

NOTES ON THE MINERALOGY OF THREE GOUGE CLAYS FROM PRECIOUS METAL VEINS.

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INTRODUCTION.

Ore bearing veins of the so-called "true-fissure" type, whether the ore has developed by filling of open cavities or by replacement of wall rock adjacent to fissures, in a majority of instances are accompanied by more or less of clayey material which is commonly called selvage, "talc," or clay gouge. From the relationships and appearance of this clayey material it would naturally be considered to be merely rock from the walls of the fissure which had been rendered clayey and plastic by extremely fine grinding by movements along the fissure. Were radical chemical changes not anticipated one would expect the clay gouges of veins in granitic or other igneous rocks to consist of finely comminuted fragments of quartz, feldspar, and ferromagnesian silicates with perhaps a little kaolin derived from the feldspar and perhaps some iron oxide or hydroxide derived from iron-bearing silicates. In slates, shales, and especially quartzites, rocks resistant to chemical action, the gouges would not be expected to differ appreciably either chemically or mineralogically, from the inclosing rock. For many years the clayey materials accompanying veins received little attention. It is only recently that students of ore deposits have learned that the gouges are most frequently radically different from the minerals which make up the rocks of the walls, and that, by their nature and composition these clays yield valuable information as to the character of the vein-forming solutions. Thus sericite, or finely divided fibrous muscovite, is known to be widespread as a constituent of gouges while kaolinite, alunite, serpentine, talc, and leverrierite are known from veins of certain types. In examining gouge materials from Idaho gold and silver veins in the United States National Museum the writer has recently analyzed mineralogically homogeneous clays from three mines. The results of these examinations are given in some detail below.

LEVERRIERITE GOUGE FROM THE BLACK JACK MINE, IDAHO.

The first specimen to be examined (Museum Cat. 24679) was labeled "tallow clay, Black Jack vein, Carson district, Owyhee County, Idaho." This proved to consist of the peculiar aluminous silicate leverrierite. Exact details in regard to the occurrence of the clay are not obtainable. Lindgren mentions¹ clayey minerals at several points in this vein. Where the vein is exposed at the surface by trenches small streaks of quartz and valencianite with comb structure appear, stained and incrustated by hematite and limonite and imbedded in soft brownish rhyolite, often with considerable masses of clay, resembling kaolin. In the granite the vein is intimately connected with a basaltic dike averaging 2 feet in width which is perpendicular or dips steeply west. Although the dike is often soft and clayey, its walls are always sharply defined and are separated from the granite or the vein by clay seams. The vein lies on the footwall or hanging wall of the dike or both, with an average width of 10 inches. A sharp contact with clay gouge separates vein from dike but the gangue is not uncommonly frozen to the granite. The lower part of the vein is in granite while the upper part is in extrusive rhyolite. The gangue consists of quartz and valencianite while the principal ore minerals are black finely divided argentite and chalcopyrite which is highly auriferous.

Physical properties.—The specimen, which has been cut into a rectangular block while plastic, is smooth and resembles a hard soap. Its exterior is pale pink, the color obviously being due to discoloration or darkening on exposure as the interior is snowy white. The structure is laminated and platy but suggests schistosity rather than micaceous cleavage such as was found in the Colorado leverrierite. There are air holes in the Idaho material which indicate that the material was originally moist and very plastic and that the specimen was kneaded somewhat while in this condition. When placed in water the material softens slowly and cracks up gradually. At the end of several hours immersion it had not disintegrated in the manner characteristic of bentonite. Its hardness in the specimen is about 1. The mineral has every appearance of a soaplike amorphous clay. When crushed between the teeth there is an absolute absence of any grit and, when in its original moist condition, the consistency must have been such as to make the name "tallow clay" exceedingly appropriate.

¹ Waldemar Lindgren. Gold and Silver Veins in Idaho. 20th Annual Report, U. S. Geol. Surv., pt. 3, pp. 135-140, 1899.

Optical properties.—Under the microscope the material is transparent, colorless, and entirely crystalline with a finely foliated or felted-fibrous structure. The birefringence is moderately high. The indices of refraction measured are, parallel to the cleavage $\gamma = 1.513$; perpendicular to the cleavage, $\alpha = 1.488$, both $\pm .003$. The birefringence indicated is $0.025 \pm .003$. These indices separate this clay clearly from both sericite and kaolinite which have much higher indices. The Idaho material compares very well with the lowest set of values given by Larsen² for leverrierite, the optical data thus being in agreement with the chemical evidence as discussed below.

Pyrognostics.—Heated in a closed tube the clay yields abundant neutral water at a very moderate temperature. In the forceps it decrepitates mildly and fuses with moderate ease on thin edges to a white blebby enamel, the fused portion becoming markedly incandescent.

Composition and chemical properties.—Material which had been proven free from contaminating impurities by careful optical examination was available in quantity for investigation and the analysis was carefully made upon ample material. The dehydration phenomena were not studied in detail as it is planned to do this as part of another research later. The loss of water at 110° C. was found to be 14.48 per cent, the mineral reaching constant weight for this temperature with two hours heating. The first hour the loss was 14.28 per cent. During the second hour an additional loss of 0.20 was obtained while several hours additional exposure to the same temperature occasioned no further loss in weight. When exposed again to the air of the room, however, the material proved to be exceedingly hygroscopic and a sample which had been dried to constant weight at 110° C. regained all of its original water content upon standing overnight in the air of the room. A similarly dehydrated sample regained 2.18 per cent of its original weight upon standing overnight in a desiccator over fresh calcium chloride. Samples dehydrated at 110° C. and allowed to stand overnight over concentrated sulphuric acid show a gain of several per cent following which they can not again be brought to the original dry weight at this temperature. This suggests that sulphuric acid has been adsorbed, an assumption which has not as yet been confirmed. This phenomenon has repeatedly been observed by the writer to occur with hygroscopic mineral powders, and the use of sulphuric acid desiccators has accordingly been discontinued in mineral analysis.

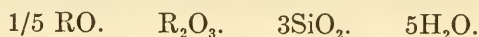
²Esper S. Larsen. U. S. Geol. Surv. Bull. 679, p. 245, 1921.

The analysis gave the results and ratios tabulated below:

Analysis and ratios of leverrierite from Idaho.

SiO ₂	45.32	0.7516	75.16	1.00×3
Al ₂ O ₃	27.84	.2724	27.68	1.10×1
Fe ₂ O ₃.....	.70	.0044		
CaO.....	2.76	.0492	5.60	1.12× $\frac{1}{5}$
MgO.....	.16	.0039		
K ₂ O.....	.12	.0013		
Na ₂ O.....	.10	.0016		
H ₂ O+110°C.....	8.16	.4529		
H ₂ O-110°C.....	14.48	.8037	125.66	1.00×5
Total.....	99.64			

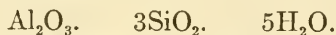
These ratios yield the formula:



or expanded:



The miscellaneous bases may in all probability be safely assumed to replace the basic hydrogen, the simplified formula becoming



Obviously there must remain a considerable amount of uncertainty regarding the nature of this mineral, an uncertainty not cleared by the discussion by Wherry and Larsen.³ These authors add univalent and bivalent bases to the trivalent alumina, tentatively assuming that they occur as a replacement of this oxide. They show that the various minerals of the group vary in base (Al₂O₃+R''O+R'O): silica ratio from 1:1.86 to 1:2.76. Unpublished investigations in this laboratory indicate a much wider range. To quote from the above authors "this variableness in composition within definite limits suggests that a mineral group is represented or at least a species including several subspecies, as is the case, for instance, with muscovite."

The leverrierite group of minerals is now being investigated here with especial reference to the bentonitic clays and any speculation now with reference to the constitution of the group would be premature. Consequently it is deemed sufficient, for the present to record the properties and composition and mode of occurrence of the Idaho mineral.

SERICITIC MUSCOVITE GOUGE FROM THE CARROLL-DRISCOLL MINE,
BOISE BASIN, BOISE COUNTY, IDAHO.

While sericite has for some years been recognized as an important mineral of metalliferous ore deposits and its mineralogical

³ Esper S. Larsen and Edgar T. Wherry. Leverrierite from Colorado. Journ. Wash. Acad. Sci., vol. 7 p. 208, 1917.

identity with muscovite has been sufficiently demonstrated, there are in the literature very few records of thorough chemical investigation of material from metalliferous veins, especially upon samples of demonstrated homogeneity and freedom from extraneous impurities. Some specimens of very excellent and typical material of this sort from a gold vein in the Boise Basin recently having been received at the Museum, the writer undertook to examine the mineral especially to secure data for incorporation in his manuscript on the minerals of Idaho which is in preparation. The results seem worthy of detailed presentation here. Grateful acknowledgment is due Mr. Clarence S. Ross, of the United States Geological Survey, for assistance in determining the optical properties of the mineral, proving the homogeneity of the analyzed material by optical methods, and in devising a method for freeing the mineral from contaminating impurities.

Occurrence.—The specimen came in a series collected by Edward L. Jones, jr., of the United States Geological Survey. Jones' ⁴ description of the deposit gives such an excellent idea of the occurrence of the mineral that it may advantageously be quoted entire, as follows:

The Carroll-Driscoll group comprises 14 claims which extend in a northeasterly direction from the end lines of the Gold Hill group to Garden Valley Pass. The property was worked in the early days and many thousand dollars' worth of gold was produced from surface workings and by sluicing disintegrated veins on the Ivanhoe and Capital claims at the head of California Gulch. The principal development work on this group consists of two tunnels, 178 feet apart, on the Ivanhoe claim. The upper tunnel, which is several hundred feet long, is now partly caved. It is a shallow drift on the vein, which strikes N. 30° E. and dips steeply east. Considerable ore has been produced but the amount is not definitely known. The ore consists of veinlets of massive pyrite and a little quartz which carry free gold. The country rock is granite.

The lower tunnel is driven on a course N. 60° W. for 1,450 feet. It intersects a shear zone 135 feet wide, which contains several sulphide veins in zones of more intense shearing. These veins trend from N. 30° E. to north and dip steeply east. The largest vein is near the hanging wall of the main shear zone, and its width ranges from 3 to 12 feet. The zone is further explored by a drift on its hanging wall and by short crosscuts driven to the main vein. The shear zone carries an abundant flow of water, which, with the softness of the vein matter, renders mining somewhat difficult.

The vein matter is composed largely of a soft white gouge which incloses the sulphides. The gouge is sericite, a secondary mica derived from the alteration of feldspars. Pyrite in well developed crystal aggregates or individuals, is the dominant sulphide in the gouge, but here and there are fragments of older vein material in which quartz, calcite, pyrite, galena, sphalerite, and tetrahedrite were recognized. These sulphides, however, have largely been ground up and incorporated in the gouge. It is evident that there have been two general periods of sulphide deposition and that extensive alteration and movement have occurred in the vein subsequent to the first period. Pyrite is the latest mineral in the seri-

⁴ Edward L. Jones, jr., Lode Mining in the Quartzburg and Grimes Pass Porphyry Belt, Boise Basin, Idaho. U. S. Geol. Survey, Bull. 640, p. 104, 1916.

cite gouge, as proved by its well-developed crystal form. According to E. F. Blain superintendent of the property, the vein assays from \$5 to \$15 a ton in gold and \$2 to \$3 a ton in silver. No assays were made to determine whether the pyrite of the lower tunnel contains any gold and silver, but it is thought more probable that these metals are contained in the older sulphides.

The samples examined were numbered SI S2 and the label accompanying them reads "sericite from shear zone." They consist in the main of the fine scaly sericite containing disseminated pyritohedral crystals of pyrite up to 1 cm. in diameter. One of the larger specimens contained a mass of the quartz containing sulphides of the first mineralization and this was washed free from sericite by scrubbing with a brush under water. This was a nodule of white quartz which was rounded as if by solution, which contained pyrite, galena, tetrahedrite, and a colorless to light resin or greenish-yellow sphalerite, the latter in well-formed crystals up to 1 cm. in diameter. There was also a little of a peculiar appearing mineral of grayish purple color with well-defined cleavage which agreed in optical properties and blowpipe reactions with barite.

Physical properties.—In the hand specimen the sericite is visibly micaceous with a very finely foliated structure and distinctly silky luster. The color varies from cream or dirty white to pale greenish. When moistened it is plastic with a greasy feel.

Optical properties.—The optical properties were very kindly worked out by Mr. Ross, who obtained the data given in column 1 below. In column 2 are given for comparison the properties of normal muscovite as given in Larsen's tables.⁵

Comparison of optical properties of sericite and muscovite.

1.	2.
Sericite (Ross):	Muscovite (Larsen):
Biaxial.	Biaxial.
Negative (-).	Negative (-).
2V 25°	2V = 40°
X = c.	X = c.
Indices:	Indices:
$\alpha = 1.550 \pm .003$	$\alpha = 1.561$
$\beta = 1.585 \pm .003$	$\beta = 1.590$
$\gamma = 1.587 \pm .003$	$\gamma = 1.594$
Birefringence .037.	Birefringence .033.

While the indices of refraction are slightly lower and the birefringence is somewhat higher than those given for normal muscovite it is noteworthy that the optical properties are essentially those of muscovite.

Pyrognostics.—Heated before the blowpipe this sericite fuses on thin edges to a white enamel. This property is important since muscovite and kaolinite are commonly listed as infusible and leverrierite

⁵Esper S. Larsen. The microscopic determination of the nonopaque minerals. U. S. Geol. Surv. Bull. 679, p. 252, 1921.

has heretofore been separated from these minerals in a qualitative way on the basis of its fusibility. Heated in a closed tube the mineral first darkens and then becomes white again and yields water having an acid reaction.

Composition and chemical properties.—Optical examination by Mr. Ross of the material which had been hand selected for analysis showed it to be essentially homogeneous except for minor amounts of two minerals, one certainly colorless zircon in minute crystals, the other an isotropic colorless mineral which was doubtless the light-colored sphalerite mentioned above. These were entirely removed by a method which deserves mention as it is applicable to numerous micaceous minerals. A screen was selected which had meshes smaller than a majority of the sericite flakes and the material was screened repeatedly, alternating the screening with rolling the powder, spread thinly on plate glass, with a hardened steel rod. The brittle impurities were thus crushed so as to pass the screen while the micaceous sericite remained behind. Even before purification the impurities amounted only to a fraction of 1 per cent.

Upon analysis the purified sample gave the following results and ratios:

Analysis and ratios of sericite from Idaho.

	Per cent.		Ratios.	
SiO ₂	46.58	0.7725	77.25	1.00×2
Al ₂ O ₃	37.46	.3665	37.15	.96×1
Fe ₂ O ₃.....	.80	.0050		
CaO.....	trace.			
MgO.....	1.16	.0288	44.32	1.15×1
K ₂ O.....	6.38	.0677		
Na ₂ O.....	.64	.0103		
H ₂ O above 110°.....	6.06	.3364		
H ₂ O below 110°.....	.30			
Total.....	99.38			

The ratios yield the formula (H,K)₂O, Al₂O₃, 2SiO₂ with the univalent bases—potash and water—replaced to a slight extent by magnesia. The bases are somewhat high which probably indicates that a part of the water, about 1 per cent, is adsorbed. The remainder of the water (5.03 per cent) is essential to the mineral which agrees with the normal muscovite formula. The percentage of alkalis is 7.02 while the water is 5.03, the former being slightly higher in weight. Molecularly, however, the ratio of water to alkalis is 3.58 : 1.00. Assuming the mineral to be an isomorphous mixture of a theoretical pure potash muscovite molecule (KAlSiO₄) and a theoretical hydrogen muscovite end molecule (HAlSiO₄), the latter is greatly in excess in the present muscovite. The very low content of low temperature water is noteworthy.

CLAY GOUGE FROM GARFIELD TUNNEL, DE LAMAR DISTRICT, IDAHO.

Lindgren⁶ writes regarding the vein clays of the De Lamar district, Owyhee County, Idaho, as follows: "It remains to mention the white chalky or 'talcose' material often forming parts of the vein. This is sometimes a product of metasomatic replacement of the rhyolite, but may also form the filling between the comb quartz in veins and vugs. All of this material is exceedingly fine grained and with highest magnifying power appears as scaly aggregates of faint double refraction. To judge from the determinations available, it is either pure kaolinite or a mixture of that mineral with one of sericitic character." Lindgren gives determinations of soda, potash, and water above and below 100° C. on six gouge clays from various localities in the De Lamar district and the percentages of these constituents, while very variable, substantially support his conclusion that the clays are mixtures of kaolinite and sericite in various proportions. However, while it is true that sericite and kaolinite are both common minerals, they represent the results of alteration processes of divergent character, operating on the same primary materials and it would be noteworthy if these processes had acted simultaneously to produce a mixture of the two minerals. Some light on the problem is given by the analysis of the sericite from Boise County described above since that material, though proven by optical methods to be a well characterized and homogeneous mica, is of such a composition that, on the basis of its water and alkalis contents, it would certainly have been interpreted as a mixture of kaolinite and sericite. Only one of the original specimens tested for Lindgren was available for more thorough examination. This he describes as follows:

A soft white material from the Garfield Tunnel, south side, end of drift, containing much marcasite in arborescent forms yielded:

	Per cent.
Water (H ₂ O) -100°.....	2. 20
Water (H ₂ O) +100°.....	4. 60
Potassa (K ₂ O).....	6. 52
Soda (Na ₂ O).....	. 18

This also is probably kaolinite mixed with a sericitic mineral.

The modern method of investigating such fine-grained materials under the microscope by immersing them in media of known refractive index allows the easy detection of mechanical admixtures of minerals of dissimilar indices of refraction. The above-mentioned specimen from Lindgren's collection was accordingly reexamined with the following results.

Physical properties.—In the hand specimen the material from the Garfield Tunnel is a very fine-grained clay. The specimen consists of approximately equal parts of marcasite and the clay, the former min-

⁶ Waldemar Lindgren. Gold and silver veins in Idaho, 20th. Ann. Rept., U. S. Geol. Survey, pt. 3, pp. 171-172, 1899.

eral having a peculiar dendritic form from the arrangement of its crystals in branching fernlike growths. Although interiorly the clay is white as mentioned by Lindgren, the exterior of the specimen is now pinkish and fresh fractures gradually turn from white to greenish and finally pink, probably from the oxidation of minute amounts of ferrous sulphate formed by breaking down of the marcasite. The clay portion of the specimen is compact and shows contraction cracks. When soaked in water the material cracks up gradually without conspicuous swelling.

Optical properties.—Under the microscope the material is very fine grained and is composed of aggregates, shreds, and flakes which give a brown dispersion color in transmitted light. Between crossed nicols the mineral shows rather high birefringence. It is seen, when immersed in an oil of its own refractive index, to be homogeneous although slightly variable in index, with the following average indices:

$$\alpha = 1.547, \quad \gamma = 1.556, \quad \gamma - \alpha = 0.009.$$

The apparent birefringence is much greater, as seen under the microscope, than the birefringence indicated above. Upon standing in oils for about a week the indices had not changed appreciably.

Composition and chemical properties.—Upon analysis selected material from this specimen yielded the following results:

Analysis and ratios of clay from Garfield Tunnel.

SiO ₂	45.94	0.7618	76.18	15.24×5	1.00×5
Al ₂ O ₃	34.14	.3341	34.20	17.10×2	1.12×2
Fe ₂ O ₃	1.26	.0079			
CaO .....	.84	.0149	47.97	15.99×3	1.05×3
MgO .....	.18	.0044			
K ₂ O	6.52	.0692			
Na ₂ O .....	.18	.0027			
H ₂ O+110° C.....	7.00	.3885	15.00	15.00×1	1.00×1
H ₂ O-110° C.....	2.70	.1500			
Total.....	98.76				

Chemically this, like the sericite from Boise County described above, is like a muscovite in which the potash has to a considerable extent been replaced by water although ratios of this last analysis do not agree quite so well with the simplified muscovite formula, the higher silica ratio indicating some admixture of the phengite molecule. The bases also are high as compared with the silica but, owing to the finer and more felted structure, this sample probably has more adsorbed water than the Boise County specimen. The chief chemical difference, however, lies in the additional molecule of water which is given off at 110° C. On the basis of this water content and its indices of refraction this sample might be called leverrierite although this content of water is much less than that ordinarily found in leverrierite.

SUMMARY AND DISCUSSION.

Of three gouge clays from gold and silver veins in Idaho, which were examined, all are homogeneous and crystalline with microscopic micaceous structure. All of these, from their occurrence and appearance under the microscope, would be classified as sericite. On the basis of their alkali content the first would be classified as kaolin while the two latter would be interpreted as mixtures of sericite and kaolin in approximately equal amounts. On their optical properties the first would be considered leverrierite, the second muscovite, and the third leverrierite.

The first described, the clay from the Black Jack vein, is a well-defined leverrierite, practically free from alkalis and iron and with a large content—nearly 15 per cent—of water which is released at a temperature of 110° C. and is quickly regained when the material is allowed to stand in air. The second, from the Carroll-Driscoll claim in the Boise Basin, Idaho, is a well-defined muscovite optically but chemically it is found to be muscovite in which the theoretical potash-free hydrogen-muscovite molecule is greatly in excess of the potash-muscovite molecule. It contains practically no water which is released at a temperature of 110° C. The third clay, from Garfield Tunnel, De Lamar district, Idaho, which had been called a mixture of sericite and kaolinite is homogeneous and similar to the last in composition but has lower indices of refraction and the equivalent of one molecule of water which is released at 110° C.

From these data it is concluded that muscovite, or at least sericite, varies from a theoretical hydrogen-free potash molecule on one hand to a potash-free hydrogen molecule on the other and that most sericites are intermediate. Consequently the potash content is no index to the amount of sericite present in a clay and many of those clays from veins which have been interpreted, on the basis of their alkali content, as mixtures of sericite and kaolinite, may well have been homogeneous sericites. Since the presence of sericite does not necessarily imply the presence of abundant potash it is unsafe to assume that this type of alteration in a given area was accomplished through the medium of potash-bearing thermal waters until it is definitely established by analysis that the sericitized rocks are notably higher in alkali content than the same rocks where not affected by the alteration.

Many such sericitic materials are more properly classified as leverrierite although from existing knowledge leverrierite can not be separated from sericitic muscovite except on the basis of its low temperature water. Leverrierite may be defined as a clayey mineral of micaceous structure conforming in general with muscovite in composition but with a large content of low temperature water, i. e.,

water which is released upon heating to 110° C., and which is quickly regained upon exposure to the air. The mode of combination of this water is at present not understood. That it is not inherent to the physical structure is proven by the fact that other specimens of identical structure, form and size of grain are practically devoid of low temperature water. Careful determination, by proper apparatus, of the dehydration curves of these materials may give some information bearing on this problem. At present the geologist, dealing with ore deposits can not be criticized for failing to distinguish between sericite and leverrierite and he is justified, where opportunity for detailed mineralogic work is lacking, in treating all such materials simply as sericite.

The fusibility test is unreliable as all three of the above-described clays are fusible before the blowpipe.