact metamorphic	Pegmatites and aplites	Sericitization.	Silicification.	Dissemination in granites.	Quartz veins.	Fissure veins.
no. of localities:	①	②	④	③	④	③	③	①
quartz	1	1	4	3	4	3	3	1
orthoclase	1	2	4	2	2	2	1	
plagioclase	1		4	1	1	2		
microcline	1	2	1	1	1	1		
scapolite		1						
muscovite			1	3	3	1	3	
biotite	1	1	2	2	3	2	1	
hornblende	1	1	1					
augite	1	1						
diopside		1						
epidote				1				
chlorite				2			1	
rutile	1							
titanite	1	1	1					
fluorite	1		1	1	2			
apatite	1		1	2	2	1		
zircon	1		1					
tourmaline	1		1					
spinel			1					
molybdenite	1	2	4	3	4	3	3	1
pyrite	1		1	1	2	3	1	
pyrrhotite		2						
chalcopyrite				1	1		2	
magnetite	1	1	1	1	1	1		
bornite			1					
ilmenite			1	1				
molybdite					2		1	
calcite	1	1		2	1	1	1	
beryl								1
malachite					1			
azurite					1			
ilsemanite						1		

The table of minerals shows the mineral associations which one would expect to exist in the different types of deposits. The contact metamorphic type contains augite, diopside, and acapolite. The pegmatitic deposits are characterized by tourmaline and fluorite. A strong similarity is observed between the column of Quyon deposits and that of the pegmatitic deposits indicating the similarity of origin. Chalcopyrite does not come in until sericitization takes place, indicating that it travels far from the source before its precipitation.

It is the writer's belief that there are no true magmatic segregation deposits of molybdenite and that a revised classification of deposits would be as follows:

Contact metamorphic deposits

Pegmatites and aplites. (Pipes and veins.)

Deep vein deposits accompanied by sericitization.

Deep vein deposits accompanied by silicification.

Disseminations in granite (pneumatolytic action.)

Quartz veins (closed.)

Quartz veins (fissure.)