POTASH IN CERTAIN COPPER AND GOLD ORES.

Compiled by B. S. Butler.

COPPER ORES.

INTRODUCTION.

The amount of copper ore that is treated by concentrating methods has rapidly increased during the last few years and now exceeds 30,000,000 tons a year. Probably 25,000,000 tons of western copper ores are now annually treated by this process. Any commercial use that might be made of the tailings from such treatment would be of prime importance. In the past the Survey, in its study of these deposits, has collected a large amount of information concerning the composition of the ores, much of which has recently been published for the first time.[1] An inspection of these analyses shows the fact well known to students of the deposits, that the ores are relatively rich in potassium.

In the treatment of the ores for the recovery of the metals contained they are finely ground. If the recovery of potash from silicates should ever become a commercial possibility it would seem that the tailings from these ores are in a condition well suited to cheap treatment and would furnish a very large supply. They are, moreover, accessible to transportation facilities and in many places to moderately cheap supplies of electric power, water, etc., that have been provided for recovering the metal content of the ores. The recovery of potassium from silicates has received much attention in recent years, but no commercially successful method has yet been put into operation. The large and cheap supply of such material, however, is certain to encourage further investigation. It seems reasonable to suppose that in the treatment of ores in which the potassium occurs in the mineral muscovite, the muscovite will tend to collect in the finer material or "slimes," and these finer tailings may be considerably higher in potassium than the coarser material. If they are, it may be to the interest of the companies to impound separately the fine and coarse tailings.

In the following pages have been brought together portions of some complete analyses of copper ores from different districts showing the potash content and the percentages of the commoner oxides.

[1] Clarke, F. W., Analyses of rocks and minerals from the laboratory of the United States Geological Survey, 1880–1914: U. S. Geol. Survey Bull. 591, 1915.

For each district are given the amount of ore available and the quantity that has been treated. The last item gives an approximation of the amount of tailings that have resulted from past operations.

For the convenience of the reader wishing to examine the full analyses in the original publications, the letters designating the excerpts from the analyses are those used in the publication from which they were taken.

BINGHAM DISTRICT, UTAH.

B, C, D, Mineralized monzonite porphyry, collected by J. M. Boutwell from British tunnel, Last Chance mine, and described in Professional Paper 38, page 178. E. T. Allen, analyst.

E, F, Altered porphyry, collected by B. S. Butler, who supplies the petrographic data. George Steiger, analyst. E, Dark ore; contains biotite, orthoclase, muscovite, rutile, and quartz. F, Light ore; contains quartz, orthoclase, muscovite, rutile, and very little biotite.

[From Bulletin 591, p. 146.]

	B	C	D	E	F
SiO_2	56.78	56.17	58.64	63.09	66.27
Al_2O_3	16.90	15.94	15.35	16.33	15.01
Fe_2O_3	6.87	3.43	3.25	1.37	1.84
FeO	2.34	1.92	2.54	3.29	.39
MgO	.03	1.60	3.84	3.53	.71
CaO	1.18	5.19	5.37	.70	.18
Na_2O	.37	2.48	3.60	2.79	.72
K_2O	7.02	4.91	4.23	3.91	9.62

These analyses represent rocks that have undergone the alteration that has accompanied the deposition of ore minerals. The composition of the ore mined is probably most nearly represented by analyses E and F. Mineralogically the ores differ considerably, but potash is present in the minerals muscovite, biotite, and orthoclase, in varying amounts. Analysis F, the one highest in potash (K_2O), represents a specimen of the "light ore," in which much of the potassium is in the mineral orthoclase.

By churn drilling and other means of exploration, 377,690,400 tons of ore of this type, of which 35,190,400 tons had been mined and milled, had been developed in this district to the end of 1914.

Samples of tailings from the mill of the Utah Copper Co. were examined in the laboratory of the Survey by R. C. Wells with the following results: Sand vanner tailings, 6.81 per cent K_2O, 0.53 per cent Na_2O; slime vanner tailings, 5.88 per cent K_2O, 0.56 per cent Na_2O.

SAN FRANCISCO DISTRICT, UTAH.

Altered quartz monzonite, collected by B. S. Butler and described in Professional Paper 80. C, O K mine; D, Cactus mine. R. C. Wells, analyst.

[From Bulletin 591, p. 148.]

	C	D
SiO_2	66.87	62.56
Al_2O_3	18.14	17.21
Fe_2O_3	1.36	2.29
FeO	1.06	3.64
MgO	.68	1.13
CaO	.11	.29
Na_2O	.61	.07
K_2O	4.12	6.02

These are analyses of ores. The tailings dump from the Cactus mill is estimated to contain over 500,000 tons of material.[1] The potassium in this ore is in the mineral muscovite.

SANTA RITA DISTRICT, N. MEX.

Rock from the Santa Rita mine, 300-foot level. W. T. Schaller, analyst.

[From Professional Paper 68, p. 39.]

SiO_2	65.15
CaO	1.96
Na_2O	2.81
K_2O	5.52

No series of analyses that can be said to represent the ore has been published.

The ore consists of mineralized igneous and sedimentary rocks The sedimentary rocks (quartzite, limestone, and shale) originally contained little or no potash, and it is reasonable to suppose that in the mineralization they did not become as rich in this material as the igneous rocks, which contained several per cent of potash before mineralization. It seems likely, then, that this deposit as a whole is not so rich in potash as some deposits formed in rocks all of which carried potash before mineralization.

A sample of the "slime" produced at the Hurley plant of the Chino Copper Co., where the ores from the Santa Rita district are treated, was examined in the laboratory of the Survey and found to contain 4.42 per cent of potash (K_2O).

To the end of 1914 there had been developed in this district 95,300,000 tons of ore, of which 5,012,800 tons had been milled.

[1] Bur. Mines Tech. Paper 90, p. 18, 1915.

RAY DISTRICT, ARIZ.

Rocks collected from mines of Ray Consolidated Copper Co. by F. L. Ransome, who supplies the petrographic data. R. C. Wells, analyst.

G. Metallized Pinal schist, "primary ore," Ray mine. Contains quartz, sericite, chlorite, biotite, pyrite, chalcopyrite, pyrrhotite, and zircon.

H. Altered Pinal schist, "primary ore," No. 1 mine, 2,075-foot level.

I. Altered Pinal schist, enriched ore, No. 1 mine, 1,940-foot level.

J. Altered Pinal schist, "primary ore," No. 2 mine, 2,190-foot level.

K. Altered Pinal schist, enriched ore, No. 2 mine, 1,925-foot sublevel.

[From Bulletin 591, p. 154.]

	G	H	I	J	K
SiO_2	78.91	68.00	68.44	71.05	68.95
Al_2O_3	10.76	16.56	15.34	13.49	12.88
Fe_2O_3	.87	.79	.36	.45	None.
FeO	1.57	1.73	1.33	1.15	1.12
MgO	1.66	1.04	.21	.41	.34
CaO	.25	.27	.07	.17	.18
Na_2O	.16	.73	.41	.31	.80
K_2O	3.44	5.37	5.74	3.80	4.99

The potash present is in the mineral muscovite (sericite).

On December 31, 1914, the known ore reserves of this district amounted to 74,765,789 tons, and 7,061,821 tons of ore had been mined and milled.

MIAMI DISTRICT, ARIZ.

Pinal schist, the so-called "primary ore," collected by F. L. Ransome. Chase Palmer, analyst.

A. 420-foot level, Miami mine.

B. 570-foot level, Miami mine.

C. 3,480-foot level, Scorpion shaft.

D. 3,350-foot level, Joe Bush shaft.

[From Bulletin 591, p. 154.]

	A	B	C	D
SiO_2	70.63	63.04	63.70	66.92
Al_2O_3	14.02	17.82	19.53	19.23
Fe_2O_3	2.73	2.26	3.46	1.09
FeO	.72	.89	1.36	.45
MgO	.70	.58	1.60	.97
CaO	.13	.13	.41	.27
Na_2O	.41	.62	.46	.39
K_2O	4.93	6.58	5.08	5.61

The potash in these ores is in muscovite.

At the end of 1914 there were known ore reserves in the district amounting to about 133,000,000 tons, and about 3,650,000 tons had been milled.

MORENCI DISTRICT, ARIZ.

Rocks collected by Waldemar Lindgren and described in Professional Paper 43, p. 168. W. F. Hillebrand, analyst.

B. Altered porphyry, Ryerson mine. 100-foot level.
C. Altered porphyry, chalcocite zone, Humboldt stopes.
D. Surface alteration of altered porphyry, Copper Mountain.
E. Primary silification of porphyry, Ryerson mine.

[From Bulletin 591, p. 156.]

	B	C	D	E
SiO_2	46.67	64.88	72.78	69.55
Al_2O_3	20.92	16.41	15.35	16.43
Fe_2O_3	.37	.65 (with FeO, bracketed)	.55	.46
FeO	.36		.10	.11
MgO	.85	1.12	.89	.62
CaO	.15	.11	.14	.15
Na_2O	.16	.12	.36	.17
K_2O	4.33	4.96	5.00	5.05

The potash in these deposits occurs in the mineral muscovite.

There are large ore reserves in this district. In the five years 1910 to 1914, inclusive, more than 7,000,000 tons of ore was concentrated in the district, and this together with earlier operations has resulted in the accumulation of a large quantity of tailings.

ELY, NEV.

Rocks collected by A. C. Spencer.

B. Altered monzonite, Veteran mine. The plagioclase is partly changed to sericite. Also contains biotite, orthoclase, quartz, and pyrite. George Steiger, analyst.

F. Enriched ore, bottom of Copper Flat mine. Original plagioclase destroyed by sericitization. George Steiger, analyst.

G. Ore, west side of Copper Flat mine. Plagioclase replaced by sericite; orthoclase not attacked. Quartz and sulphides added. R. C. Wells, analyst.

H. Ore material after complete oxidation, west side of Copper Flat mine. Composed mainly of quartz and sericite, with some orthoclase and kaolin. R. C. Wells, analyst.

I. Sulphidized monzonite, shaft of Ely Central Co. George Steiger, analyst.

[From Bulletin 591, p. 162.]

	B	F	G	H	I
SiO_2	64.11	64.73	74.62	80.58	60.37
Al_2O_3	16.52	14.41	10.23	8.51	15.96
Fe_2O_3	.41	None.	....	1.15	.51
FeO	1.07	.53	.55	Undet.	1.80
MgO	1.85	.76	.83	None.	1.63
CaO	1.00	.44	Trace.	.15	4.12
Na_2O	1.64	.70	.33	.41	3.13
K_2O	8.26	7.84	6.57	5.33	5.07

The potash in these ores occurs in the minerals muscovite, biotite, and orthoclase.

To the end of 1914 more than 75,000,000 tons of ore had been developed, of which more than 15,000,000 tons had been milled.

BUTTE DISTRICT, MONT.

Altered Butte granite, collected by W. H. Weed and G. W. Tower, and described in Professional Paper 74.

I. Decomposed near quartz-pyrite veins. Shows opaline silica, with sericite derived from feldspar. Hornblende gone; mica recognizable only as sericite masses having the form of biotite. H. N. Stokes, analyst.

J. 300-foot level, Colusa mine. Contains quartz, altered orthoclase and plagioclase, and sericite. E. T. Allen, analyst.

K. Wall rock, 1,300-foot level, Parrot mine. Contains quartz, sericite, pyrite, bornite, etc. E. T. Allen, analyst.

L. Enargite vein, 1,000-foot level, Leonard mine. Contains quartz, kaolin, pyrite, etc. W. F. Hillebrand, analyst.

M. Veinlets in Original mine. Contains quartz, sericite, partly altered feldspars, calcite, zinc blende, etc. W. F. Hillebrand, analyst.

[From Bulletin 591, p. 94.]

	I	J	K	L	M
SiO_2	64.81	56.80	62.09	66.90	54.30
Al_2O_3	19.44	21.02	15.49	15.83	13.63
Fe_2O_3	1.82	3.06	8.52	(?)	1.89
FeO	.16	.90	....	(?)	2.22
MgO	.19	1.21	.42	Trace.	2.13
CaO	.18	.35	.20	.05	7.36
Na_2O	.21	.50	.37	.08	.16
K_2O	5.30	4.78	4.34	.03	4.41

Potash is present in the mineral muscovite.

The Butte district contains large reserves of concentrating ore. During the last 10 years the district has made an annual output of ore ranging from 3,700,000 to 5,600,000 tons. As a large part of this ore was concentrated it is evident that these and earlier operations have resulted in the accumulation of millions of tons of tailings.

GOLD ORES.

The ores of several of the large gold-producing districts of the West are notably rich in potassium, and although the tonnage in these deposits is usually small compared with that of the copper deposits, nevertheless in several places there have been large accumulations of tailings. It is probable that the analyses quoted below, all of which were made for other purposes than the determination of the potash content of the ore, give a less accurate idea of the potassium content of the material as actually mined and milled than the analyses of the copper ores. Some facts concerning a few of the larger districts are given in the following paragraphs.

CRIPPLE CREEK DISTRICT, COLO.

Altered latite-phonolite.

A. Washington shaft, Stratton's Independence mine. Collected by Whitman Cross. W. F. Hillebrand, analyst.

C. Level 11, vein No. 3, Vindicator mine. Collected by Waldemar Lindgren and F. L. Ransome. W. T. Schaller, analyst.

[From Professional Paper 54, p. 189.]

	A	C
SiO_2	56.74	57.91
Al_2O_3	20.30	....
Fe_2O_3	1.06	....
FeO	....	....
MgO	.23	.33
CaO	.57	.81
Na_2O	.62	.45
K_2O	13.36	13.35

Breccia from Golden Cycle mine. Collected by Waldemar Lindgren and F. L. Ransome. W. T. Schaller, analyst.

[From Professional Paper 54, p. 192.]

SiO_2	54.57
CaO	2.79
MgO	1.06
Na_2O	3.85
K_2O	7.50

Fresh and altered granitic rock from level 6, Ajax mine, B 1 foot from A. Collected by Waldemar Lindgren and F. L. Ransome. W. F. Hillebrand, analyst.

[From Professional Paper 54, p. 194.]

	A	B
SiO_2	66.20	59.58
Al_2O_3	14.33	16.00
Fe_2O_3	2.09	.30
FeO	1.93	.65
MgO	.89	.03
CaO	1.39	2.03
Na_2O	2.58	.98
K_2O	7.31	11.93

During the period 1904 to 1914, inclusive, the Cripple Creek district produced 7,796,000 tons of ore. As most of this was milled, it is evident that a large accumulation of tailings has resulted.

GOLDFIELD DISTRICT, NEV.

The rocks of the Goldfield district, Nev., contain potassium in the form of alunite, but so far as indicated by available analyses [1] the percentage of potassium in the ores is not very high.

To the end of 1914 the Goldfield district had produced about 2,400,000 tons of ore, a large part of which was treated in the mills of the district.

[1] Ransome, F. L., Geology and ore deposits of Goldfield, Nev.: U. S. Geol. Survey Prof. Paper 66, 1909.

TONOPAH DISTRICT, NEV.

Rocks collected by J. E. Spurr and described in Professional Paper 42.

C. Kaolinic alteration of hornblende andesite, from a pit in the saddle between Halifax shaft and the Mizpah mine. Entirely altered to quartz, kaolin, and muscovite. George Steiger, analyst.

D. Hornblende andesite, altered to chlorite and calcite; Mizpah shaft, 675 feet down. Contains chlorite, calcite, a little quartz, feldspar, sericite, hematite, zircon, and apatite. George Steiger, analyst.

E. Hornblende andesite, partly altered to orthoclase (?), Mizpah Hill. Ferromagnesian minerals completely decomposed. Some secondary quartz is present. George Steiger, analyst.

F. Hornblende andesite altered to quartz and muscovite, Mizpah vein. Little more than quartz and muscovite can be made out. George Steiger, analyst.

G. Early andesite, hanging wall of vein, 300-foot level, Mizpah mine. A more advanced stage of quartz-muscovite alteration than F. George Steiger, analyst.

H. Extreme stage of alteration of andesite to quartz and muscovite, west drift, Mizpah vein. Quartz, with much muscovite. George Steiger, analyst.

J. Pyroxene-biotite andesite, completely decomposed, Montana-Tonopah shaft. Feldspars entirely altered to calcite, sericite, and quartz. Biotite and hornblende altered to chlorite, calcite, quartz, sericite, siderite, and pyrite. George Steiger, analyst.

M. Biotite-pyroxene andesite, North Star shaft. Entirely altered. Feldspar altered to calcite. Pyrite, siderite, and rutile are present. George Steiger, analyst.

[From Bulletin 591, pp. 158, 159.]

	C	D	E	F	G	H	J	M
SiO_2	71.14	55.60	73.50	72.98	76.25	91.40	57.51	51.64
Al_2O_3	15.24	16.70	14.13	14.66	12.84	4.31	16.55	15.58
Fe_2O_3	1.77	2.23	1.51	1.01	.54	.77	3.20	.16
FeO	.26	3.51	.26	.16	.33	.11	2.02	.58
MgO	.16	2.60	.21	.33	.56	.18	2.30	2.79
CaO	.09	4.27	.12	.18	.16	None.	6.06	6.25
Na_2O	.24	4.08	.24	None.	.12	.06	2.76	.27
K_2O	6.31	3.17	5.11	6.03	3.20	1.68	2.81	2.46

An inspection of these analyses shows a marked variation in the potassium content, and a sampling of the tailings would be required to determine the average composition.

Since 1904, 3,342,000 tons of ore has been mined in the district, and as most of this was milled there is a large accumulation of tailings.

OTHER DISTRICTS.

There are numerous other districts in which the ores and associated rocks contain notable amounts of potassium, among which may be mentioned the deposits of the Black Mountains, Ariz.,[1] which contain potassium in the mineral adularia (orthoclase feldspar).

[1] Schrader, F. C., Mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Ariz.: U. S. Geol. Survey Bull. 397, p. 48, 1909.

Schrader [1] has described deposits in the Jarbidge district, Nev., which contain an unusual amount of potassium. A general sample of the ore from one mine gave 11.84 per cent of potash (K_2O), and it is estimated that some of the ore contains as much as 15 per cent.

Lindgren [2] has described deposits in Idaho, specimens of the ore from which contained 15.12 per cent and 14.95 per cent of potash (K_2O).

There are doubtless numerous other deposits in the West that contain potassium in noteworthy amounts.

NOTE ON MUSCOVITE.

By George Steiger.

In connection with the general subject of the constitution of silicates, some experimental work was done on muscovite in the chemical laboratory of the United States Geological Survey several years ago, and the results may possibly have some bearing upon the commercial extraction of potash from that mineral.

Clarke [3] states that from the composition of muscovite a splitting up into water, leucite, and sillimanite may be inferred according to the equation—

$$Al_3KH_2Si_3O_{12} = AlKSi_2O_6 + Al_2SiO_5 + H_2O$$

Doelter [4] identified large quantities of leucite and a substance resembling nephelite in the fusion product of muscovite. As shown by Clarke and Steiger,[5] if leucite is heated in a sealed tube with ammonium chloride the potassium is wholly converted into the soluble chloride and may be easily separated by treating with water.

A brief outline of the results of the experiments on muscovite follows and is published in advance of the complete report on the investigation, in the belief that the facts determined have a technologic bearing and may possibly be used as a starting point in the development of a commercial process for the utilization of muscovite-bearing rocks.

Finely ground muscovite [6] was intimately mixed with ammonium chloride in a mortar, and the material was then put into glass tubes, sealed, and heated to 350° C. in a bomb furnace. The tubes were next opened and their contents were leached with hot water and

[1] Schrader, F. C., A reconnaissance of the Jarbidge, Contact, and Elk Mountain mining districts, Elko County, Nev.: U. S. Geol. Survey Bull. 497, p. 53, 1912.

[2] Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, p. 167, 1900.

[3] Clarke, F. W., The data of geochemistry, 2d ed.: U. S. Geol. Survey Bull. 491, p. 376, 1911.

[4] Doelter, C., Neues Jahrb., 1897, Bd. 1, p. 1.

[5] Clarke, F. W., and Steiger, George, U. S. Geol. Survey Bull. 207, p. 16, 1902.

[6] Most of the slime tailings from the copper mill pass through a 200-mesh screen.

washed until the wash water gave no test for chlorine. The results are stated below.

Results of heating muscovite with ammonium chloride.

		1	2	3
Leach water	K_2O+Na_2O	10.38	10.53	2.70
Residue from leach water:				
Soluble in HCl	Al_2O_3	4.79	3.55	8.19
	K_2O	.60	.33	1.08
	$(NH_4)_2O$	3.78	3.50	1.00
Soluble in Na_2CO_3 after HCl	SiO_2	10.34	Undet.	Undet.

1, 2, Ammonium residues from fused muscovite; 3, ammonium residue from unfused muscovite. K_2O in leach water given in calculated percentages of raw muscovite; other determinations in calculated percentages of dried residues.

The muscovite used contained 9.55 per cent of K_2O and 1.20 per cent of Na_2O, a total of 10.75 per cent. Of this amount practically the whole was found in the leach water, showing that by first fusing the muscovite and then treating it with ammonium chloride its potassium was entirely converted into the soluble form. The results given in column 3 show that more than 25 per cent of the potassium present may be converted into the soluble form by the treatment with ammonium chloride alone.

Some experiments were also made to determine to what extent potassium might be extracted from muscovite by treatment with hydrochloric acid. The results stated below show that by a very superficial treatment with hydrochloric acid approximately one-third of the potassium may be extracted.

	Per cent K_2O.
Boiled 5 minutes with 1–1 HCl	3.36
Boiled 5 minutes with 1–10 HCl	2.94
Boiled 30 minutes with 1–1 HCl	4.24
Boiled 30 minutes with 1–50 HCl	3.21

As shown in Bulletin 207, the treatment of a leucite rock[1] with ammonium chloride without the preliminary fusion will convert the potassium of the leucite entirely into the soluble form. If an open vessel is used, however, instead of the sealed tube, and the heating is continued too long the action is reversed. The soluble potassium salt which is formed at first will react with the insoluble ammonium compound, and the potassium itself will become insoluble.

[1] An estimate of the quantity of leucite-bearing rock available in the Leucite Hills, Wyoming (U. S. Geol. Survey Bull. 512, p. 35, 1912) gives nearly 2,000,000,000 tons, containing an average of 10 per cent of potash.