ALTERATION OF MICACEOUS MINERALS BY SULFIDE SOLUTIONS[1]

by

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ABSTRACT

A mineralogical study by the Bureau of Mines and the University of Utah of the shale beds on the 1600 ft level of the Ophir Hill mine, Utah, disclosed that the micaceous minerals in the shale were altered as a function of proximity to the sulfide ore zones. The principal mineral in the shale distant from ore is 2M sericite. Within 100 ft along the bedding plane and 15 ft normal to the bedding plane, the sericite was altered successively to a modified form of sericite, two polymorphs of chlorite, and finally phlogopite.

A general sequence of the mineral changes from barren to ore-bearing ground was: (1) sericite; (2) modified sericite; (3) modified sericite and 7 Å chlorite; (4) modified sericite, 14 Å chlorite, and phlogopite; (5) 14 Å chlorite and phlogopite; and (6) phlogopite. This sequence of alteration of sericite in the shale was not noted in the mine areas barren of ore.

INTRODUCTION

In cooperation with U.S. Smelting Refining & Mining Co., the Bureau of Mines made a paragenesis study of the copper–lead–zinc–tungsten ore mineralization on the 1600 ft level of the Ophir Hill mine, Tooele County, Utah. This paper is based on a portion of a thesis submitted by the senior author to the University of Utah in partial fulfillment of the requirements for a Master of Science degree. A phase of this research involved a detailed study of the relation between the minable ore and alteration of the shale beds within the Cambrian Ophir formation.

The ore bodies in the Ophir Hill mine occur in four principal limestone layers of the Cambrian Ophir formation, which is composed of a series of alternating limestone and shale beds. The deposits were formed by replacement in and around the intersection of several narrow fissures with the limestone beds. The ore bodies are elongated down dip but are usually short along strike of the beds. The geology of the district and the Ophir Hill mine has been described by Gilluly (1932).

The Ophir Hill mine is in Ophir Canyon on the west side of the Oquirrh Mountains about one-fourth mile northwest of the town of Ophir (Fig. 1). The mine is about 12 miles southwest of the Bingham district and about 30 miles north of the Tintic district.

[1] Approved for publication by the Director, Bureau of Mines, U.S. Department of the Interior.

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METHODS OF INVESTIGATION

Sampling

Chip samples of the shale beds overlying and underlying the exposed "Green" limestone layer were cut every 50 ft along the 1600 ft-level drift of the mine. Samples of shale also were cut at 1 to 10 ft intervals from the core of a diamond-drill hole that was drilled northerly from the 1600 ft level at a 30 degree inclination. The locations of the diamond-drill hole, the chip samples, and the ore bodies exposed in the 1600 ft-level drift are shown in Fig. 2.

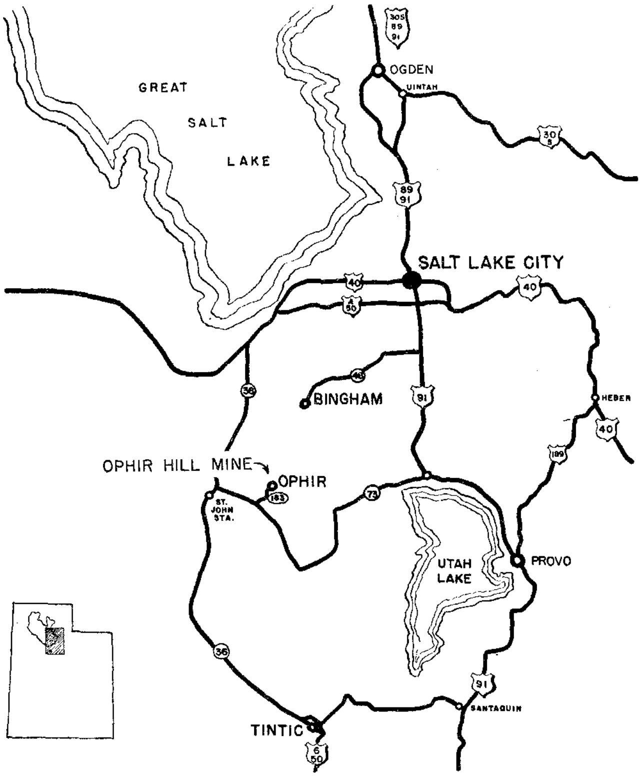

Figure 1.—Index map showing location of the Ophir Hill mine.

x-Ray Diffraction Studies

Each sample was dried, crushed, pulverized and analyzed with an x-ray diffraction unit, using copper K_α radiation. The various forms of sericite, chlorite and phlogopite in the shale samples were identified by determining the relative intensities of the 10.0 Å and the 3.2 Å peaks of the sericite and

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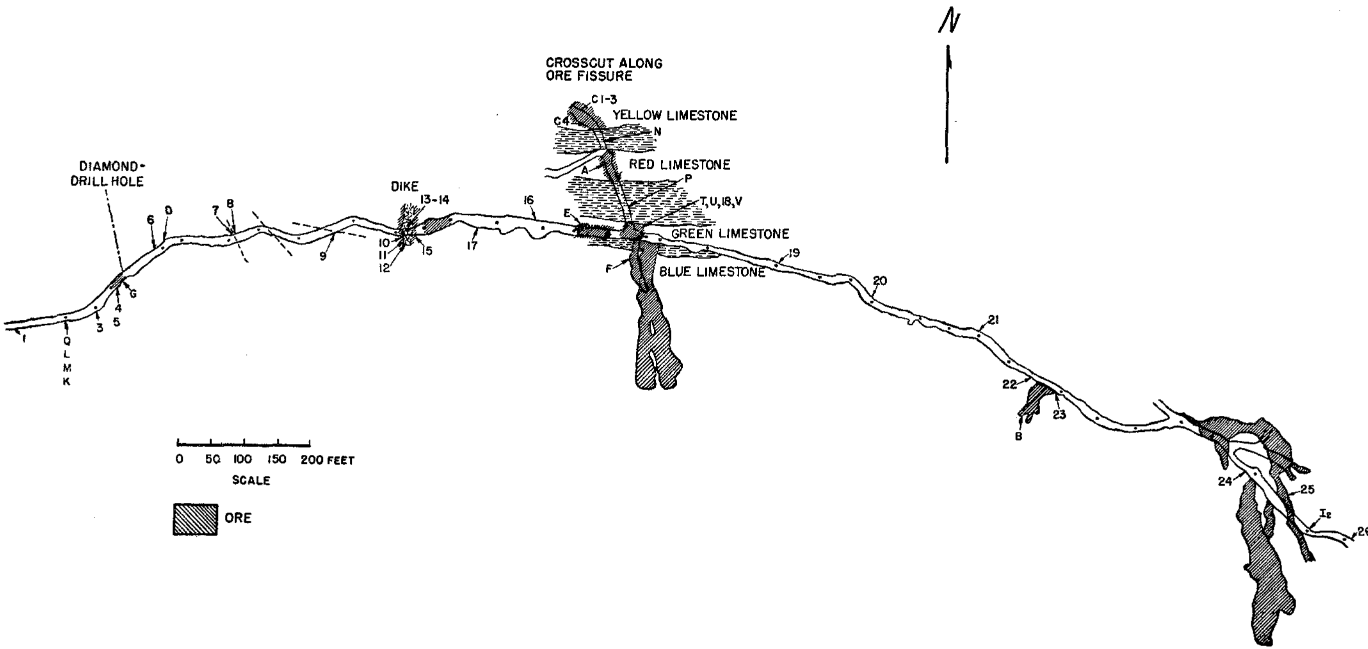

FIGURE 2.—Map showing sample locations on 1600 ft level, Ophir Hill mine.

phlogopite and the 7 Å and 14 Å peaks of the chlorite. The presence of 7 Å chlorite in some samples was confirmed by analyzing duplicate portions that had been heated to 550°C for 2 hr to convert the 7 Å chlorite to the 14 Å polymorph. Identification of phlogopite was confirmed by chemical analysis of selected mineral grains.

RESULTS

A definite sequence of alteration of the micaceous minerals was noted in the 42 samples taken from the drift and drill core. The sequence from barren ground to ore was found to be as follows:

Sericite
Modified[1] sericite
Modified sericite and 7 Å chlorite
Modified sericite, 14 Å chlorite, and phlogopite
14 Å chlorite and phlogopite
Phlogopite[2].

[1] " Modified " signifies only that the relative peak intensities have changed.
[2] $K\ (Li_{0 \cdot 06}\ Mg_{1 \cdot 81}\ Al_{0 \cdot 77})\ (AlSi_3)\ O_{10}\ (OH)_2$.

This sequence was not found in areas barren of ore. The changes in the micaceous minerals along the drift and in the drill core are shown diagrammatically in Fig. 3 and in Tables 1 and 2.

Using the data of Yoder and Eugster (1954, 1955) for natural and synthetic muscovites and phlogopites, the sericite at some distance from ore in the mine was identified as an ordered two-layered monoclinic (2M) polymorph. This polymorph is the most stable form of muscovite at high temperatures

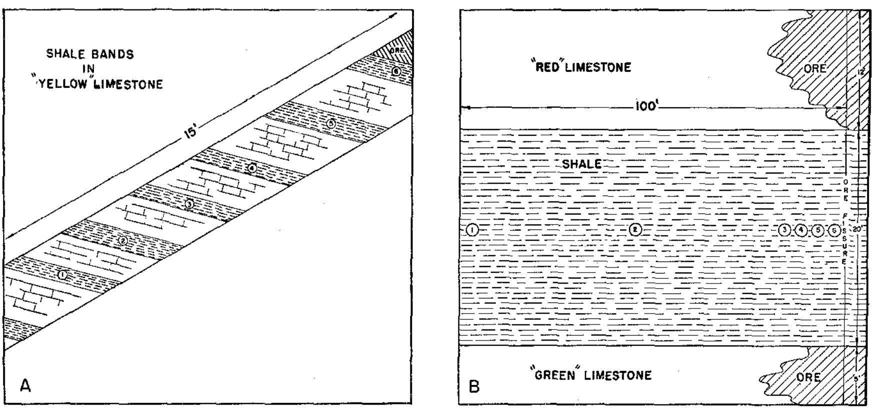

FIGURE 3.—Alteration of shale minerals from barren ground to ore-bearing ground. A, Pictorial log of diamond-drill core. B, Diagrammatic wall section at 1600 ft level drift. (1) sericite; (2) modified sericite; (3) modified sericite and 7 Å chlorite; (4) modified sericite, phlogopite and 14 Å chlorite; (5) phlogopite and 14 Å chlorite; (6) phlogopite.

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TABLE 1.—MICACEOUS CONSTITUENTS IN SAMPLES OF OPHIR SHALE FROM 1600 FT LEVEL DRIFT

(Samples taken along strike of the " Green " bed)

Sample	Micaceous Minerals	Distance from Ore
M	Sericite	150 ft west of sample G.
Q	,,	140 ft west of sample G.
3	Modified sericite	100 ft west of sample G.
5	,, ,,	60 ft west of sample G.
G	Phlogopite and 14 Å chlorite	Cu–Ag ore.
6	Modified sericite	80 ft east of sample G.
D	Sericite	110 ft east of sample G.
7	,,	220 ft east of sample G.
9	Modified sericite	120 ft west of sample 11.
10	Indeterminate mica and 14 Å chlorite	15 ft west of sample 11.
11, 12	Phlogopite	FeS_2 and $CaWO_3$ mineralization (west contact of dike).
15	Modified sericite and 7 Å chlorite	10 ft west of Pb–Zn–Ag–Cu ore (east contact of dike).
17	Sericite	150 ft west of sample E.
16	,,	80 ft west of sample E.
E	Phlogopite	Cu–Pb–Zn–Ag–W ore.
18 T, U, V	,,	Cu–Pb–Zn–Ag–W ore.
19	Sericite	230 ft east of sample U.
20	Modified sericite	70 ft east of Zn–Ag–Cu–Pb ore.
21	Sericite	110 ft west of sample 23.
23	Phlogopite	Cu–Pb–Zn–Ag–W ore.

but also persists at lower temperatures. The phlogopite found in or near the ore at the Ophir Hill mine is a one-layered monoclinic (1M) or three-layered trigonal (3T) polymorph, both of which are high-temperature forms. Both 7 Å and 14 Å polymorphs of chlorite were identified in the shales, with the 14 Å variety occurring in close proximity to ore and the 7 Å variety between 10 and 15 ft from ore.

Plotting the relative intensities of the 10.0 Å and 3.2 Å diffraction peaks with respect to the location of samples in the mine revealed that alteration of the micaceous minerals is a function of proximity to the sulfide ore. The results of this study are shown in Figs. 4 and 5. The intensities of the 3.2 Å peaks are omitted in Fig. 4 as the presence of coinciding quartz peaks interfere with interpretation. Quartz is concentrated in the vicinity of the dike along the 1600 ft level drift.

SUMMARY AND CONCLUSIONS

Alteration of micaceous minerals in the Ophir shale at the 1600 ft level of the Ophir Hill mine was studied by x-ray diffraction techniques and was found to increase, from barren ground to ore-bearing ground, in the following

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TABLE 2.—MICACEOUS CONSTITUENTS IN SAMPLES OF OPHIR SHALE FROM DRILL CORE

Distance on Core from Main Drift	Micaceous Minerals	Distance from Ore
Ft		
2	Sericite	28 ft south of ore.
9	,,	21 ft south of ore.
19	,,	11 ft south of ore.
23	Phlogopite and 14 Å chlorite	7 ft south of ore.
26	,, ,,	4 ft south of ore.
28	,, ,,	2 ft south of ore. Cu ore.
33	Modified sericite and 7 Å chlorite	2 ft north of ore.
34	,, ,, ,,	3 ft north of ore.
37	,, ,, ,,	6 ft north of ore.
39	Sericite	8 ft north of ore.
48	,,	24 ft south of ore.
56	,,	16 ft south of ore.
61	Modified sericite and a trace of 7 Å chlorite	11 ft south of ore.
64	Modified sericite and 7 Å chlorite	8 ft south of ore.
66	Mixture of phlogopite and sericite	6 ft south of ore.
67	Phlogopite and a trace of 14 Å chlorite (7 Å peak strong)	5 ft south of ore.
69	Phlogopite	3 ft south of ore.
71	Phlogopite and 14 Å chlorite	1 ft south of ore. Cu–Pb–Zn–Ag ore.

sequence: (1) sericite; (2) modified sericite; (3) modified sericite and 7 Å chlorite; (4) modified sericite, 14 Å chlorite, and phlogopite; (5) 14 Å chlorite and phlogopite; and (6) phlogopite. The sericite in shale more than 100 ft from ore was unaltered.

The chemical and structural changes resulting from alteration of the micaceous minerals by the ore solutions can be used to guide underground exploration for ore in the Ophir Hill mine. Further work will be necessary to determine if alteration of micaceous minerals can be used as a reliable guide for ore exploration in similar limestone replacement deposits.

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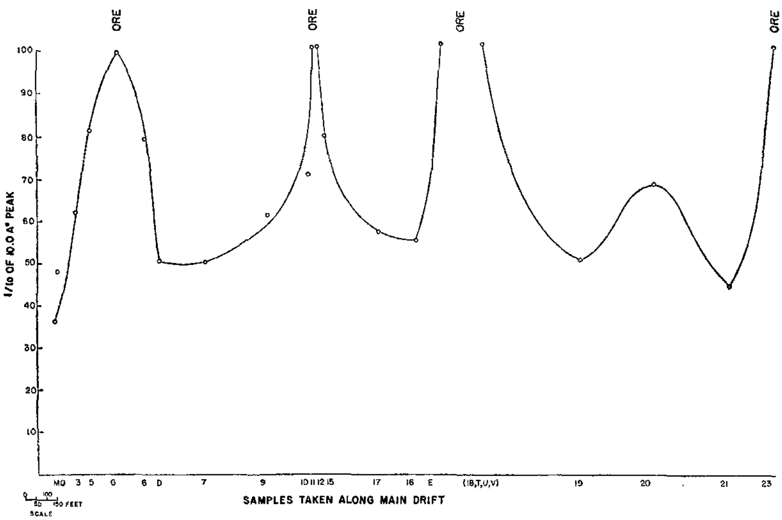

FIGURE 4.—Plot of intensity of the 10.0 Å (002) diffraction peak vs. proximity to ore.

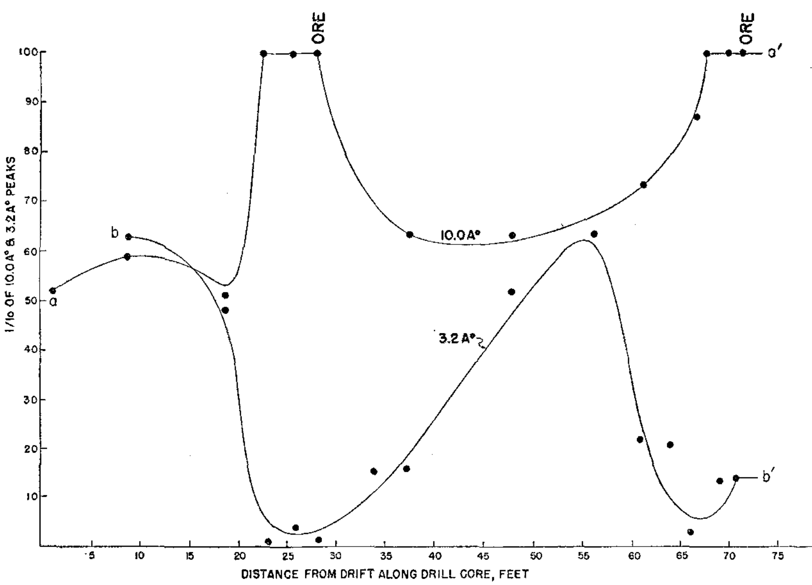

FIGURE 5.—Plot of intensity of 10.0 Å and 3.2 Å diffraction peaks vs. proximity to ore.

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Table 3.—x-Ray Powder Diffraction Data for Micaceous Minerals

						Sericite–Phlogopite and 14Å Chlorite[1]				14 Å Chlorite and Modified Phlogopite[2]				14 Å Chlorite and Phlogopite[3]					
Sericite		Slightly Modified Sericite		Modified Sericite with 7Å Chlorite		14 Å Chlorite Phase		Sericite–Phlogopite Phase		14 Å chlorite		Modified Phlogopite Phase		14 Å Chlorite Phase		Phlogopite Phase		Phlogopite	
d, Å	I/I_0	d, Å	I/I_0	d, Å	I/I_0	d, Å	I/I_0	d, Å	I/I_0	d, Å	I/I_0	d, Å	I/I_0	d, Å	I/I_0	d, Å	I/I_0	d, Å	I/I_0
10.0	50	10.0	64	10.0	64	14.0	54	10.0	68	14.0	56	10.0	100	14.2	55	10.0	100	10.1	100
4.98	18	5.0	21	7.19	8	7.0	100	5.0	14	7.07	100	5.0	6	7.1	100	4.56	9	5.00	4
4.44	19	4.46	15	4.98	19	4.69	51	4.23	19	4.72	60	3.36	48	4.72	59	4.06	8	4.55	2
4.21	22	4.23	20	4.46	16	3.52	74	3.32	100	3.55	71	2.62	9	4.56	50	3.75	13	3.66	4
3.91	13	3.78	22	4.25	15	2.82	26	3.22	17	2.82	38	2.50	5	3.54	95	3.65	13	3.36	52
3.75	29	3.47	21	3.86	11	2.69	54	2.59	18	2.69	18	2.43	10	2.82	32	3.36	54	3.24	4
3.46	26	3.36	100	3.75	12	2.21	30	2.42	28	2.21	18	2.17	6	2.02	45	2.92	13	3.14	8
3.33	100	3.24	38	3.49	16	1.81	20	2.27	20	1.81	8	1.99	11	..		2.79	9	2.92	6
3.23	47	2.98	32	3.34	100	1.63	51	2.16	18	1.63	50	1.67	8	..		2.71	5	2.71	4
2.98	40	2.86	15	3.21	23	..		1.99	34	..		1.53	8	..		2.61	28	2.62	10
2.88	17	2.79	12	2.98	20	..		1.66	12	..		..		..		2.51	18	2.51	6
2.78	15	2.56	32	2.86	13	..		1.54	16	..		..		..		2.43	20	2.43	9
2.56	38	2.51	8	2.79	11	..		..		..		..		..		2.29	7	2.29	2
2.49	10	2.44	6	2.63	7	..		..		..		..		..		2.26	6	2.26	1
2.45	10	2.38	10	2.56	26	..		..		..		..		..		2.17	18	2.17	8
2.38	12	2.16	9	2.51	8	..		..		..		..		..		2.01	15	2.00	13
2.23	6	2.13	13	2.45	12	..		..		..		..		..		1.91	5	1.91	2
2.16	12	2.06	7	2.38	7	..		..		..		..		..		1.83	7	1.74	1
2.12	18	1.99	26	2.28	6	..		..		..		..		..		1.67	17	1.67	10
2.06	6	1.81	7	2.23	7	..		..		..		..		..		1.54	19	1.54	10
1.99	23	1.79	10	2.13	12	..		..		..		..		..		..		1.43	1
1.97	12	1.64	11	2.05	6	..		..		..		..		..		..		1.36	5
1.92	6	1.54	5	2.00	18	..		..		..		..		..		..		1.32	2
1.79	15	..		1.81	8	..		..		..		..		..		..		1.31	2
1.64	11	..		1.71	4	..		..		..		..		..		..		..	
1.59	5	..		1.67	8	..		..		..		..		..		..		..	
1.54	7	..		1.64	9	..		..		..		..		..		..		..	
..		..		1.59	4	..		..		..		..		..		..		..	
..		..		1.54	9	..		..		..		..		..		..		..	

[1] Sample selected from more than 5 ft from ore. [2] Sample selected 5 ft from ore.
[3] Sample selected from less than 5 ft from ore.

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REFERENCES

Gilluly, James (1932) Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah : U.S. Geol. Survey Prof. Paper 173, 171 pp.

Yoder, H. S. and Eugster, N. P. (1954), Phlogopite synthesis and stability range : *Geochim. Cosmochim. Acta*, v. 6, pp. 157–185.

Yoder, H. S. and Eugster, H. P. (1955), Synthetic and natural muscovites : *Geochim. Cosmochim. Acta*, v. 8, pp. 225–280.

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