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A MICROSCOPIC INVESTIGATION OF MOLYBDENITE ORE FROM CLIMAX, COLORADO

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It is a well known fact that although the occurrence of molybdenum minerals is widespread, the deposits of economic value are very few; the one at Climax, Colorado, being the largest known deposit.

A microscopic study of a large suite of specimens from this deposit was undertaken in the hope that it might shed some light on the origin of this very important ore body. It is, therefore, not the purpose of this paper to present a detailed description of the many sections studied, but rather to record those observations which may possibly have a bearing on the question of the origin of the deposit.

LOCATION AND DEVELOPMENT

The camp of the Climax Molybdenum Company is located on the top of the Continental Divide at Fremont Pass, about fifteen miles northeast of Leadville. The town of Climax has an altitude of 11,300 feet, and the present working tunnel is about one mile east of the village at an altitude of 12,200 feet. There is a glacial cirque or amphitheater which opens toward the northwest at Fremont Pass and is bounded on the northeast by Bartlett Mountain and on the southwest by Ceresco Mountain. It is on the southwest flank of Bartlett Mountain that the principal outcrop of the ore occurs.

The Climax region was first prospected because of the discovery of rich gold placers in the district. In 1903 a tunnel 900 feet long was driven in the hope of finding gold but the venture was unsuccessful. Molybdenite was noted but little attention was paid to it, it being mistaken at different times for graphite and silver. In 1916 the American Metal Company, Ltd., examined the property and finding it to be a commercial deposit, started operations. Development was initiated in 1917 and February 1918 marked the first shipment of concentrates. In May 1918 the mill was treating 250 tons of ore per day, while at present with the new mill unit an average of about 2000 tons may be milled daily. This increase in capacity has not been uniform throughout the period, but has been marked by the fluctuations common to all enterprises.

The deposit at Climax is the largest known molybdenite deposit in the world and there are probably several hundred million pounds of elemental molybdenum represented in the mineralized area.

GEOLOGY OF DEPOSIT

The deposit was first discussed by Horton[1] who wrote, "In places where the snow had blown off, large quantities of slide rock were exposed, which on an average appeared to contain 0.5 to 1 per cent molybdenite, the mineral occurring in the cracks and fractures of a crystalline quartz, most of which was associated with more or less pyrite, but was practically free from copper minerals."

Two years later, in May 1918, Brown and Hayward[2] gave the following description of the deposit: "The eastern end of this amphitheater consists of a granite gneiss which has been intruded by the granitic rock in which the molybdenite deposits occur. The ore body is made up of a large, irregular-shaped mineralized zone having a siliceous phase of this granite intrusion. The rock in the ore body itself consists largely of quartz, with minor amounts of feldspar. This siliceous mass merges in all directions into typical granite. Throughout the mineralized zone, the rock is traversed by an intricate network of quartz stringers, which are undoubtedly of magmatic origin. The fact that the molybdenum is found both in these quartz veinlets and in the larger masses of quartz clearly indicates that it is genetically related to the granitic intrusive."

Haley,[3] in a paper read in September, 1918, and published in 1920, said, "The high ridge forming the cirque is a coarsely crystalline biotite-gneiss. The alaskite is unquestionably an intrusive into the gneiss, and the latter at one time probably covered the

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[1] Horton, F. W., Molybdenum; Its Ores and Their Concentration, *U. S. Bureau of Mines, Bull.* **111,** p. 68, 1916.

[2] Brown, H. L., and Hayward, M. W., Molybdenum Mining at Climax, Colorado, *Engineering and Mining Journal,* May 18, **1918.**

[3] Haley, D. F., Molybdenite Operations at Climax, Colorado, *Trans. Am. Inst. of Min. Eng.,* Vol. **61,** 1920.

whole area, but has been eroded from Bartlett and Ceresco Mountains."

Holland,[4] in describing the deposit said, "The alaskite-granite has intruded an older gneiss, and a large zone in the alaskite-granite has been fractured and further silicified. Chunks of the gneiss are occasionally included in the alaskite-granite. Areas of quartz-porphyry containing little or no mineral also appear."

Worcester[5] describes the rock into which the rhyolite porphyry has been intruded as a white even grained granite poor in muscovite and the ferro-magnesian minerals.

Hess[6] says, "The origin of the ore is probably connected with the intrusion of a quartz porphyry, now so altered by sericitization and silicification as to be difficult of differentiation from the granites, large volumes of which are also altered in the same manner."

Evidence both from field observation and from microscopic examination indicates that there can be no question but that the ore body represents silicification of a portion of the Pre-Cambrian granite-gneiss complex. This idea was apparently held by Hess, but the theory expressed by Horton, Brown and Hayward, Haley, and Holland, embodying the idea of a later granitic or alaskite intrusion, seems to be opposed to the facts.

The question of the extent to which the extremely silicified portion of the deposit represents an alteration of granite, gneiss and schist is difficult to determine. In many instances sections of drill cores give strong indication of the silicification of gneiss or schist, rather than of granite. There is also evidence of the presence of a silicified quartz or rhyolite porphyry that further complicates the determination.

A sample taken from a drill core just north of the ore body and at a depth of 625 feet shows very good banding. A thin section from it contained much disseminated pyrite, a vein of pyrite and magnetite parallel to the banding, and many large grains of muscovite being altered to sericite. It seems probable that this specimen represents a highly sericitized gneiss.

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[4] Holland, L. F. S., Recent Developments in Molybdenum, *Mining and Scientific Press*, Oct. 19, **1918**, pp. 529–531.

[5] Worcester, P. G., Molybdenum Deposits of Colorado, with General Notes on the Molybdenum Industry, *Colo. Geol. Survey, Bull.*, **14**, pp. 87–94, 1919.

[6] Hess, F. L., Molybdenum Deposits, *U. S. Geol. Survey, Bull.* **761**, p. 12. 1924.

The change of muscovite to the sericitic form (Plate I A) is, we believe, rather an unusual phenomenon. Clarke[7] says, "The analyses of sericite usually show a small excess of silica over that contained in normal muscovite." It seems probable that the sericitic form may be more stable under conditions which tend to

Plate I A. Veinlet of orthoclase (O) cutting muscovite (M). The small laths on the muscovite are of sericite. Microphotograph with crossed nicols. ×100.

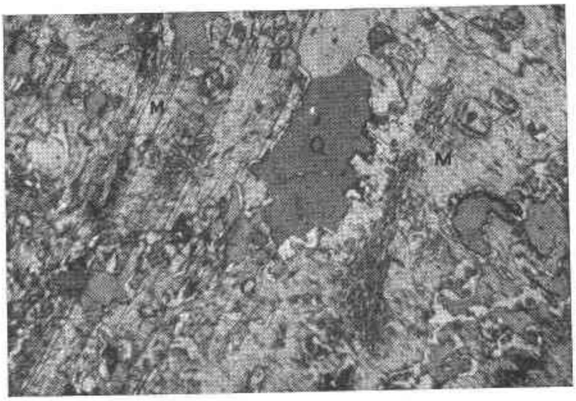

Plate I B. Corrosion of muscovite (M) by quartz (Q). The quartz has followed the cleavage planes in the two differently oriented muscovite grains. Microphotograph with crossed nicols. ×100.

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[7] Clarke, F. W., The Data of Geochemistry, *U. S. Geol. Survey, Bull.* **770,** p. 605, 1924.

produce silicification. The fact that we do tend to have considerable sericite at Climax where the conditions are extremely siliceous would favor this possibility. The continuance of these siliceous conditions is evidenced by the fact that fresh quartz, which is later than the sericite and the muscovite, is found corroding and following the cleavage planes of the latter. This is clearly shown in Plate I B, where the direction of penetration of the quartz is completely influenced by the cleavage directions of the muscovite.

In the case of the granite the progressive silicification from unaltered granite to the intensely silicified material can be shown by a description of a series of typical specimens.

The unaltered granite is a biotite granite strikingly similar in appearance to the Silver Plume granite, with large grains of quartz, feldspar and mica, the latter chiefly biotite. Nearer to the ore body we find the quartz and the biotite persisting, but all the feldspar has been altered, retaining in many cases, however, its crystal form. A stage nearer to the ore body shows a complete loss of all the original crystal forms, the rock is brecciated, and the fissures are filled with quartz. The last stage, taken from the center of the ore body presents a highly silicified rock with only small areas of the altered original rock remaining between the siliceous veins. It is to be noted that there are two types of silicification; first, sharp cut silica veins; second, areas in which the rock has been silicified without regard to vein boundaries. The sharp cut silica veins are found to be most numerous in the less altered parts of the deposit. As the center of the ore body is approached the alteration becomes more intense and the areas of silicification without regard to vein boundaries are more prominent. In some cases practically the whole rock is highly silicified. Very often a hand specimen presents evidence of the quartz veinlets cutting across the silicified areas. Where it is not possible to see this megascopically, a microscopic examination will usually show it quite clearly. The significance of the relationship between sharp cut veins and silicified areas will be discussed later.

As already suggested, in the ore body proper, where the silicification is greatest, it is usually impossible to tell the type of rock that has undergone alteration. Examination of many sections has shown that there are at least three types of rocks that have undergone silicification: a gneiss, a granite, and a rhyolite or quartz porphyry. The altered porphyry is shown in Plate II A. A corroded quartz phenocryst and sericitized areas, representing former feldspar grains, may be seen in the illustration.

In close association with the ore body is a rhyolite or quartz porphyry that is only very slightly altered. Microscopically it shows a striking resemblance to the altered porphyry described above and it may be that the latter represents an altered phase

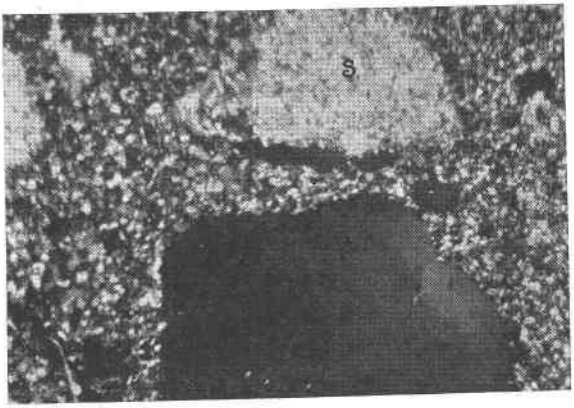

Plate II A. Alteration of quartz porphyry. Large phenocryst of quartz surrounded by small grains of quartz and orthoclase. The lighter areas (S) are areas of orthoclase altered to sericite. Microphotograph with crossed nicols. ×50.

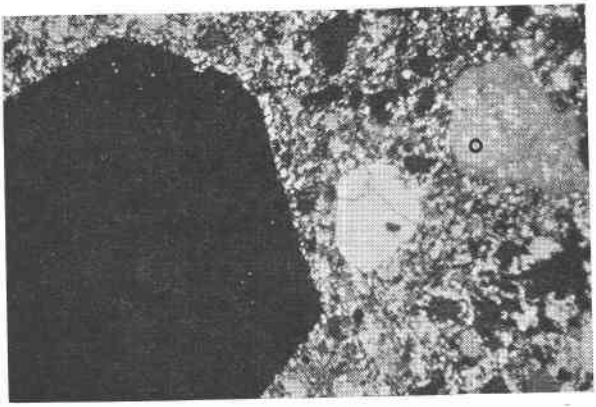

Plate II B. Quartz or rhyolite porphyry with large euhedral quartz phenocryst (black). Orthoclase (O) shows slight alteration. Groundmass is of quartz and orthoclase. Note similarity to altered porphyry in Plate II A. Microphotograph with crossed nicols. ×50.

of the rhyolite porphyry. Plate II B is a microphotograph of the unaltered rock and shows a large euhedral quartz crystal, with unaltered orthoclase in close proximity. A comparison with Plate II A shows the very great similarity.

Gradations in the silicification make an interesting microscopic study. In some of the rocks there still remains what seems to be the primary muscovite and biotite. A further stage shows only the feldspars remaining, but they are still in large grains. A still more altered stage shows just quartz and orthoclase but both of these minerals are fine grained and appear fresh, the orthoclase being usually finer grained than the quartz.

There are three possible sources for the very fine grained and fresh orthoclase. First, it may be due to the recrystallization of the original orthoclase. A second possibility is that it was brought in with the quartz, at the time of silicification, possibly as a eutectic mixture. There is a third possible origin, which is rather unusual, but is shown quite clearly to occur to some extent here. In order to obtain a clear understanding of this, it will be necessary to consider the formation of sericite from orthoclase.

Carbon dioxide or water may react with orthoclase to produce sericite and free silica, according to the equations:

$$3KAlSi_3O_8+H_2O=KH_2Al_3Si_3O_{12}+K_2SiO_3+5SiO_2$$

$$3KAlSi_3O_8+H_2O+CO_2=KH_2Al_3Si_3O_{12}+K_2CO_3+6SiO_2$$

The Climax deposit, especially in the upper part, has much sericite that was probably formed in this way.

A microscopic study of the specimens shows an occurrence that is interesting in this connection. In practically all of the cases where quartz has come into contact with the muscovite, a rim of orthoclase between the two has been produced. The rim is uniform in width and grades into the muscovite. It seems evident that the quartz has reacted with the muscovite to produce orthoclase, in other words, the above equations have been reversed. This reaction rim of orthoclase enclosing quartz is shown in Plate III A. Tyrell[8] says that sericitization is reversible, especially with more intense thermal action. It is quite possible that a temperature change may have produced this reaction, but it seems better to explain it in the same way that the change from muscovite to sericite has been explained, that is, due to an environment with excess silica.

[8] Tyrell, G. W., *Principles of Petrography*, p. 309.

The gases producing the sericitization would precede the silica. Later in an extremely siliceous environment, it seems probable that the law of mass action would operate to produce the opposite action.

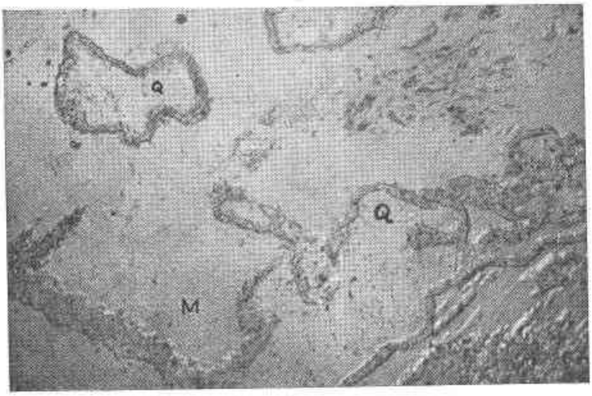

Plate III A. Rings of fine grained orthoclase surrounding quartz (Q), and formed in the muscovite (M). ×50.

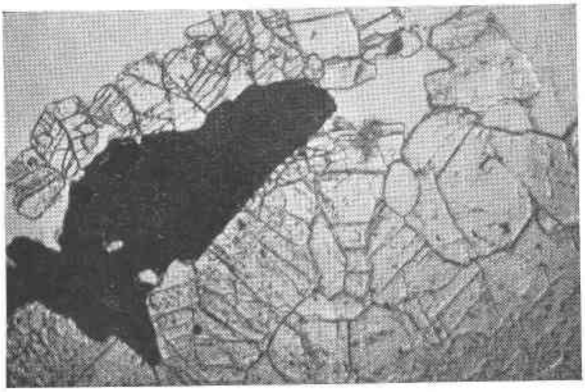

Plate III B. Topaz showing basal cleavage and high relief. Opaque mineral is pyrite. ×50.

How much of the fine grained orthoclase is to be explained in this way is very difficult to say, because in most cases all traces of muscovite and quartz have been removed. In Plate I A, the veinlet cutting the muscovite is almost entirely of orthoclase. If this veinlet is traced through the rest of the section it is found to broaden out and the center becomes all quartz. This would indicate that originally there was a quartz vein which reacted with the muscovite along its borders. When the veinlet narrowed the reaction extended from edge to edge producing the effect seen in the plate, where the quartz is almost entirely lacking.

In Brown and Hayward's[9] report, the statement was made that "No other minerals occur in the deposit with the exception of a small amount of pyrite." Undoubtedly, what was meant was metallic minerals. Since that report, and as noted by Hess,[10] wolframite has also been added to the list. As a result of further study, a more complete list of the metallic minerals includes molybdenite, pyrite, chalcopyrite, molybdite, wolframite (possibly ferberite or huebnerite), and magnetite.

Among the non-metallic minerals of the ore body the following have been previously noted: Quartz, feldspars (altered), muscovite and sericite, biotite, fluorite, apatite, and rutile. To this list there may also be added topaz, which occurs extensively in the lower part of the deposit, and which has probably not been noted before because of the lack of microscopic study. Plate III B shows considerably topaz in association with pyrite. The importance of the topaz in the deposit and its possible significance will be discussed later.

Fracturing of the Deposit

There are two unique features of the Climax ore; first, the extreme brecciation, and second, the molybdenite differs from that of most other occurrences in that it is fine grained instead of being flaky, or coarse. The significance of each of these features will be considered separately.

Hess[11] states that "No uncracked piece containing as much as two cubic inches was seen in the main ore body." It is possible to count fifteen distinct fractures in a random piece of this size. The cause of the fracturing has been explained differently by the several geologists that have studied the ores. Brown and Hayward[12] attributed it to shrinkage on cooling. They say, "When the igneous mass was intruded into the overlying sediments, an outer shell was formed, attributable to quick cooling of the magma in

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[9] Brown, H. L., and Hayward, M. W., *op. cit.*, p. 906.

[10] Hess, F. L., *op. cit.*, p. 11.

[11] Hess, F. L., *op. cit.*, p. 10.

[12] Brown, H. L., and Hayward, M. W., *op. cit.*, p. 906.

contact with the sediments. Shrinkage cracks and fractures were later formed throughout this shell, and these cracks and fractures were afterward filled with silica and molybdenite expelled from the gradually solidifying core of granite."

Haley[13] postulates the same explanation for the fracturing as given above, and Hess[14] does not offer any explanation.

There are many objections to the theory stated above, most of the objections being due to the fact that the theory was founded on the assumption that the main mass of the ore body represented a late intrusive into the Pre-Cambrian rocks.

Just what forces produced the intense fracturing has not been definitely determined. The present writers would suggest that there is a strong probability that the forces which were effective in producing the movement along the Mosquito fault, were also the cause of this intense fracturing. Why the fracturing should have been localized at this point, as it apparently has been, cannot be positively stated. However, the fact that the Mosquito fault changes the direction of its dip from east to west at or near this point suggests a plausible explanation. Such a change in direction of dip, in the case of a fault having such great displacement, would result in the development of large torsional strains. The relief of these strains would be accompanied by intense fracturing, just as glass under a torsional strain shatters when struck with a hammer. Daubree,[15] in a series of experiments has shown the effect of torsion on glass and the effect produced is strikingly similar to the shattering in the Climax ore. The existence of strains seems to be corroborated by a microscopic study of the rocks. Very often the micas show torsional strain while the secondary quartz shows no strain at all and indicates that the silicification was subsequent to the straining and resultant brecciation.

NATURE OF ORE DEPOSITION

The ore at Climax occurs in a highly silicified zone, in which most of the rocks have been so altered by silicification that it is not possible to determine their original nature megascopically, and often it is not possible to do so microscopically. The rock

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[13] Haley, D. F., *op. cit.*, p. 73.

[14] Hess, F. L., *op. cit.*

[15] Daubree, August, *Études Synthetiques de Geologie Experimentale*, Chapitre II, Paris, **1879.**

is greatly brecciated and quartz veinlets carrying molybdenite are found following the fractures, producing a network of dark colored ore veinlets in a light colored silicified rock. Plate IV A shows a typical specimen of the ore. The tendency of the quartz veins to follow the fractures is seen in this illustration, in which it appears as though the quartz vein (Q) had been faulted but it is really continuous at (C) and follows the earlier fractures. In other parts of the deposit the ore is all so highly silicified that the individual quartz veinlets are not apparent.

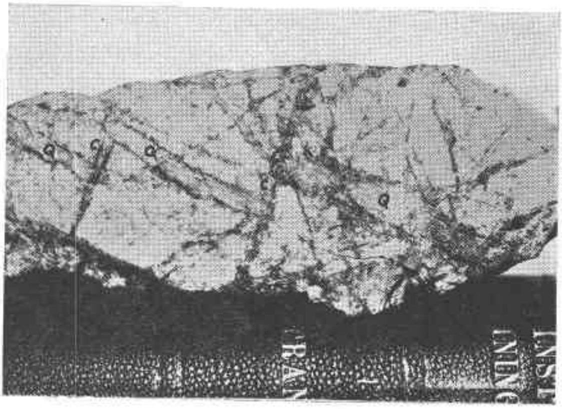

Plate IV A. Specimen of ore showing veinlets with molybdenite concentrated along the borders. $\times\frac{1}{2}$.

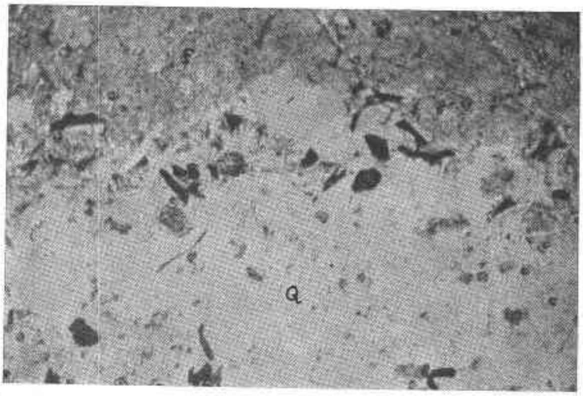

Plate IV B. Microphotograph showing concentration of molybdenite (opaque mineral) along border of quartz veinlet (Q). Cloudy mineral (F) is feldspar. ×50.

It has been mentioned that topaz has been added to the list of minerals at Climax. However, this is not found in great amounts, although it seems to increase with depth. Above this there is a zone of extreme silicification which grades into a higher zone of sericitization. This distribution must be taken into account and explained by any satisfactory theory of ore deposition.

Although the fact that the molybdenite is extremely fine grained was noted by Brown and Hayward,[16] they did not attempt any explanation of the fact, neither have any subsequent writers offered an explanation.

In this connection it is interesting to note that a German, F. Cornu, while studying the mineral ilsemanite, the composition of which according to Yancey[17] is $MoO_2 \cdot 4MoO_3 \cdot 6H_2O$, searched in vain for the primary molybdenum mineral from which it had been derived. Later, it became apparent to Cornu that the ilsemanite had been derived from a black dusty colloidal sulphide of molybdenum, which he called jordisite,[18] and which was included by Spencer[19] in his fifth list of new mineral names. If Cornu's observations are correct, molybdenite may occur in the colloidal form. It seems very probable that the molybdenite at Climax was introduced in this form, since by postulating this method of introduction a much better explanation of the factors described above may be obtained.

The temperature above which colloids are stable will vary with conditions, but we may take the result of Köningsberger[20] who obtained chalcedony from a silica gel at 350 degrees and, using this as the upper limit, conclude that quartz may crystallize from a silica sol or gel up to this temperature. Therefore our ascending solutions above this temperature, as they cooled, would precipitate the highest temperature mineral first, which at Climax is topaz, forming a bottom zone in which this mineral is concentrated. When the temperature fell to 350 degrees the silica might be considered to be in the colloidal state and with it the molybdenum sulphide as jordisite. With decreasing temperature there would tend to be precipitated the colloidal molybdenum sulphide. If

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[16] Brown, H. L., and Hayward, M. W., *op. cit.*, p. 906.

[17] Yancey, *Chem. and Met. Engr.*, Vol. **19**, p. 189, 1918.

[18] Cornu, F., *Zeits. für Chemie und Industrie der Kolloide*, Vol. **IV**, p. 190, 1909.

[19] Spencer, L. J., Fifth List of New Mineral Names, *Mineralogical Magazine*, Vol. **15**, 1910.

[20] Köningsberger, *Centr. Mineral. Geol.*, Nos. 11 and 12, **1906**.

this were true the reason for the highly silicified zone below, and the sericitized zone above with clearly defined quartz veins, becomes apparent. Above 350 degrees the silica would be in solution and would be able to thoroughly impregnate the rocks. As the temperature decreased the silica would become colloidal and produce well defined veins with clear cut edges, since the poor state of dispersion would not permit easy impregnation. In this lower temperature zone, which is higher in the deposit, the gases would leave the colloidal veins and the carbon dioxide would react with the feldspars of the granite to produce sericite. The molybdenite would tend to be concentrated most in that intermediate zone where the silicification was giving way to sericitization.

Haley,[21] in his paper on Climax says, "At the center of each veinlet very fine grains of molybdenite are visible to the eye, but toward the edges the grains become so fine as to appear simply as a dark coloration." A study of many specimens both megascopically and microscopically has indicated that Haley's statement does not generally hold true. If we study any clear cut quartz veinlet we find the molybdenite lining the two sides of the veinlet and becoming very scarce in the center. This is clearly shown in Plate IV A, where the dark coloration, due to the concentration of the molybdenite, is seen bordering the veins. The same thing is shown microscopically in Plate IV B, where the molybdenite, which is the opaque mineral, is seen bordering the quartz (Q). The clouded areas (F) are of altered feldspars.

The concentration of molybdenite as shown in Plates IV A and B, is another proof of the colloidal origin. The colloidal quartz and molybdenum would be confined to the vein and unable to impregnate the inclosing rock. Any gases, such as carbon dioxide and hydrogen sulphide, would be able to escape. They would tend to aid the migration of the molybdenum sulphide to the borders of the vein and it would there be deposited because of its relatively coarse colloidal state.

RELATION OF MINERAL ZONES

A study of specimens from different parts of the ore deposit at Climax indicates a regular zoning. However, this is not as easy to observe here as it is at many other places, because pyrite

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[21] Haley, D. F., *op. cit.*, p. 73.

is the only metal, besides molybdenite, that occurs in fairly large amounts, and this is of little asisstance in determining zones because of its widespread range.

At depth there seems to be a topaz zone, which has already been mentioned. Above this is the ore zone proper and this may be divided into three parts; a lower zone of great silicification, a middle zone of less silicification and increasing sericitization, and an upper zone of greater sericitization in which most of the silicification is in the form of sharply defined silica veins. Above and beyond the ore body, there is decreasing silicification and some indication of the possible existence of a former tungsten zone. A consideration of the temperature relationships of the minerals involved will be necessary for an understanding of this zoning.

It is generally recognized that the oxides of tin and tungsten are formed at high temperatures, and these are usually associated with mineralizers, especially boron and fluorine. At lower temperatures the sulphides tend to be formed and the first of these is molybdenite, which shows a closer relationship with the oxides of tin and tungsten than with the sulphides. It is to be especially noted that in practically all of the cases where the normal sequence of tin, tungsten, molybdenum, is found, the pneumatolitic minerals topaz, containing fluorine, and tourmaline, containing boron, are present. However, J. Morrow Campbell[22] describes a deposit at Tavoy in which these minerals are absent and it is an interesting fact that at Tavoy the deposition has been the reverse of the usual one, that is, we find tin later than tungsten and this later than molybdenum. Since, as has been mentioned, there is evidence of a tungsten zone above the molybdenite at Climax, the deposit may be somewhat analogous to the Tavoy deposits.

There are two possible explanations for the anomalous sequence in which tungsten apparently overlies molybdenite at Climax.

First, since colloidal behavior is different than the behavior of electrolytes in solution, it is possible that the molybdenite would coagulate from the gel before the tungsten. We have no direct proof of this, but further investigation might aid in clearing up the problem.

Second, since it is possible to explain the zoning quite well by postulating the normal sequence of deposition, in which tungsten

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[22] Campbell, J. Morrow. The Ore Minerals of Tavoy, *Mining Magazine* (London), Feb., 1919.

is a higher temperature mineral than molybdenite, from both solutions and colloids, this is to be preferred.

There are three stages of silicification in the deposit: At the lower depths of the deposit the ore is extremely silicified, presenting a glassy appearance; in the middle zone there is an increase in the number of veinlets, and these are rich in molybdenite; toward the top of the deposit, the silicified areas become fewer and sericitization is of increasing importance. The following theory not only accounts for the relative positions of tungsten and molybdenite, but also explains these stages of silicification.

As has already been described in this paper, the silicification is found in two distinct forms; sharp cut veinlets and silicified areas. It has been shown that the silicified areas were due to impregnation of the host rock by siliceous solutions at high temperatures, while the sharp cut veinlets were of colloidal silica at lower temperatures. Since we have both types of silicification in the same specimens, it indicates that the two conditions must have existed there, in other words, at any given locality there was entrance of material first at one temperature and later an entrance at a different temperature. A careful study shows that the sharply defined veins cut the silicified areas and are undoubtedly later. This means then, that a given locality was first under conditions of high temperature (let us say above 350 degrees) and later the conditions were those of a lower temperature (below 350 degrees), possibly due to a retreat of the magma below, or a cooling of it, resulting in a retreat of isothermal zones.

During the first period of deposition, tungsten was deposited in that zone which is now just above the surface, due to subsequent erosion. Whether above this we had molybdenite cannot be determined because it would have been removed by erosion. The silicification accompanying the tungsten was great at depth but decreased in amount toward the surface. In a later depositional period the molybdenite was deposited below the former tungsten zone, and there were various types of silicification accompanying it. At depth there was great silicification due to the ability of the highly heated solutions to permeate the rocks. Nearer to the surface and due to the lower temperatures the silica was in the colloidal form and followed the fractures, producing sharp cut veinlets. Considerable sericitization accompanied this phase.

If we superimpose the results of these two depositional periods upon each other, the result is just what is found at Climax. At depth there would be extreme silicification and production of a glassy appearance, since there was great silicification during both periods. Higher up, and in what might be called a central zone, there would be the silicification of the first period cut by the sharp veins of the second period. As one moves up from this, the silicification of the first period decreases, whereas the importance of the veinlets and sericitization increases. The main molybdenite zone occurs at this point. Above this and in a zone now eroded, the tungsten deposition took place. Thus by considering the composite effects of the two depositional periods, which were probably just phases of the one period, caused by a retreating or cooling magma, the zoning is well explained. Although it is not absolutely essential to use the colloidal theory for veinlet formation in the above explanation, the sharp cut veins seem to be best explained in this way for reasons that were brought out in the discussion of the nature of the ore body.

Conclusions

The facts presented above indicate that there is a basis for drawing the following general conclusions:

1. The fracturing which preceded the formation of the deposit was most likely the result of the same forces which were involved in the production of the Mosquito Fault, whereas the localization of the intense fracturing was probably due to the development of torsional strains accompanying the reversal of dip of the Mosquito Fault.

2. The highly altered rocks of the deposit are the result of recrystallization, silicification, and sericitization of granites, gneisses, and quartz or rhyolite porphyries.

3. There are areas of general silicification and also sharp cut silica veins. It seems probable that the former were produced at high temperatures with an abundance of mineralizers. The sharp cut veins may best be explained by a colloidal origin at lower temperatures.

4. The ore was introduced subsequent to the fracturing of the deposit and was aided in its migration by the fractures. The molybdenite is associated with the quartz veinlets and accompanied the silicification. It is possible that the colloidal theory which explains the quartz veinlets also holds for the molybdenite, since the mineral is known to occur in the colloidal form.

5. There is a zonal arrangement in the deposit. At depth there is a highly silicified-topaz zone; above this the silicification decreases and well defined quartz veins become apparent, sericite increasing as the silicification decreases.

6. Topaz has been found in the rocks, especially those from the deeper zones. Further petrographic study would probably be able to relate this with a definite zone in the deposit, which would aid in studying movements along faults and in indicating the limits of ore deposition.