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Author ~~XXXX~~ and Agency: John E. Shelton, USBM

Title: "Flotation Studies on Copper-Nickel Sulfide Ores From Deposits Near Rockport, Maine."

Submitted by Bureau of Mines for approval for publication

as (or in) Report of Investigation

This manuscript (with accompanying illustrations) has been reviewed for compliance with the joint memorandum of the Directors (with concurrence by the Administrator) dated June 8, 1953, and except for the points listed below the manuscript meets the principles outlined therein.

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OME	G. C. Selfridge	7/19/60	7/22/60

Page 4, 3rd Par. Sample T-1, 5th line, states "conditioned with 0.06 pound of pine oil... ." But Table 1, on page 6, shows same sample as conditioned with 0.03 pounds pine oil. In title same Table 1, p. 6, Amendability?

Page 27. Conclusions, last sentence, clear?

/Roland F. Beers, Inc., DMEA-4947, Idm-E1224/

FLOTATION STUDIES ON COPPER-NICKEL SULFIDE ORES FROM DEPOSITS NEAR ROCKPORT, MAINE

By John E. Shelton

* * * * * * * * Report of Investigations ____

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Fig.
1. Batch flotation of Cu-Ni sulfide ore .....

FLOTATION STUDIES ON COPPER-NICKEL SULFIDE ORES FROM DEPOSITS NEAR ROCKPORT, MAINE 1/

by

John E. Shelton 2/

SUMMARY

Flotation test work was conducted on two samples of Cu-Ni-bearing ore from the Harriman Area near Rockport, Maine. The samples were taken by Roland F. Beers, Inc., for testwork in cooperation with the Federal Bureau of Mines.

Sample T-1 analyzing 0.38 percent Cu and 0.71 percent Ni was essentially a disseminated pyrrhotite in hypersthene. Pentlandite, chalcopyrite, pyrite and millerite were intimately associated with the pyrrhotite.

Locked series flotation tests on this sample showed that 87.3 and 73.2 percent of the Cu and Ni respectively could be recovered in a bulk concentrate that analyzed 2.43 percent Cu and 5.28 percent Ni. The copper and nickel-bearing minerals were collected with sulfhydric collectors in an alkaline circuit. Cleaning the concentrate three times with the addition of pH regulators was sufficient in attaining the grades reported above.

Sample T-3 had analyses of 0.32 percent Cu and 0.85 percent Ni and contained talc in addition to the hypersthene as the main gangue minerals. Bulk sulfide flotation was made after depressing the talc and resulted in a concentrate that analyzed 2.33 percent Cu and 4.70 percent Ni at recoveries of 70.0 and 54.4 percent respectively. Flotation of the

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1/ Work on manuscript completed June 1960.
2/ Supervising Metallurgist, Bureau of Mines, College Park Metallurgy Research Center, Region V, College Park, Maryland.

talc followed by bulk sulfide flotation resulted in grade of Ni in excess of 5 percent. A locked series test similar to the one conducted on Sample T-1, except for a talc flotation circuit prior to the sulfide flotation, showed that 60.7 percent of the Cu and 73.7 percent of the Ni could be recovered at grades of 1.29 percent and 4.85 percent respectively.

Attempts to make selective copper concentrates on Sample T-1 showed that a concentrate could be made that had analyses of 20.3 percent Cu and 2.67 percent Ni. All selective copper flotation attempts on Sample T-3 resulted in concentrates that contained more Ni than Cu.

INTRODUCTION

This testwork was conducted in cooperation with Roland F. Beers, Inc., which is presently evaluating a copper-nickel deposit near Rockport, Maine. Geophysical prospecting with some core drilling in cooperation with the Office of Mineral Exploration have indicated over 2-million tons of ore similar to that used for the testwork. The development of such a deposit with a method of concentrating the contained valuable minerals would be of great benefit to the national economy and defense of the United States.

The minimum objective for the nickel-bearing concentrates was arbitarily set at 5 percent Ni with no minimum on the copper.

ACKNOWLEDGEMENT

The author acknowledges the assistance of Dr. Roland F. Beers, President, Roland F. Beers, Inc., in supplying the samples and furnishing funds to make the testwork possible.

NATURE OF ORE

Two samples of ore from the Harriman Area, about 5 miles west of Rockport, Maine were submitted by Roland F. Beers, Inc., for beneficiation studies. Petrographic examination of the two samples designated T-1 and T-3, showed that Sample T-1 was essentially a disseminated pyrrhotite in hypersthene. Associated in the pyrrhotite were minor amounts of pentlandite, chalcopyrite, pyrite and trace amounts of millerite. Other gangue minerals were anorthosine, feldspar, hornblende, tremolite, phlogopite and talc.

Examination of Sample T-3 showed it contained disseminated pyrrhotite in talc and hypersthene. Intimately associated with the pyrrhotite were minor amounts of pentlandite, chalcopyrite, pyrite, and millerite. Other gangue minerals were chlorite, phlogopite, muscovite, tremolite, anthophyllite and dolomite.

Some nickel oxides and silicates were found in both samples. Approximately 5-8 percent of the nickel was in the oxides and silicates and not recoverable by flotation using sulfhydric reagents.

Quantitative chemical analyses showed Sample T-1 contained 0.39 percent Cu and 0.71 percent Ni, and Sample T-3 0.31 percent Cu and 0.85 percent Ni.

Screen analyses were made on samples of each material after crushing to minus 10-mesh. The screen analyses showed that the minus 100-mesh fractions of each material were upgraded slightly, and the coarser fraction decreased in grade. None of the fractions had low enough Cu or Ni analyses to be discarded nor were the finer sizes high enough in Ni or Cu content to be considered a final product.

BENEFICIATION TESTWORK

Testwork conducted in the past [3] on ores containing chalcopyrite

3/ Shelton, J. E., Beneficiation Studies of Nickelferrous Ores from the Shamrock Mine, Jackson County, Ore., and the Congress Mines, Ferry County, Wash.: Bureau of Mines Report of Investigations 5261, Oct. 1956, 8 pp.

and pentlandite or millerite showed that these minerals could be concentrated by flotation using Minerec B [4] and secondary butyl xanthate in alkaline

4/ Minerec Corporation, 120 Broadway, New York City, New York

circuits.

The two samples from the Maine deposit contained the same minerals as the Oregon ores and application of similar reagent schemes should be successful. Careful control of the pH might also result in selective separation of the copper from the nickel provided the minerals are liberated from each other at the size the material was ground for testwork. Figure 1 shows a test in progress.

Sample T-1 (low talc)

The first tests were made to determine the amenability of the ore to selective copper and nickel flotation. Representative portions of Sample T-1 were ground to approximately 50 and 75 percent minus 200-mesh with 0.06 pound of Minerec B per ton of ore. The ground pulps were separately conditioned with 0.06 pound of pine oil and 3.0 pounds of CaO per ton to raise the pH to 10.7. Rougher concentrates were floated and then cleaned once at a pH of 10.2 with out further reagent additions.

The rougher and cleaner tailings were combined and conditioned with 0.5 pound of secondary butyl xanthate, called xanthate for the balance of the report, 0.06 pound of pine oil per ton of ore and enough

WEMCO

Fig. 1 - Batch flotation of Cu-Ni sulfide ore.

H_2SO_4 to lower the pH to 8.6. Rough Ni concentrates were floated and cleaned once at a pH of 8.6 without additional reagents. Results of these tests, as shown in Table 1, indicate that copper concentrate grades of 20.3 percent can be made from the finer ground material by this scheme, but the nickel content was 2.3 percent. The copper recovery was 61.2 percent. An additional 22.5 percent of the copper reported in the nickel concentrate at a grade of 0.9 percent Cu.

This reagent scheme, while not resulting in good selective copper or nickel concentrates, did indicate a way to achieve satisfactory bulk concentrates.

The next test was made to determine the effect of bulk flotation followed by selective copper flotation. The ore was ground to about 50 percent minus 200-mesh with 0.15 pound of Minerec B per ton of ore. A bulk sulfide flotation was made after conditioning the ground pulp with 0.5 pound of xanthate and 0.06 pound of pine oil per ton of ore. The rougher concentrate was cleaned once at a pH of 7.8 without additional reagents.

The cleaned concentrate was conditioned with 3.0 pounds of CaO per ton of ore to raise the pH to 11.8. The copper minerals were floated to leave a nickel-rich tailing as shown in Table 2. The liberated pentlandite was depressed at the higher pH but unliberated chalcopyrite-pentlandite admixtures and millerite floated resulting in the high-nickel content of the copper concentrate.

TABLE 1 - Amenability of Sample T-1 to selective copper and nickel flotation tests

Reagent Scheme

Circuit	Time, min.	pH	Reagents consumption, pounds per ton: Minerec B	Xanthate	Pine oil	CaO
Cu rougher	3	10.7	0.06	---	0.03	3.0
Cu cleaner	2	10.2	----	---	----	---
Conditioning	3	----	----	0.4	0.03	---
Ni rougher	5	8.3	----	---	----	---
Ni cleaner	4	7.7	----	---	----	---

Metallurgical Data

50 percent minus 200-mesh grind

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Cu concentrate	5.2	6.2	9.1	87.7	69.0
Ni concentrate	7.4	<.01*	1.16	.2	12.5
Ni cleaner tailing	8.1	.15	.30	3.3	3.5
Rougher tailing	79.3	.04	.13	8.7	15.0
Calculated head	100.0	0.37	0.69	100.0	100.0
Assay head		0.38	0.71		
Combined Cu, Ni concentrate	12.6	2.5	4.4	87.9	81.5

75 percent minus 200-mesh grind

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Cu concentrate	1.1	20.3	2.28	61.2	3.9
Ni concentrate	8.8	.93	5.37	22.5	72.7
Ni cleaner tailing	8.5	.22	.54	5.1	7.1
Rougher tailing	81.6	.05	.13	11.2	16.3
Calculated head	100.0	0.37	0.69	100.0	100.0
Assay head		0.38	0.71		
Combined Cu, Ni concentrate	9.9	3.08	5.03	83.7	76.6

*Calculated as 0.01 percent Cu.

TABLE 2 - Bulk flotation followed by selective copper flotation on ore Sample T-1 ground to 50 percent minus 200-mesh

Reagent Scheme

Circuit	Time, min.	pH	Reagents consumption, pounds per ton: Minerec B	Xanthate	Pine oil	CaO
Grind	---	---	0.15	----	----	----
Conditioning	5	---	----	0.5	0.06	----
Bulk rougher	5	8.2	----	----	----	----
Bulk cleaner	4	7.8	----	----	----	----
Cu rougher	3	11.8	----	----	----	3.0

Metallurgical Data

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Cu concentrate	2.4	13.0	2.67	83.8	9.1
Ni concentrate	10.4	.29	4.80	8.1	71.0
Bulk cleaner tailing	7.5	.15	.49	3.0	5.2
Rougher tailing	79.7	.024	.15	5.1	14.7
Calculated head	100.0	0.37	0.70	100.0	100.0
Assay head		0.38	0.71		
Bulk cleaner concentrate	12.8	2.67	4.40	91.9	80.1

The next series of tests was made to determine the effect of higher pH during rough flotation, finer grind and the addition of CaO in the grinding circuit.

Ore samples were ground to 75 and 85 percent minus 200-mesh with 0.12 pound of Minerec B per ton of ore. A bulk flotation was made on samples from each size of ground feed. The pH was adjusted to 9.2 with the addition of 1 pound of CaO per ton of ore. Each rougher concentrate was cleaned once at a pH of 9.5 with 0.5 pound of CaO per ton of ore and recleaned with no reagent additions. Results of these tests, shown in Table 3, indicate that finer grinding will increase the grade of concentrate but at lower recoveries.

Tests were then made in which CaO was added in the grinding circuit. The addition of CaO during the grind coated or in some way depressed the sulfide minerals. The grades and recovery of Cu and Ni in the concentrates were lower than in earlier tests and there was no preferential flotation of chalcopyrite at higher pH values. Addition of H_2SO_4 or $CuSO_4$ reactivated the copper and nickel minerals.

A similar test was run to substantiate the observations. Very little floated until $CuSO_4$ was added, then the recoveries approached those of tests in which CaO was not used or added to conditioning circuit, but the grades of concentrates were lower as shown in Tables 4 and 5. A scavenger circuit was run on the second test to decrease the loss in tailing. Cleaning the scavenger concentrate did not increase the grade to that of the head sample.

It was also noted in other tests that if the pH of the rougher flotation was above 9.5 or if CaO was added that the recoveries

TABLE 3 - Bulk flotation tests on Sample T-1 ground to 75 and 85 percent minus 200-mesh

Reagent Scheme

Circuit	Time, min.	pH	Reagent consumption, pounds per ton: Minerec B	Xanthate	Pine oil	CaO
Grind	----	---	0.12	---	----	---
Bulk rougher	6	9.2	----	0.5	0.06	1.0
Bulk cleaner No. 1	5	9.5	----	---	0.03	.5
Bulk cleaner No. 2	3	8.5	----	---	----	---

Metallurgical Data

75 percent minus 200-mesh grind

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Bulk concentrate	12.2	2.67	4.38	86.8	76.0
Cleaner tailing No. 2	3.1	.38	.96	3.1	4.3
Cleaner tailing No. 1	8.4	.18	.52	4.0	6.4
Rougher tailing	76.3	.03	.12	6.1	13.3
Calculated head	100.0	0.38	0.69	100.0	100.0
Assay head		0.38	0.71		

50 percent minus 200-mesh grind

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Bulk concentrate	7.1	4.55	6.85	81.9	69.2
Cleaner tailing No. 2	4.5	.43	1.20	4.9	7.7
Cleaner tailing No. 1	18.7	.13	.42	6.1	11.2
Rougher tailing	69.7	.04	.12	7.1	11.9
Calculated head	100.0	0.39	0.70	100.0	100.0
Assay head		0.38	0.71		

TABLE 4 - Effect of CaO in grinding circuit on Sample T-1

Reagent Scheme

Circuit	Time, min.	pH	Reagent consumption, pounds per ton				
			CaO	Minerec B	Xanthate	Pine oil	$CuSO_4$
Grinding	---	9.5	2.0	0.12	---	----	---
Conditioning	5	---	1.0	----	0.5	0.06	---
Rougher float	3	10.5	nothing floated		---	----	---
Conditioning	5	---	.5	----	---	----	0.2
Rougher float	5	10.5	---	----	---	----	---

Metallurgical Data

Product	Weight, percent	Analyses, percent		Distribution, percent	
		Cu	Ni	Cu	Ni
Concentrate	2.48	1.4	2.3	90.0	82.8
Rougher tailing	75.2	.05	.16	9.8	17.2
Calculated head	100.0	0.39	0.70	100.0	100.0
Assay head		0.38	0.71		

TABLE 5 - Effect of CaO in grinding circuit of Sample T-1 with scavenger float

Reagent Scheme

Circuit	Time min.	pH	Reagent consumption, pounds per ton: Minerec CaO	Minerec B	Xanthate	Pine oil	$CuSO_4$	H_2SO_4
Grinding	---	9.5	2.0	0.12	---	----	---	---
Conditioning	5	---	1.0	----	0.5	0.06	---	---
Rougher flotation	3	10.5	very little floated			----	---	---
Conditioning	5	---	.5	----	---	----	0.2	---
Rougher flotation	5	10.5	---	----	---	----	---	---
Conditioning	3	---	---	----	.2	.03	---	1.5
Scavenger flotation	3	7.8	---	----	---	----	---	---
Scavenger cleaner flotation	3	---	---	----	---	----	---	---

Metallurgical Data

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Rougher concentrate	18.1	2.19	3.06	94.3	78.1
Scavenger concentrate	12.9	.05	.58	1.5	10.6
Cleaner tailing	7.5	.07	.25	1.3	2.6
Rougher tailing	61.5	.02	.10	2.9	8.7
Calculated head	100.0	0.42	0.71	100.0	100.0
Assay head		0.38	0.71		

were not as good as when H_2SO_4 was added for pH adjustment. Addition of <0.2 pound of $CuSO_4$ per ton helped to increase recoveries, when H_2SO_4 was not added but the grades of Cu and Ni were lower. This decrease in grade probably was because some of the nickeliferous pyrrhotite and pentlandite-pyrrhotite admixture was activated, increasing recovery, but diluting the concentrate.

Evaluation of the test shown in Table 1 indicated that the loss of copper and nickel in the rougher tailing was lowest for the coarser grind. Since the grade was not sufficiently high the next tests were made to determine if the grades could be improved by regrinding the rougher or first cleaner concentrate followed by additional cleaning. The regrind would then be made on 14-25 percent of the weight of original material saving considerable grinding costs.

Samples were ground to about 50 percent minus 200-mesh with 0.12 pound of Minerec B and the ground pulps were conditioned with 0.5 pound of secondary butyl xanthate and 0.06 pound of pine oil per ton of ore. The bulk rougher concentrate from one test and the bulk cleaner concentrate for the other were reground to about 90 percent minus 325-mesh. The first sample was cleaned twice after regrinding the rougher concentrate with the addition of 0.1 pound of xanthate and 0.3 pound of pine oil at a pH of 8.7 for the first cleaner and no additional reagents and a pH of 8.4 for the second cleaner. The second sample was cleaned once, reground, and cleaned a second time at a pH of 8.6 with the addition of 0.1 pound of xanthate and 0.03 pound of pine oil per ton of ore.

The nickel grades in the bulk concentrates from these tests were 5.0 and 5.6 percent at recoveries of 66.6 and 57.0 percent, respectively, indicating that this process would produce satisfactory grade concentrates at a relatively low recovery.

Selective copper flotation was made from the final bulk concentrate from each test to determine if selectivity had been improved by the finer grinding. The copper floats were made by raising the pH to 11.1 and 11.2 by adding 3.0 pounds of CaO per ton of ore. The copper grade was improved, but there was still poor selectivity between the copper and nickel minerals. Results of the test on one sample are shown in Table 6.

Screen analyses were made on samples of rougher tailings from the tests shown in Table 3 to determine if there was a concentration of copper or nickel in any size fraction. As seen in Table 7 there were increases in grades in the minus 325-mesh fraction but not enough to be significant or warrant further testwork on these fractions.

Wet magnetic separations were also made on the tailings from the coarser ground sample shown in Table 3 to determine if flotation of all the pyrrhotite (which was magnetic) would increase recovery of the nickel. There was no improvement in grade and any nickeliferous pyrrhotite recovered would dilute the concentrate grade resulting in unsatisfactory concentrates. Results are shown in Table 8.

Evaluation of the testwork up to this point showed that the attempts to make selective copper flotation with Minerec B only, as shown in Table 1, resulted in the best Ni grade at good recovery. An increase

TABLE 6 - Regrind of bulk rougher or cleaner concentrates from sample T-1 with selective copper flotation from final bulk concentrate

Reagent Scheme

Circuit	Time min.	pH	Reagent consumption, pounds per ton: CaO	Minerec B	Xanthate	Pine oil
Grind 50%-325	---	---	---	0.12	---	----
Condition	5	---	---	----	0.5	0.03
Rougher flotation	5	8.7	---	----	---	----
Cleaner flotation No. 1	3	9.0	---	----	0.1(1)	0.03(1)
Cleaner flotation No. 2	2	8.5	---	----	0.1(1)	0.03(2)
Cu flotation	---	11.1	2.5	----	---	----

(1) Added after regrind of rougher concentrate only
(2) Added after regrind of first cleaner concentrate only

Metallurgical Data

Regrind of rougher concentrate

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Cu concentrate	0.8	18.6	4.60	37.5	5.4
Ni concentrate	6.1	2.74	5.73	34.5	51.5
Cleaner tailing No. 2	7.6	.69	1.60	13.2	17.9
Cleaner tailing No. 1	11.2	.32	.60	9.0	9.9
Rougher tailing	74.3	.031	.14	5.8	15.3
Calculated head	100.0	0.40	0.68	100.0	100.0
Assay head		0.38	0.71		
Combined Cu and Ni concentrate	6.9	4.14	5.6	72.0	56.9

Regrind of cleaner concentrate

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Cu concentrate	2.6	8.07	7.18	56.5	28.9
Ni concentrate	6.7	1.16	3.79	20.2	37.7
Cleaner tailing No. 2	4.6	.79	1.53	9.4	10.4
Cleaner tailing No. 1	8.2	.33	.66	7.0	8.0
Rougher tailing	77.8	.034	.13	6.9	15.0
Calculated head	100.0	0.39	0.67	100.0	100.0
Assay head		0.38	0.71		
Combined Cu and Ni concentrates	9.4	3.14	5.0	76.7	66.6

TABLE 7 - Screen analyses of rougher tailing from tests shown in Table 5-

72 percent minus 200-mesh grind

Size fraction, mesh	Weight, percent	Analyses, percent Cu	Ni	Distribution, percent Cu	Ni
plus 200	23.7	0.03	0.09	20.9	17.3
200/325	18.1	.02	.08	10.6	11.8
minus-325	58.2	.04	.15	68.5	70.9
Calculated head	100.0	0.03	0.12	100.0	100.0
Assay head		0.03	0.12		

85 percent minus 200-mesh grind

Size fraction, mesh	percent	Analyses, percent Cu	Ni	Distribution, percent Cu	Ni
plus 200	13.9	0.02	0.10	10.4	11.6
200/325	17.8	.02	.10	12.9	14.7
minus-325	68.3	.03	.13	76.7	73.7
Calculated head	100.0	0.03	0.12	100.0	100.0
Assay head		0.04	0.12		

TABLE 8 - Low intensity wet magnetic separation on rougher tailing from tests shown in Table 5

Product	Weight, percent	Analyses, percent Cu	Ni	Distribution, percent Cu	Ni
Magnetic	18.4	0.02	0.12	10.2	18.4
Non-magnetic	81.6	.04	.12	89.8	81.6
Calculated head	100.0	0.04	0.12	100.0	100.0
Assay head		0.03	0.12		

in the amount of Minerec B should increase the recovery with little decrease in grade. Since this appeared to be the best flowsheet a locked series test was conducted on Sample T-1 to determine the effect of recycling products and reagent buildup and to minimize the weight and loss of valuables as reflected in the cleaner tailings. The test was conducted as follows:

Five portions of Sample T-1 of 1,000 grams each were labled A, B, C, D, and E. Sample A was ground to about 60 percent minus 200-mesh with 0.35 pound of Minerec B per ton of ore. The sulfides were floated with the addition of 0.05 pound of pine oil per ton of ore at the natural pH of 8.9 for 3 minutes. An addition of 0.1 pound of secondary butyl xanthate was then made and the flotation continued for 2 minutes.

The concentrate was cleaned twice with no further reagent addition at pH of 8.6 and 8.4. The concentrate was then cleaned a third time with the addition of 0.05 pound of Minerec B and 0.025 pound of pine oil per ton of ore.

The first cleaner tailing from sample A was added to the ball mill and ground with sample B. The second and third cleaner tailings from sample A were advanced to the first and second cleaner steps for sample B. Samples B, C, and D were treated the same way. The cleaner tailings from sample E were final products and saved for analyses.

The pH gradually increased in each flotation step and 0.2 pound of H_2SO_4 was added to the rougher third cleaner of sample E. The amount of froth gradually increased as the test proceeded and no pine oil was added in the third cleaner flotation for sample E. Otherwise there were no changes in reagent additions. Results shown in Table 9.

TABLE 9 - Locked series test on Sample T-1

Reagent Scheme

Circuit	Time minutes	pH A	pH B	pH C	pH D	pH E	Reagent consumption, pounds per ton: Minerec B	Pine oil	Butyl Zanthate	H_2SO_4
Grind	---	---	---	---	---	---	0.35	----	---	---
Rougher	5	8.9	9.2	9.1	9.0	8.8	----	0.05	0.1	0.2 (2)
Cleaner No. 1	3	8.6	8.9	8.7	9.1	9.3	----	----	---	---
Cleaner No. 2	2	8.4	8.7	8.6	9.1	9.0	----	----	---	---
Cleaner No. 3	2	8.1	8.4	8.3	9.1	8.8	----	0.025(1)	---	0.2 (2)

(1) Omitted for sample E
(2) Added for sample E only

Metallurgical Data

Product	Weight, percent	Analyses, percent Cu	Analyses, percent Ni	Distribution, percent Cu	Distribution, percent Ni
Concentrate A	1.5	4.31	6.90	16.6	14.5
Concentrate B	2.1	3.34	5.23	18.1	15.4
Concentrate C	1.7	3.82	5.61	16.7	13.4
Concentrate D	2.1	3.28	5.01	17.7	14.7
Concentrate E	2.4	2.95	4.51	18.2	15.2
Cleaner tailing 3E	1.4	.50	1.40	1.8	2.7
Cleaner tailing 2E	2.3	.37	.67	2.2	2.2
Cleaner tailing 1E	4.1	.14	.41	1.5	2.4
Rougher tailing A	14.8	.03	.13	1.2	2.7
Rougher tailing B	15.8	.04	.16	1.6	3.5
Rougher tailing C	17.8	.04	.21	1.8	5.2
Rougher tailing D	17.0	.03	.18	1.3	4.3
Rougher tailing E	16.9	.03	.16	1.3	3.8
Calculated head	100.0	0.39	0.71	100.0	100.0
Assay head	(1)	0.39	0.71		
Combined concentrates	9.9	3.43	5.28	87.3	73.2
Cleaner tailing 3E	1.4	.50	1.40	1.8	2.7
Cleaner tailing 2E	2.3	.37	.67	2.2	2.2
Cleaner tailing 1E	4.1	.14	.41	1.5	2.4
Combined rougher tailing (1)	82.3	.03	.17	7.2	19.5

(1) All values are calculated.

The natural pH of the ore was determined while using College Park tap water. Water from other areas might require a pH modifier to achieve optimum results.

Sample T-3 (high talc)

The methods used on sample T-1 to recover copper and nickel would probably be applicable to sample T-3 with modifications, therefore, testwork on this sample was conducted along two lines: (1) removal of the easily floated talc using only frothers followed by flotation of the Cu-Ni sulfide minerals with xanthates or Minerec B, and (2) direct flotation of the sulfide minerals with xanthates while the talc was depressed.

The expected advantage of the first method would be higher grade concentrates and probably higher recoveries. The second method might result in lower grades and recoveries. It was anticipated that all of the talc could not be depressed, which would cause some dilution of the concentrates and the talc depressant would also depress some of the Cu-Ni minerals. The advantage of the second method would be the elimination of one circuit from the flowsheet.

The first series of tests was made by first floating the talc, followed by bulk flotation of the copper and nickel. Results of the tests showed that bulk concentrates containing 2.5 percent Cu and 5.4 percent Ni could be made after cleaning once. The recoveries were 73.3 percent of the copper and 57.8 percent of the nickel. Results of one of these tests are shown in Table 10.

Several attempts were made to selectively float the copper, but in all cases the nickel content was higher than the copper. Selective

TABLE 10 - Talc flotation followed by bulk sulfide flotation on Sample T-3 ground to 75 percent minus 200-mesh

Reagent Scheme

Circuit	Time min.	pH	Reagent consumption, pounds per ton: $Pb(NO_3)_2$	Minerec B	Xanthate	Pine oil	CaO
Grind	---	---	---	---	---	---	---
Condition	5	---	0.2	---	---	---	---
Talc rougher float	7	8.0	---	---	---	---	---
Talc cleaner float No. 1	5	8.2	---	---	---	---	---
Talc cleaner float No. 2	5	8.4	---	---	---	---	---
Conditioner (Combined tailings)	5	---	---	0.06	0.5	.03	1.0
Bulk rougher float	5	9.1	---	---	---	---	---
Bulk cleaner float	3	8.8	---	---	---	---	---

Metallurgical Data

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Talc concentrate	11.2	0.13	0.18	5.0	2.5
Bulk concentrate	8.7	2.46	5.36	73.3	57.8
Cleaner tailing	12.3	.24	.95	10.0	14.5
Rougher tailing	67.8	.05	.30	11.6	25.2
Calculated head	100.0	0.29	0.81	100.0	100.0
Assay head		0.31	0.82		

copper concentrates from one of these tests showed that the copper grade could be raised to 9.0 percent, but the nickel content was 12.5 percent. Recoveries of copper and nickel were less than 60 percent and 30 percent, respectively. Regrinding the bulk concentrates prior to selective copper flotation did not alter the high ratio of nickel-to-copper. The two minerals are so finely disseminated in each other that they are not completely liberated by regrinding or the millerite in this ore apparently floats in the same pH range as chalcopyrite.

During the testwork on the Congress Mine ore[5] it was noted

5/ Work cited in footnote 3, page 4.

that higher pH values tended to depress millerite, but the depression was not quantitative, some still floated. The presence of copper ions in the Harriman ore could also be activating the millerite causing it to float at the high pH.

AC620[6] was used as a talc depressant during the bulk sulfide

6/ American Cyanamid, 30 Rockefeller Plaza, New York, New York.

flotation in the second line of testwork. Samples were ground to 90 percent minus 200-mesh with Minerec B and conditioned with xanthate, pine oil, $CuSO_4$ and AC620. The bulk sulfide rougher flotation was made at a pH of about 8.5 and the rougher concentrate was cleaned twice at a pH of 8.5 with the addition of AC620. Results of one of these tests are shown in Table 11.

Attempts were made to raise the grade of the concentrates by regrinding after the rougher or first cleaner flotation to approximately 90 percent minus 325-mesh. The recoveries of both copper and nickel were improved but the grades were lower.

TABLE 11 - Bulk sulfide flotation from Sample T-3 ground to 50 percent minus 200-mesh

Reagent Scheme

Circuit	Time min.	pH	Reagent consumption, pounds per ton: Minerec B	Xanthate	Pine oil	$CuSO_4$	AC620
Grind	---	---	0.15	---	----	---	---
Condition	5	---	----	0.5	0.03	0.2	0.5
Rougher flotation	5	8.5	----	---	----	---	---
Cleaner flotation No. 1	3	8.5	----	---	----	---	.25
Cleaner flotation No. 2	3	8.5	----	---	----	---	.25

Metallurgical Data

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Concentrate	9.0	2.33	4.70	70.0	54.4
Cleaner tailing No. 2	15.1	.27	1.03	13.6	20.0
Cleaner tailing No. 1	18.8	.14	.54	8.8	13.1
Rougher tailing	57.1	.04	.17	7.6	12.5
Calculated head	100.0	0.30	0.78	100.0	100.0
Assay head		0.31	0.82		

It was thought that regrinding might improve the selectivity in the copper flotation. The final bulk concentrate from one sample was reground after rougher flotation, repulped and the pH raised to 11.2 with 3.0 pounds of CaO per ton of ore. The selective copper concentrate still had higher nickel than copper analyses (5.25 percent Cu and 5.67 percent Ni). The results of tests utilizing the regrind are shown in Tables 12 and 13.

Generally the direct flotation tests did not result in as high grade concentrates as those in which the talc was floated prior to the sulfides and in many cases the recoveries were lower. After the talc flotation the sulfides had responded the same as those in Sample T-1 so a locked series test was made for comparison of results.

The locked series test run on sample T-3 was similar to the one on sample T-1 except that a talc flotation circuit was added at the beginning of the flotation and the first cleaner tailings from the sulfide circuit were not reground. All cleaner tailings from one sample were advanced to the next earlier step on the next sample. The reagent scheme and metallurgical balance for this test are shown in Table 14. The decrease in the grade of the concentrate was probably due to gradual lowering of the pH in the third cleaner float caused by recycling the products. Recycling the products also caused an increasing loss of copper in the talc concentrate. This loss of copper could probably be reduced by cleaning the talc concentrate a third time or by adding cyanide to the cleaners. Any depressed copper and nickel could be reactivated with $CuSO_4$ before adding Minerec B.

TABLE 12 - Bulk sulfide flotation from Sample T-3 ground to 50 percent minus 200-mesh followed by regrind of rougher concentrate to 90 percent minus 325-mesh, two additional cleaners and selective copper flotation

Reagent Scheme

Circuit	min.	pH	Reagent consumption, pounds per ton: Minerec B	Xanthate	Pine oil	CaO	$CuSO_4$	AC620
Grind	---	---	0.12	---	----	---	---	---
Condition	5	---	----	0.5	0.06	---	0.1	0.2
Rougher flotation	5	8.6	----	---	----	---	---	---
Regrind	---	---	.03	---	----	---	---	---
Cleaner flotation No. 1	5	8.3	----	.1	.03	---	---	.1
Cleaner flotation No. 2	3	8.3	----	---	----	---	---	.03
Copper flotation	2	11.2	----	---	----	3.0	---	---

Metallurgical Data

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Copper concentrate	4.2	5.25	5.67	69.9	29.3
Nickel concentrate	13.2	.24	2.20	10.1	36.2
Cleaner tailing No. 2	8.4	.18	.77	4.8	8.0
Cleaner tailing No. 1	16.2	.15	.49	7.7	9.8
Rougher tailing	58.0	.04	.23	7.5	16.3
Calculated head	100.0	0.31	0.81	100.0	100.0
Assay head		0.31	0.82		
Combined Cu and Ni concentrate	17.4	1.43	3.03	80.0	66.7

TABLE 13 - Bulk sulfide flotation of Sample T-3 ground to 50 percent minus 200-mesh with regrind of cleaner concentrate to 90 percent minus 325-mesh

Reagent Scheme

Circuit	Time min.	pH	Reagent consumption, pounds per ton: Minerec B	Xanthate	Pine oil	$CuSO_4$	AC620
Grind	---	---	0.12	---	----	---	---
Condition	5	---	----	0.5	0.06	0.1	0.2
Rougher flotation	5	8.6	----	---	----	---	---
Cleaner flotation No. 1	3	8.6	----	---	----	---	.1
Regrind	---	---	.03	---	----	---	---
Cleaner flotation No. 2	3	8.1	----	.1	.03	---	.1

Metallurgical Data

Product	Weight, percent	Analyses, percent: Cu	Ni	Distribution, percent: Cu	Ni
Concentrate	20.3	1.36	2.72	84.1	68.8
Cleaner tailing No. 2	6.5	.21	.80	4.2	6.5
Cleaner tailing No. 1	14.3	.10	.44	4.3	7.8
Rougher tailing	58.9	.04	.23	7.4	16.9
Calculated head	100.0	0.33	0.80	100.0	100.0
Assay head		0.31	0.82		

TABLE 14 - Locked series test on Sample T-3

Reagent Scheme

Circuit	Time min.	pH A	pH B	pH C	pH D	pH E	Reagent consumption, pounds per ton: Minerec B	Pine oil	Xanthate
Grind	---	---	---	---	---	---	----	---	----
Talc rougher	5	8.4	8.4	8.6	8.4	8.4	----	0.05	----
Talc cleaner No. 1	3	8.4	8.4	8.6	8.4	8.5	----	---	----
Talc cleaner No. 2	3	8.4	8.5	8.7	8.4	8.5	----	---	----
Condition	3	---	---	---	---	---	0.35	.03	----
Sulfide rougher	5	8.7	8.7	8.6	8.6	8.5	----	---	0.075 (1)
Sulfide cleaner No.1	3	8.4	8.7	8.7	8.5	8.5	----	---	----
Sulfide cleaner No.2	2	8.4	8.3	8.7	8.5	8.4	----	---	----
Sulfide cleaner No.3	2	8.4	8.3	8.4	8.4	8.2	----	---	----

(1) Added after floating for 3 minutes. Float continued for 2 more minutes.

TABLE 14 - Continued

Metallurgical Data

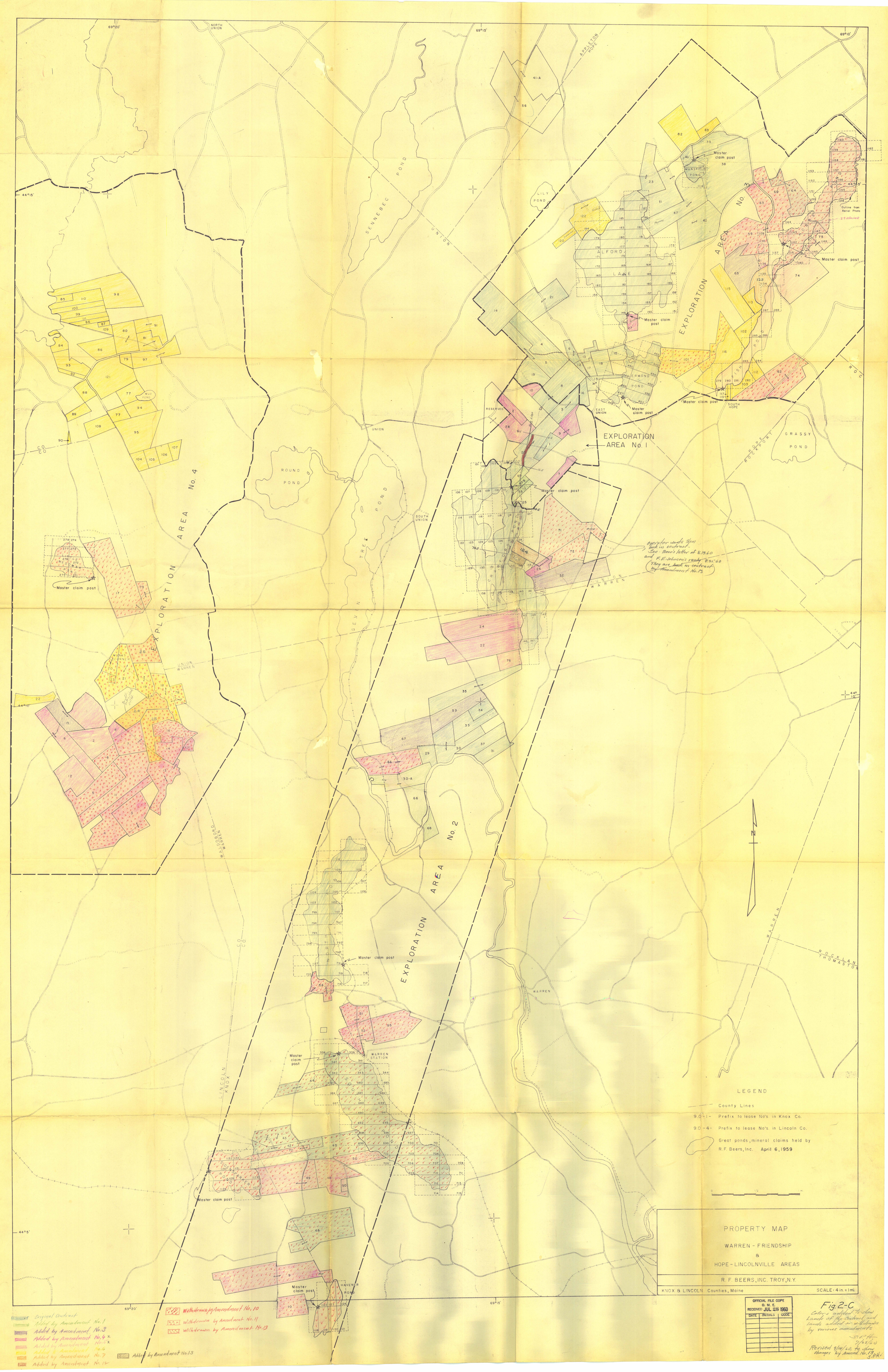
Product	Weight, percent	Analyses, percent Cu	Analyses, percent Ni	Distribution, percent Cu	Distribution, percent Ni
Talc concentrate A	2.2	0.14	0.15	1.1	0.4
Talc concentrate B	2.9	.21	.25	2.2	.9
Talc concentrate C	3.4	.36	.24	4.4	1.0
Talc concentrate D	2.7	.37	.20	3.6	.6
Talc concentrate E	3.2	.48	.20	5.6	.8
Talc cleaner tailing 2E	1.8	.66	.56	4.3	1.2
Talc cleaner tailing 1E	1.4	.42	.70	7.5	4.0
Sulfide concentrate A	1.1	2.25	9.02	9.0	11.7
Sulfide concentrate B	2.9	1.20	4.42	12.7	15.1
Sulfide concentrate C	2.5	1.39	5.10	12.6	15.0
Sulfide concentrate D	2.7	1.35	4.91	13.3	15.6
Sulfide concentrate E	3.7	.97	3.74	13.1	15.3
Sulfide cleaner tailing 3E	2.2	.19	.78	1.5	2.0
Sulfide cleaner tailing 2E	3.8	.10	.47	1.4	2.1
Sulfide cleaner tailing 1E	5.8	.06	.24	1.3	1.6
Rougher tailing A	8.0	.04	.17	1.2	1.6
Rougher tailing B	10.7	.03	.17	1.2	2.3
Rougher tailing C	11.9	.03	.20	1.3	2.8
Rougher tailing D	12.9	.04	.18	1.9	2.7
Rougher tailing E	10.9	.02	.19	.8	2.4
Calculated head	100.0	0.28	0.85	100.0	100.0
Assay head		0.31	0.85		
Combined talc concentrate (1)	14.4	0.32	0.21	16.9	3.7
Talc cleaner tailing 2E	1.8	.48	.56	4.3	3.7
Talc cleaner tailing 1E	4.9	.66	.70	7.5	4.0
Combined sulfide concentrate (1)	12.9	1.29	4.85	60.7	73.7
Sulfide cleaner tailing 3E	2.2	.19	.78	1.5	2.0
Sulfide cleaner tailing 2E	3.8	.10	.47	1.4	2.1
Sulfide cleaner tailing 1E	5.8	.06	.24	1.3	1.6
Combined rougher tailing(1)	54.2	.03	.18	6.4	11.7
Calculated head	100.0	0.28	0.85	100.0	100.0

(1) All values are calculated.

Continuous circuit flotation or pilot plant tests will be needed to determine optimum reagent amounts and any necessary additions of other reagents. A more selective talc circuit will lower the losses of copper in the talc product. Additional copper in the sulfide circuit will not only increase recovery but also the grade of copper.

CONCLUSIONS

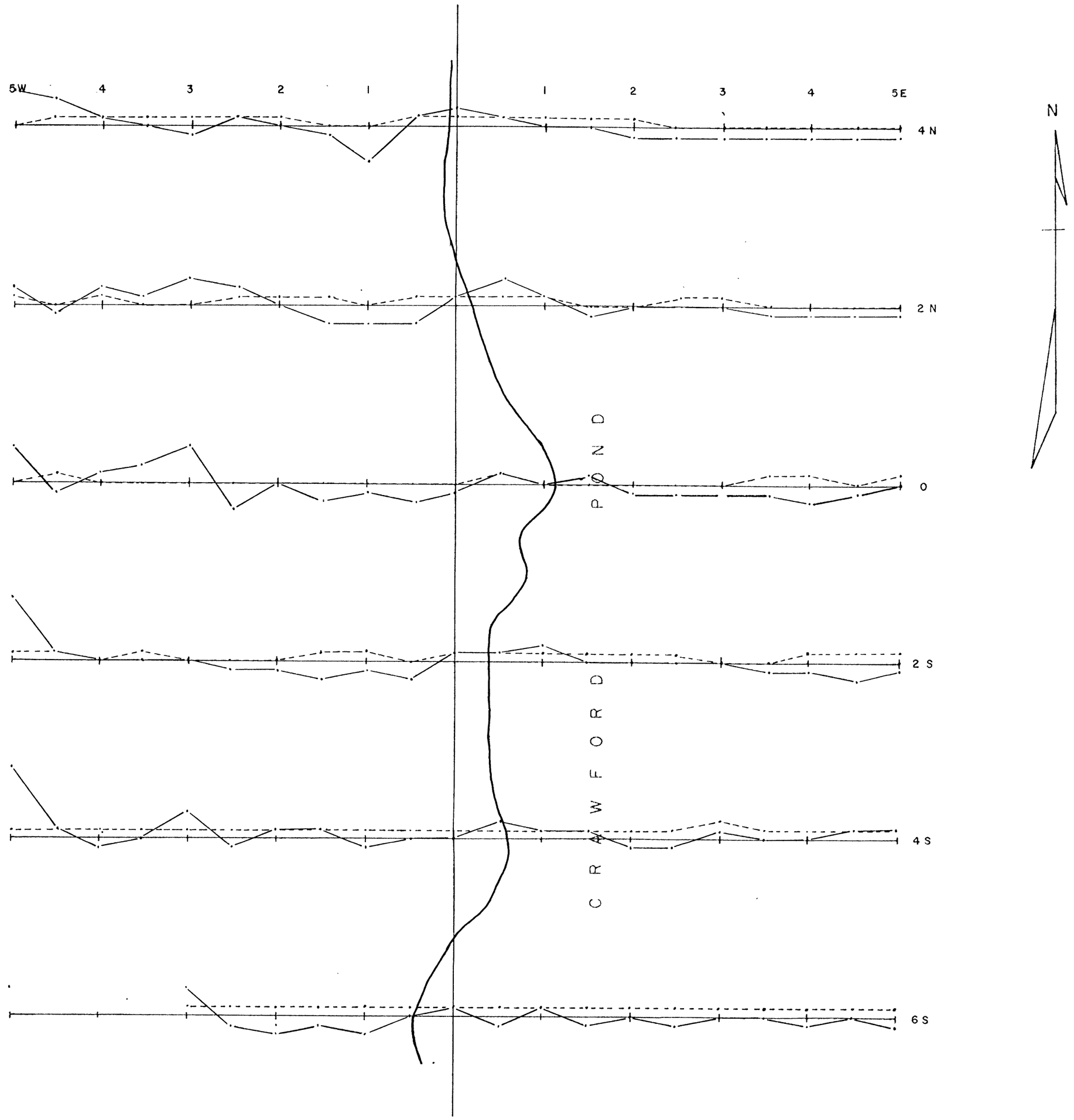
Bulk sulfide flotation will result in combined Cu-Ni concentrates satisfactory for feed to leaching or pyrometallurgical processes. Selective copper concentrates analyzing 20 percent copper can be made from the low talc ore, but further processing would still be required to remove the remaining nickel. If the two types of ores were to be combined for treatment the high Ni content in selective copper concentrates from the high talc ore would be prohibitive.


PROPERTY MAP
WARREN - FRIENDSHIP
&
HOPE - LINCOLNVILLE AREAS
R. F. BEERS, INC. TROY, N.Y.
KNOX & LINCOLN Counties, Maine
SCALE: 4 in. = 1 mi.
LEGEND
County Lines
9.0-1- Prefix to lease No's. in Knox Co.
9.0-4- Prefix to lease No's. in Lincoln Co.
Great ponds, mineral claims held by R.F. Beers, Inc. April 6, 1959
EXPLORATION AREA No. 1
EXPLORATION AREA No. 2
EXPLORATION AREA No. 3
EXPLORATION AREA No. 4
Master claim post
Outline from Aerial Photo
29 claims
operator wants them back in contract - See Beer's letter of 8.19.60 and F.E. Johnson's reply 8.25.60 (They are back in contract by Amendment No. 13)
Original Contract
Added by Amendment No. 1
Added by Amendment No. 3
Added by Amendment No. 4
Added by Amendment No. 5
Added by Amendment No. 6
Added by Amendment No. 7
Added by Amendment No. 12
Withdrawn by Amendment No. 10
Withdrawn by Amendment No. 11
Withdrawn by Amendment No. 13
Added by Amendment No. 13
OFFICIAL FILE COPY. O. M. E. RECEIVED JUL 28 1960
DATE INITIALS CODE
Fig. 2-C
Colors added to show Lands of the Contract and lands added or withdrawn by various amendments
Revised 9/14/60 to show changes by Amend. No. 13

SUMMARY, ASSAY EVALUATION
NOT INCLUDING BARREN ROCK

Line	Hole	Area (ft^2)	$/ton value	Cross-Section Value Ni ft^2 x $/ton	Cross-Section Value Co ft^2 x $/ton	Cross-Section Value Cu ft^2 x $/ton	Longitudinal Interval	Volume ft^3 ($x 10^6$)	Tons ($x 10^6$)	$ Ton Ni	Total Ni ($x 10^6$)	$ Ton Co	Total Co ($x 10^6$)	$ Ton Cu	Total Cu ($x 10^6$)
Harriman															
4N	CP-10	10,989	4.53	31,753	11,554	6,469	4N - 2N	2.11	0.224	4.13	.92	1.02	0.23	0.94	0.21
2N	CP-B	9,225	6.81	43,053	8,754	11,015									
2N	CP-18	919	17.19	12,300	1,208	2,300									
		10,144	7.75*	55,353	9,962	13,315	2N - 0	1.97	0.209	7.56	1.58	1.53	0.32	1.56	0.33
0	CP-33	5,200	12.60	45,775	10,400	9,329									
0	CP-31	4,350	15.11	47,706	9,827	8,195									
		9,550	13.74*	93,481	20,227	17,524	0 - 2S	1.62	0.172	9.84	1.69	2.04	0.35	1.96	0.34
2S	CP-28	1,898	7.50	8,608	2,659	2,989									
2S	CP-27	2,953	17.11	36,304	7,238	7,014									
2S	CP-11	1,798	15.70	21,100	2,930	4,214									
		6,649	14.00*	66,012	12,827	14,217	2S - 4S	1.97	0.209	7.59	1.59	1.74	0.36	1.86	0.39
4S	CP-20	3,863	6.52	16,531	5,190	3,472									
4S	CP-24	6,359	10.70	44,626	9,487	13,956									
4S	CP-25	2,832	12.10	22,351	6,862	5,090									
		13,054	9.77*	83,508	21,539	22,518	4S - 6S	3.77	0.400	7.54	3.01	1.72	0.69	1.84	0.74
6S	CP-2	12,666	10.04	84,760	20,987	21,896									
6S	CP-22	9,216	14.81	98,155	18,875	19,477									
6S	CP-23	2,725	9.83	17,696	3,559	5,545									
		24,607	11.82*	200,611	43,421	46,918	6S - 9S	4.85	0.514	7.64	3.92	1.73	0.89	1.75	0.90
9S	CP-6	5,736	11.50	44,721	11,590	9,678									
9S	CP-17	1,975	1.37	1,678	869	158									
		7,711	8.91*	46,399	12,459	9,836	9S - 12S	2.44	0.259	9.12	2.36	2.29	0.59	1.51	0.39
12S	CP-1	6,488	17.78	86,177	17,927	11,375									
12S	CP-36	2,088	12.47	15,859	6,859	3,338									
		8,576	16.50*	102,036	24,786	14,713	12S - 14.3S	1.98	0.210	12.11	2.54	2.62	0.55	1.80	0.38
14.3S	CP-5	8,629	16,55	106,402	20,300	16,292	14.3S - 15.8S	1.19	0.126	10.93	1.38	1.98	0.25	2.00	0.25
15.8S	H-15.8S-1	7,248	12.91	67,012	11,116	15,500	15.8S-17S	0.64	0.068	7.53	0.51	1.28	0.09	1.67	0.11
17S	CP-13	3,500	5.20	13,360	2,555	2,285									
	Total for Harriman							22.54	2.391	0.54%	19.50	.007%	4.32	.09%	4.04
	Value for Harriman												27.86 x 10^6		
Crawford Pond															
42S	E-1	500	6.14	2,225	435	410	42S - 52S	2.90	0.222	9.61	2.13	1.83	0.40	3.04	0.67
52S	E-3	3,683	15.77	37,936	7,207	12,280	52S-60S	4.15	0.440	9.36	4.12	2.03	0.89	2.51	1.10
60S	E-4	6,703	12.94	59,206	13,825	13,712	60S - 94S	13.36	1.416	9.70	13.74	2.17	3.07	2.13	3.02
94S	S-1	1,158	20.08	17,000	3,212	3,026									
	Total for Crawford Pond							20.41	2.078		19.99		4.36		4.79
	Value for Crawford Pond												29.14 x10^6		
	Grand total							42.95	4.469		39.49		8.68		8.83
	Value for Harriman and Crawford Pond												57.00 x 10^6		
	Average value (57.00 x 10^6 ÷ 4.469 x 10^6)							$12.75/ton							

* denotes Average Value

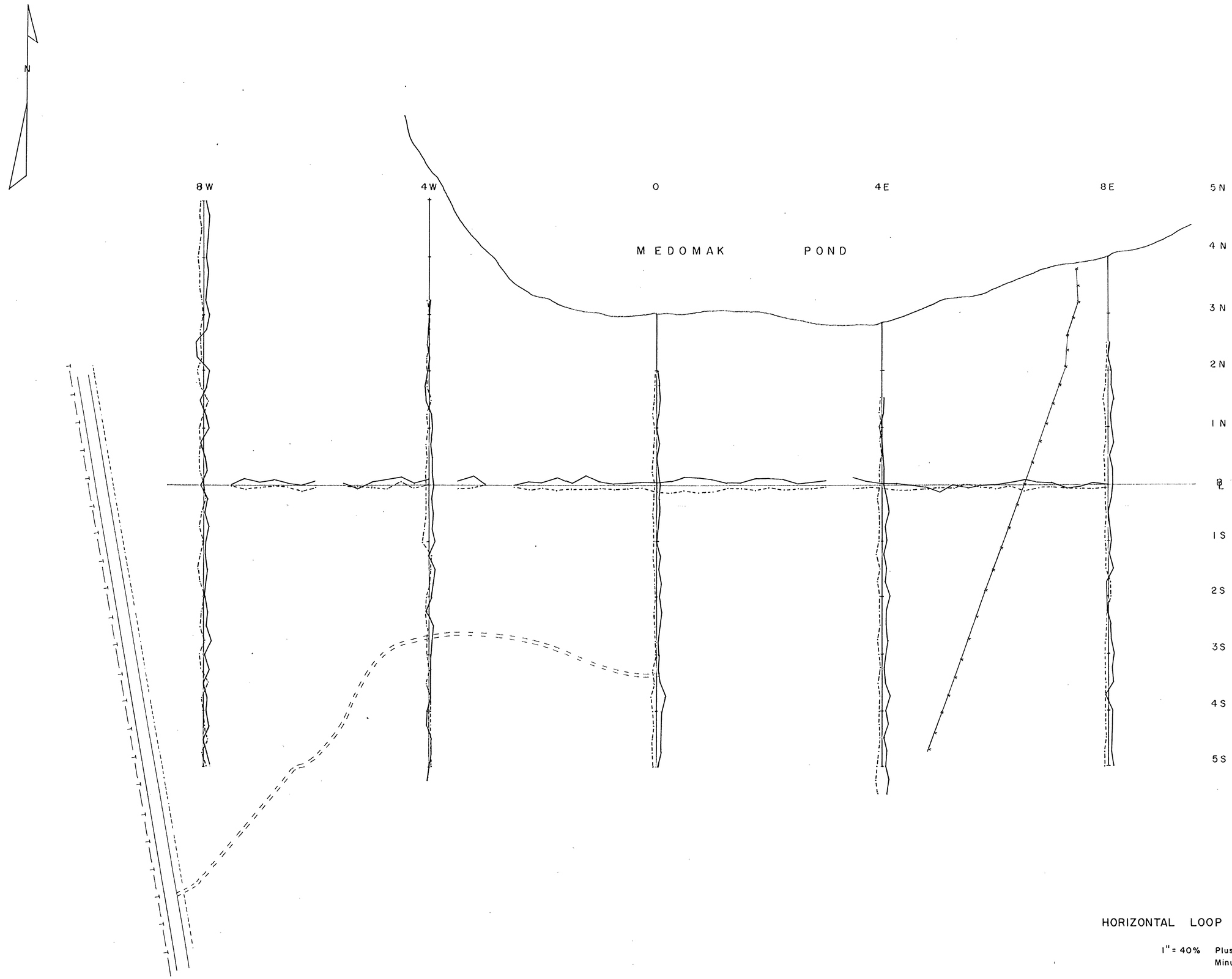


1" = 10 %

In-Phase Profile

Out-of-Phase Profile

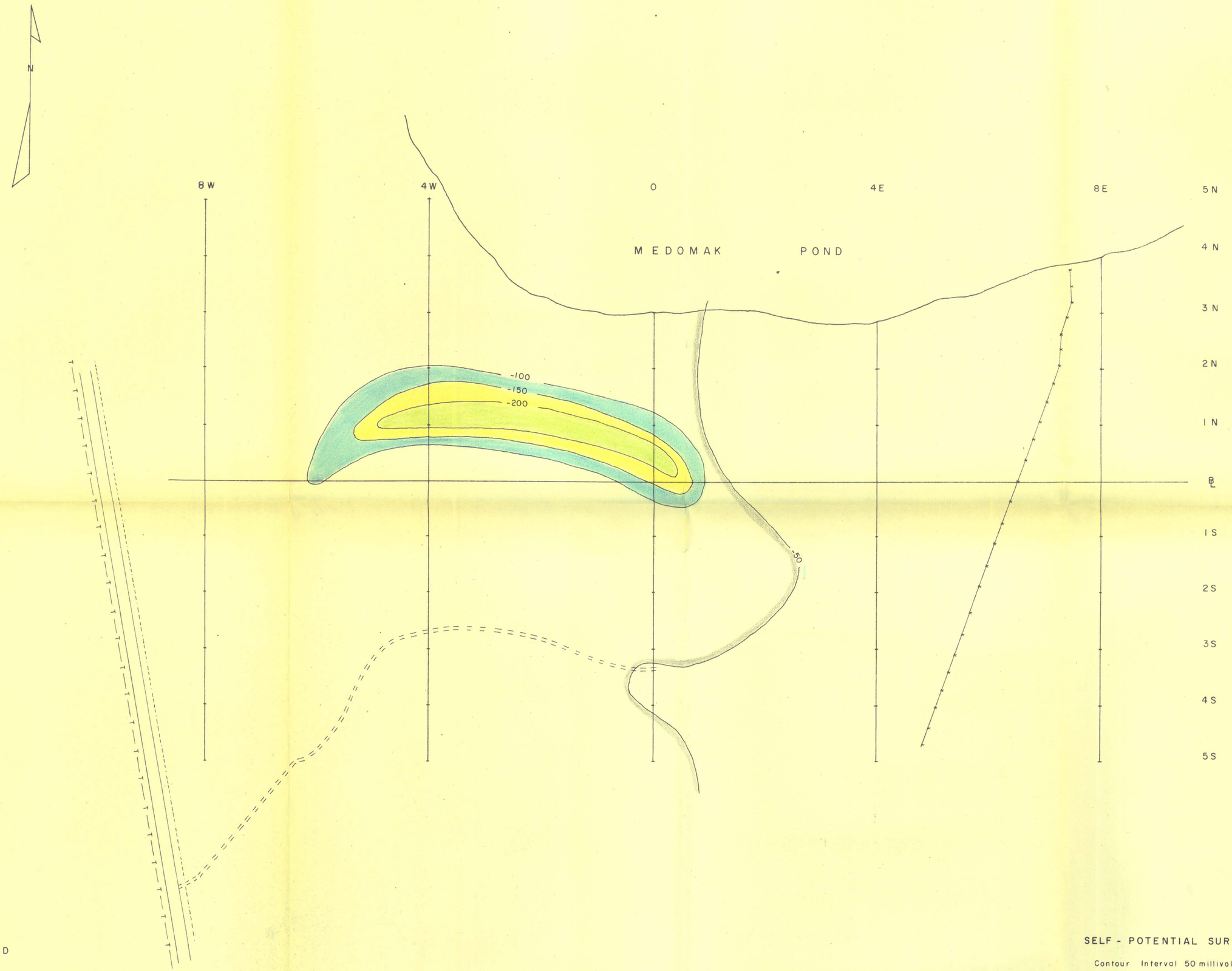
Stage 1 Area 2 Phase 1 (b)	ROLAND F. BEERS, INC. TROY, N.Y.		
	KNOX TIMBER PROSPECT (P-3) HORIZONTAL LOOP E.M.		
	County: KNOX	Twnp: WARREN	Scale: 1in. = 100 ft.



HORIZONTAL LOOP E.M.

1" = 40% Plus - North & East
Minus - South & West

Drawn by :	Stage	ROLAND F. BEERS, INC. TROY, N.Y.
Traced by : R.P	Area	WALTERS PROSPECT
Approved by :	Phase	Co. LINCOLN · Twnp. WALDOBORO · Scale : 1 in. = 100 ft.



LEGEND

- Highway
- Farm Road
- Wire Fence
- Telephone Line
- Low Power Line

SELF - POTENTIAL SURVEY

Contour Interval 50 millivolts

Drawn by :	Stage	ROLAND F. BEERS, INC. TROY, N.Y.
Traced by : R.P	Area	WALTERS PROSPECT
Approved by :	Phase	Co. LINCOLN · Twnp. WALDOBORO · Scale : 1 in. = 100 ft.