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Tittel Amendability Testing of Bidjovagge ore - graphitic shale type				
Forfatter Ottley, D.J.		Dato År 08.07 1961	Bedrift (Oppdragsgiver og/eller oppdragstaker) Kautokeino kobberfelter A/S, USB	
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Råstoffgruppe Malm/metall	Råstofftype Cu,			
Sammendrag, innholdsfortegnelse eller innholdsbeskrivelse Undersøkelser utført ved Imperial College of Science and Technology, Mining and Mineral Technology Department. Appendiks av 22.08.1961 som angir forsøksbetingelsene for alle 19 forsøkene.(testene) hvorav 15 var på grafitmalmen. Vedlagt følgebrev som peker på at behandlingen av denne type malm har vært vanskeligere enn ventet. En av konklusjonene er at den beste behandlingen av grafitmalmen er bulkflotasjon i kalkbasisk miljø med pH 11 Beste test ga 20,1% Cu i kons ved et utbytte på 64% Cu. Grafittkonc holdt 2,05% Cu. En regner med at ytterligere rensing av dette konc vil gi mye høyere utvinning og gehalt i Cu-konc. Malmen av felstype oppførte seg fint til denne type behandling. En oppnådde 26% Cu i konc og 92,5% utvinning. den valgte behandlingstypen var tilpasset begge malmtypene fordi det ble antatt at typene kom til å bli brutt sammenfengt				

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY
(UNIVERSITY OF LONDON)

MINING AND MINERAL TECHNOLOGY DEPARTMENT

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8th July, 1961.

K. Ingvaldsen, Esq.,
Kautokeino Kobberfelter,
Trondheim,
Sverres gt. 1/4,
Norway.

Dear Mr. Ingvaldsen,

Amenability Testing of Bidjovagge ore -
graphitic shale type

Enclosed herewith is a copy of our report describing the amenability testing of this ore. A second copy has been forwarded under separate cover.

The treatment of this ore has proved more difficult than expected, particularly since it is probable that it will be treated admixed with the simpler Fels type ore. Much test work remains to be done, but it is hoped that this report will provide a basis for the ultimate treatment method to be employed.

The details of the bulk of the test work and results have not been included in this report but can be forwarded to you if required.

We will be pleased to have your comments on this report in due course and should you require any additional information or clarification of any part of this document, please do not hesitate to contact us.

Yours sincerely,


D. J. OTTLEY.

INTRODUCTION

A 10 Kg. sample of ore marked "Kautokeino Kobberfelter-Bidjovagge ore - Graphitic shale type" was received on June 1st 1961 for amenability testing in accordance with the instructions of Mr. Ingvaldsen. A similar weight of the Fels type ore was also received for both initial and comparative test purposes.

This report contains the pertinent results and principal conclusions of this test work and suggestions for the further testing of this ore.

SUMMARY AND CONCLUSIONS

- 1) The best method for the treatment of the graphitic shale ore was found to be bulk flotation of the graphite and copper minerals at a 'pH' of about 11.0, using potassium amyl xanthate and pine oil. Grinding to 85% minus 100 mesh B.S.S. in the presence of lime was necessary. The chalcopyrite was separated from the graphite by treatment with sodium sulphide at a pH of about 11.0 wherein the copper minerals were depressed and the graphite floated off in the froth. The full results of this test are shown on pages 2 to 4.
- 2) In the best test, the copper concentrate assayed 20.1% Cu which represented a recovery of 64% copper. The graphite concentrate contained 2.05% Cu and 23% of the copper content of the ore. By further cleaning of this latter concentrate and the copper concentrate a much higher recovery and grade of copper concentrate could be achieved. A 25% Cu concentrate containing 90% of the copper should be possible, once optimum conditions have been found in continuous operations. An outline of further test work required to confirm this is given on pages 7, 8 & 9 of this report.
- 3) The Fels type ore responded well to this same method of treatment and gave a 25% Cu concentrate and a recovery of 92.5% copper. Details of this test are given on pages 5 and 6. The method of treatment selected for the graphitic ore had to be applicable also to the Fels type ore, since reportedly it is unlikely that the two ores could be mined and treated separately. This factor was a major consideration in this test work.
- 4) A total of 15 batch tests were conducted on the graphitic shale ore and 4 test with the Fels type ore. In addition grinding tests, screen analysis, specific gravity determinations, mineralogical and microscopic examinations of the ores and test products were made. These aspects and the other tests are summarised on pages 9-11. Fuller details of these tests can be provided at a later date should they be required.
- 5) A head sample of the graphitic shale ore assayed 3.03% Cu, 32 grams/metric ton Ag, 1.4 grams/m. ton Au and 17.9% carbon (graphitic). The Fels type ore assayed 1.93% Cu, 1.4 grams/m. ton Ag and 0.76 grams/m. ton Au. The gold and silver would probably report with the chalcopyrite but this has not been confirmed yet.
- 6) General test data, conditions and notes relating to the test work and the results obtained are given in appendices A and B.

London, 8th July, 1961.

D.J. Ottley.

JULY 1961

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE ORE

BEST TEST RESULTS AND CONDITIONS

TEST 13 - Graphitic ore:

Batch grinding of the sample in the presence of burnt lime was followed by bulk flotation of the chalcopyrite and graphite with stage additions of potassium amyl xanthate and pine oil. The bulk concentrate was retreated in the same flotation cell using sodium sulphide at an elevated 'pH' (with lime) to effect depression of the copper mineral.

Metallurgical Results.

PRODUCT	% WEIGHT	% COPPER	% DISTRIBUTION
Bulk rougher) clnr. froth) clnr. tails	32.4) 41.6 9.2)	2.05) 6.04 20.1)	23.0) 87.1 64.1)
Bulk scavenger conc.	6.3	3.45	7.5
Bulk flotation tailing	52.1	0.30	5.4
Calculated head	100.0	2.89	100.0
Measured head		3.03	

Reagent additions and Treatment conditions.

STAGE	B. LIME	P/O.	K.A.X.	SOD. SULPH.	'pH' START	'pH' END
Mill Grind	2.5 13.5	-	-	-	-	10.4
Bulk flotation Rghr. Cond. Flotn.		0.25 1 -	0.027 1 3		10.4	9.4
Bulk flotation Scavngr. Cond. Flotn.	1.25 5 -	0.005 1 -	0.004 1 1		11.1	10.6
Cleaner treatment Cond. Flotn.	1.25 5 -			5.0 5 3	1 11.2	11.0

Test 13 - Graphitic ore (cont).

Comments on the test.

Bulk flotation of the graphite and chalcopyrite results in the rejection of about 52% of the original ore containing 0.3% Cu. The froth in the initial stages of the bulk flotation was very voluminous and tough due to the presence of much fine slimed graphite. The fine graphite floats readily with merely the addition of frother. Potassium amyl xanthate was stage added in two increments in both the roughing and scavenging stages of the bulk flotation but it is thought that a single addition in the rougher stage would have proved more effective and resulted in a quicker flotation of the copper at the expense of the coarser and middling graphite.

The grade of copper concentrate obtained (20.1% Cu) could be further improved by one or more stages of recleaning. The major impurity in this concentrate was coarse graphite much of which was locked or dispersed through gangue quartz. The cleaner froth could also be cleaned to drop out the fine free chalcopyrite contained therein, although this might prove more difficult because of the tough voluminous nature of the froth. Alternative methods of removing the graphite slimes from the ground ore before the bulk rougher or bulk cleaner stages should be sought. Gravity treatment classification or elutriation appear to be attractive possibilities.

The depression of the fine chalcopyrite in particular was much less effective in the presence of graphite slimes when using potassium amyl xanthate than when slimes were absent or when potassium ethyl xanthate was used.

Optimum conditions for the depression of the sulphide minerals should result in greater economy of reagents than this test indicated as well as a higher recovery and copper concentrate grade. Sodium sulphide solution might be recirculated after thickening and filtering the cleaner cell products to further reduce reagent consumption and treatment costs.

Grinding with burnt lime and the use of amyl xanthate greatly improved both the copper recovery and selectivity over potassium ethyl xanthate, where lime was added to the cell or where the test was conducted at a lower 'pH'. Sodium isopropyl xanthate might give equally high recoveries and selectivity to that of amyl xanthate and in addition could result in a more effective and efficient depression of the copper mineral using sodium sulphide.

The screen analyses of the mill feed, ground product (stage ground) and the flotation tailings resulting from both stage and batch grinding of this ore are shown on page 4.

Graphitic shale type ore Test 13 (cont)

SCREEN ANALYSIS OF MILL FEED, STAGE GROUND PRODUCT AND BATCH
AND STAGE GROUND FLOTATION TAILINGS

Mesh BSS	Microns nominal	Percentage weight retained			
		Mill Feed	Ground Ore	Stage Tail	Batch Tail
Plus 7	2810	0.2	-	-	-
10	1670	3.7	-	-	-
14	1200	23.1	-	-	-
18	850	23.3	-	-	-
25	600	14.7	-	-	-
36	420	8.2	-	-	-
52	300	5.8	-	0.2	0.4
72	211	4.8	0.6	1.3	4.5
100	152	3.8	4.1	10.4	11.6
150	105	3.2	30.3	30.4	27.5
200	76	1.8	18.1	18.2	12.8
Minus 200	-	7.4	46.9	39.5	43.2
Total	-	100.0	100.0	100.0	100.0

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE ORE

BEST TEST RESULTS AND CONDITIONS

TEST 4F-FELS TYPE ORE:

The ore sample was batch ground with burnt lime added to the mill and the pulp subjected to flotation treatment under essentially the same conditions as those reported in Test 13 for the graphitic shale ore. An unsuccessful attempt to depress the chalcopyrite, which floats readily with frother only, using reagent 610 and sodium silicate was not thought to have any effect on the subsequent flotation. Stage addition of potassium amyl xanthate and frother gave a high grade concentrate and copper recovery without any cleaning. Depression of the chalcopyrite from the rougher concentrate at a pH of 11.1 using sodium sulphide was most effective and only a minor quantity of slimed material floated. The product from the sodium sulphide treatment were not assayed separately.

Metallurgical results.

PRODUCT	% WEIGHT	% COPPER	% DISTRIBUTION
Rougher concentrate	7.2	26.10	92.5
Scavenger concentrate	3.8	1.90	3.5
Tailing	89.0	0.00	4.0
Calculated head	100.0	2.03	100.0
Measured head	-	1.93	-

Reagent additions and Treatment conditions:

STAGE	B. LIME	610	SOD. SILIC.	MIBC	P.O.	K.A.X.	SOD. SULPH.	'pH' START	'pH' END
Mill Grind	2.5 10	-	-	-	-	-	-	-	-
Rghr. flotation Cond. flotn.	-	0.05 5	0.25 5	0.05 1/2 1/2	-	0.018 1 2	-	11.1	9.9
Scavngr. flotn. cond. flotn.	-	-	-	-	0.05 1/2	0.018 1 2	-	9.9	-
Cleaner flotn. cond. flotn.	1.25 5	-	-	-	-	-	3.75 5 3	11.1	-

Test 4F-Fels type ore(cont).

Comments on test.

Chalcopyrite floats with the addition of frother only. The addition of reagent 610 had no effect in this test but in previous test under different conditions the same addition of 610 did successfully inhibit the flotation of chalcopyrite unless collector was added. The froth was of excellent quality throughout the test. Potassium amyl xanthate was stage added in two increments of 0.009 Kg/m.ton in both the roughing and scavenging stages. The copper mineral floate quickly and cleanly at the high 'pH' and no cleaning was needed to give a high grade concentrate.

The 10 minute grind gave a much finer product than the 13.5 min grind given the graphitic ore, as seen in the screen analysis data below, compared with those shown on Page 4.

The Fels ore responded very well to treatment under similar conditions to those found suitable for the graphitic ore. Concentrate grade and recovery were clearly much higher for the Fels ore though.

The concentrate grade and recovery were superior to those obtained in two earlier tests using ethyl xanthate and the same grind or ethyl xanthate and a finer grind, at a natural 'pH' (7.4-7.6). Grinding in lime appeared to improve the flotation of chalcopyrite a improve selectivity. The depression stage using sodium sulphide was carried out in the same flotation cell at a low pulp density.

Screen analyses of Mill Feed and Flotation tailing - Test 4F -

Mesh BSS	Microns Nominal	Percentage weight retained	
		Mill Feed	Tailing
Plus 7	2810	0.3	-
10	1670	9.3	-
14	1200	24.4	-
18	850	24.6	-
25	600	12.9	-
36	420	6.9	-
52	300	4.9	-
72	211	3.1	-
100	152	2.3	1.3
150	105	1.9	6.2
200	76	1.4	16.1
Minus 200	-	8.0	76.3
Total		100.0	100.0

SUGGESTIONS FOR FURTHER TEST WORK:

Graphite slime:

Slime graphite gave considerable difficulties in both the bulk and cleaning stages of flotation and caused mechanical hold up of copper mineral as well as excessive reagent consumption, largely because of the voluminous and tough froth it caused. The fine graphite floated readily and with low copper content using frother only (MIBC) with the graphite ore but this was not satisfactory since some of the copper in the fels ore floats readily with just frother. The addition of depressants for graphite were not at all effective with the copper of the Fels ore, in the quantities used. There was an indication that these reagents were causing some depression or sluggishness to flotation of the fine calcophrite in both ores. Desliming of the ground ore prior to flotation in a glass cyclone was not effective since the 9.4% of the ore so removed assayed 2.24% Cu, a copper loss of 7%. Even then much of the fine graphite remained behind. Further tests to remove, or depress the slime graphite would simplify and improve the separation of copper mineral and graphite. Classification, elutriation or some form of gravity concentration would look attractive. The same method might also prove suitable for removing the coarser graphite and graphite-quartz particles from the bulk rougher or first cleaner concentrate. The specific gravity difference between graphite (2.3) and chalcopyrite (4.1?) is sufficient to indicate that a good separation might be possible.

Bulk flotation treatment.

The various tests carried out for the purpose of depressing the graphite and floating only the copper mineral were unsuccessful since there was a tendency to depress fine copper mineral particles and not to depress the fine graphite, as mentioned previously.

Several tests carried out using potassium ethyl xanthate under various conditions, resulted in high tailing losses in the bulk rougher stage. Concentrate grades were also lower which indicated poor selectivity also. An examination of tailings screen fractions from two of these tests showed that the larger part of the chalcopyrite was free and of minus 100 plus 150 mesh size. Grinding with lime and using potassium amyl xanthate at a high 'pH' gave good recoveries and better concentrate grades. The use of amyl xanthate, however, resulted in poorer depression of the copper mineral in the cleaner stage. It is suggested that sodium isopropyl xanthate be tried and other xanthates as well. The optimum 'pH' in the bulk flotation stage should be established and also whether lime soda ash or caustic is the best 'pH' regulator. The effects of sodium silicate, sodium cyanide and sodium carbonate on the results could also be investigated.

Cleaner flotation treatment:

With or without prior removal of the slime graphite, the

optimum conditions for Cu depression using sodium sulphide should be established. Laboratory cleaner tests were conducted in very dilute pulps (10% solids or less) using approximately 1 gram per litre of solution of $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$, a 'pH' of 11.1 using lime, and a conditioning time of 5 minutes. Conditioning at a high pulp density, followed by dilution should give more efficient depression and a lower reagent consumption. Lime as the 'pH' regulator should be compared with sodium carbonate and other regulators.

Optimum flotation times and the influence of one or more stages of recleaning of both the graphite float and the copper rich tailing would also require study.

Other sulphide mineral depressants should be tested to establish the most suitable from economic and metallurgical considerations. Included here would be dichromate, sodium cyanide and lime or sodium hydrogen sulphide.

Cyclic and later pilot scale tests would indicate the influence of recirculated middlings in both the flotation circuits on the metallurgical results as well as to provide useful operational and economic data. The effect of recirculating sulphide solutions would also be studied here.

Grinding:

In view of the very soft and friable nature of the graphite and to a lesser extent the chalcopyrite, compared with the gangue and the hard graphite-quartz grains, two stage grinding would appear to be the most logical. The size of the plant would decide whether this is an economic proposition. A significant percentage of the chalcopyrite is free at a coarse mesh (52 mesh) and a coarse primary grind in a rod mill in closed circuit with a DSM sieve bend followed by flotation appears attractive. The flotation tailings would pass to a secondary ball mill circuit via a hydrocyclone. The secondary mill would function in closed circuit with the cyclone and the ground product (minus 100 mesh) would be subjected to a second flotation treatment. There are other possible grinding circuits which might prove equally attractive.

A sketch of a possible two-stage grinding and flotation circuit which might be tested in the pilot plant is shown on a separate sheet. In any event, the optimum grind for the treatment of either of these ores or a mixture of the two, would have to be established.

General:

Water: The final treatment method and flowsheet should be confirmed using water taken from sources to be used in the plant. London tap water was used in all tests reported here, which is high in carbonates and bi-carbonates of calcium and magnesium.

Ore Mixtures: The Fels ore would appear to have a grindability of about half to three-quarters that of the graphitic ore and hence the grinding equipment should be selected to ensure

that it is suitable and adequate for whatever mixture of the two ores is to be treated.

Should it prove possible to mine the two ores separately, better, simpler but different treatment methods and circuits could be developed for each ore and superior metallurgy thus secured at lower costs. Clearly, tests should be run on suitable mixtures of the two ore types in both the laboratory and pilot plant should the segregation of the ores be uneconomical or impractical.

Gold and Silver: Indications are that the small amount of gold and silver are contained within the chalcopyrite but this has not yet been confirmed. Superpanning, microscopic examination and assays of test products would establish the distribution of the precious metal.

Flotation cells: Size degradation and sliming of the graphite continues during conditioning and flotation treatment of the ore to the apparent detriment of the process. It is felt that the use of pneumatic cells should be considered provided their performance is comparable to that obtained using mechanical cells.

SUMMARY OF TEST WORK:

A total of twenty three flotation tests were conducted, nineteen on the graphitic ore and four with the Fels type ore. Grinding tests, screen analyses of crushed and ground ore and flotation products, specific gravity determinations, qualitative and quantitative mineralogical-microscopic examinations were also carried out.

Graphitic shale ore tests:

Batch or stage grinding of samples to different degrees of fineness followed by flotation treatment under a wide variety of conditions were conducted. Initially, a frother alone was used, stage added to effect selective flotation of the graphite followed by flotation of the copper mineral with potassium ethyl xanthate. These tests were run at one of a number of different levels of 'pH'. Little success was achieved in removing the graphite selectively from the copper mineral or subsequently in obtaining a good recovery of copper. The addition of graphite depressants such as reagent 610, helped to reduce the copper content of the graphite concentrate. The use of pure alcohols in place of Dowfroth 250 or pine oil also reduced the copper content of the graphite concentrate. Reagent 610 was also tested for the purpose of depressing the graphite from the bulk concentrate but this was equally unsuccessful. A 14% copper concentrate, representing a recovery of 75% of the copper was the best result obtained in this series of tests, with 27.5% of the initial weight of the ore reporting in the graphite concentrate which assayed 0.32% Cu. Tailings were rarely below 1% Cu where potassium ethyl xanthate was used. The copper mineral in the tailings in all such cases was free and of flotation size but perhaps some grains

were slightly trashed.

Stage grinding was found to produce the proportion of slimes, particularly those of a graphite but had little apparent influence on the metallurgy. A comparison of the size analyses of batch and stage ground tailings are shown on page 4

Later tests employed amyl xanthate as collector after batch or stage grinding with lime, for the bulk flotation of the graphite and chalcopyrite. This phase of the test was followed by treatment of the bulk concentrate under various conditions using sodium sulphide to separate the copper and graphite. A bulk concentrate containing 6 - 7% copper, the remainder being slime graphite, coarse graphite or locked graphite-quartz particles was produced consistently, giving a 87 - 90% recovery and a tailing as low as 0.25% Cu. There was little pyrite in this concentrate when a high 'pH' was used (11.0) and only a small middling product was obtained containing appreciable amounts of pyrite.

These bulk concentrates after treatment with sodium sulphide at a high 'pH' yielded on one cleaning at best a 20% Cu concentrate which represented a modest 64% copper recovery. No recleaning of either the graphite or copper concentrate was practised but this should improve both recovery and concentrate grade. Sodium cyanide and lime were used in one test to depress the copper mineral but were not particularly successful. Many further tests were planned along these lines but time and lack of sample were limiting factors.

Fels type ore tests:

The first test showed that the ore was much less complex and less refractory than the graphite ore and also very much softer. At a 'pH' of 8.1 and using only frother (MIBC), 91% of the copper mineral was floated largely as a 22% Cu concentrate (87% recovery) and as a middling product assaying 6.7% copper and representing 4.4% of the copper content of the ore. The addition of a few drops of ethyl xanthate improved the recovery a further 3% giving a concentrate assaying 6.9% Cu. The grind was 98% minus 200 mesh compared with 81% minus 200 mesh for the graphite ore ground for the same time (20 minutes). The above test was repeated with comparable results at a coarser grind (15 minutes and 84% minus 200 mesh) at a higher 'pH' with lime (10.4).

Since the chalcopyrite floated so readily and since it was desirable in the treatment of the graphite ore to remove the slime and very fine graphite first, attempts were made in Test 3F to depress the copper mineral with reagent 610 so that it would not float with frother alone. Depression of the copper was achieved using 0.125 Kg. per m.ton of reagent 610 and sodium silicate. On addition of ethyl xanthate, the chalcopyrite floated but sluggishly and the recovery of copper was poorer (24.8% Cu concentrate but only 71.5% recovery).

In Test 4F the ore was batch ground with lime to a coarser size (10 minutes - 76% minus 200 mesh) and reagent 610 added to depress the copper mineral as in Test 3F. This was not in any way successful since some of the copper mineral floated with just the addition of frother. The bulk of the copper floated after the stage addition of potassium amyl xanthate. Concentrate grade (26% Cu) and recovery 92.5% Cu were the best achieved and of course vastly superior to those obtained from the treatment of the graphitic ore under similar conditions. On the basis of Tests 3 and 4 the bulk flotation of graphite and copper was decided to be the most flexible, although clearly, better metallurgy would be obtained by the separate treatment of the two ore types under quite distinct conditions, rather than by using a compromise method not really the best for either ore.

JW
8/7/61.

APPENDIX A

GENERAL TEST DATA CONDITIONS AND NOTES

All grinding and flotation tests were carried out using the equipment and conditions outlined below unless otherwise reported.

Sample weight: 400 grams - after crushing only.

Sample size: 90 - 95% minus 10 mesh (see detailed sheets)

Lab. mill size: 15 cm. diameter and 30 cm. long - mild steel rod mill.

Rod charge: Approx. 6,800 grams total weight - consisting of three rods of each size 1", 3/4", 1/2" and 3/8" - mild steel.

Mill speed: 80 r.p.m.

Mill pulp density: 50% solids - 400 ml. water.

Water used: London tap water - temperature 18 - 20° C.

Flotation cell used: Fagergren standard batch cell with Pyrex bowl - 2 litres volume to normal operating level of pulp.

Cell pulp density: Initially 17 - 18% solids, by weight.

Reagent additions: are reported in Kilograms/metric ton.

Mesh sizes: are all of the British Standard Series.

Grinding time: reported under mill in test conditions in minutes (Grind).

Conditioning time: reported in minutes under test conditions below the appropriate reagent (cond)

Flotation time: reported under the last reagent added before flotation, in minutes or fractions of minutes (floatg.)

All test results, conclusions and recommendations are based on tests carried out on the samples as received from Norway.

Specific gravities: Fels ore sample - 2.73 approx.
Graphitic ore sample - 2.66 approx.

Sample preparation: Samples were prepared for testing by stage crushing of the minus 1" ore sample received. After riffing and coning and quartering of the samples down to 400 grams the samples were stored in glass bottles fitted with screw caps until required for testing.

Assays: Head samples of both ores and principal test products were assayed by Alfred H. Knight of Liverpool. All other assays were conducted in the Bessemer Laboratory of the Royal School of Mines.

Test work: Mineralogical and microscopic examination of the ores and test products were carried out by Mr. M.P. Jones. All grinding and flotation test work, screen analyses and sample preparation were conducted by Mr. D.J. Ottley.

APPENDIX B.

ABBREVIATIONS USED IN TEST SHEETS

KAX - Potassium amyl xanthate

MIBC - Methyl Iso-butyl carbinol (frother 70-American Cyanamid Co.)

P.O. - Pine Oil.

610 - Reagent 610 (American Cyanamid Co.)

Sod. Silic - Sodium Silicate.

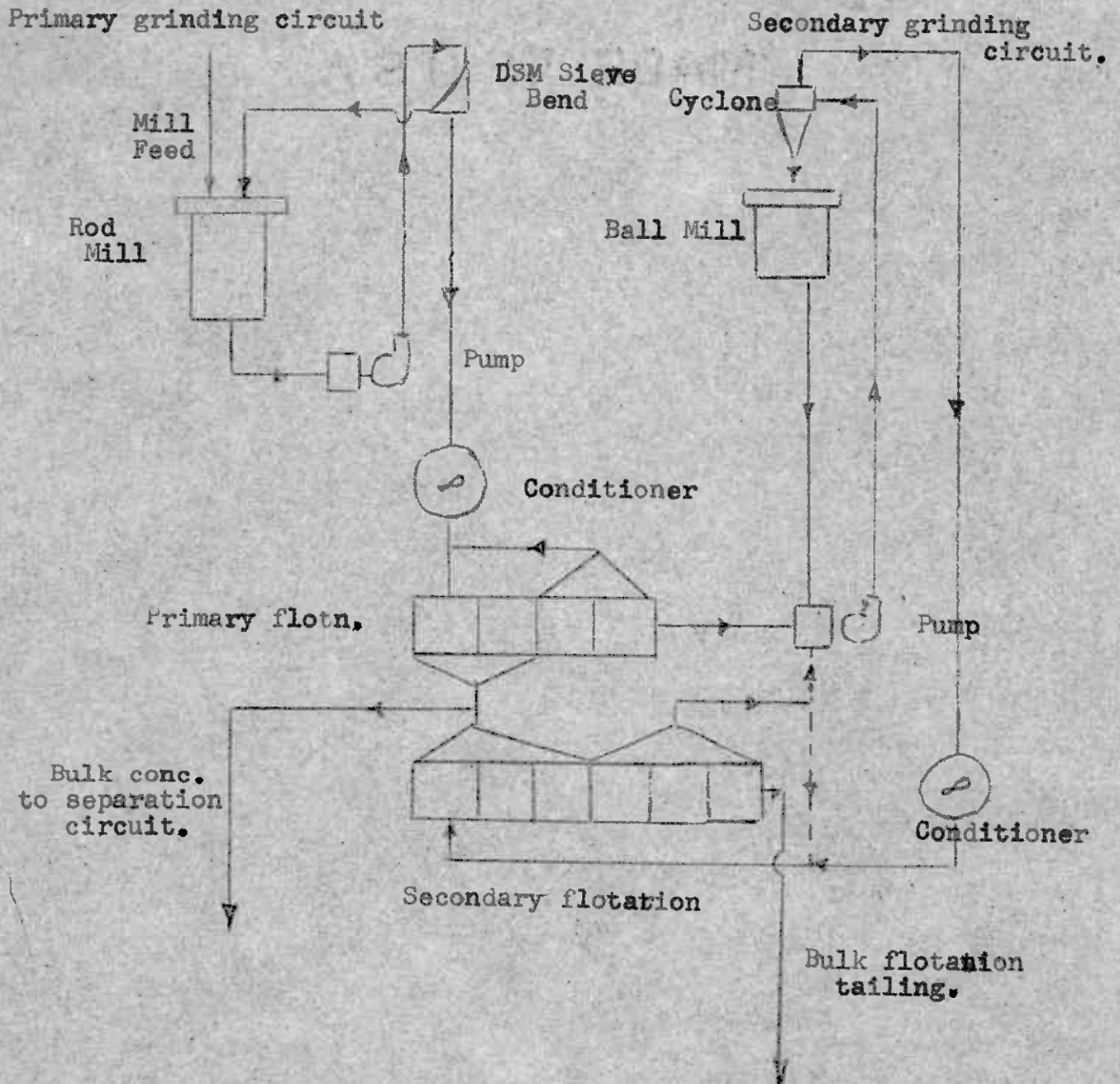
Sod. Sulph - Sodium Sulphide expressed in terms of the crystals ($\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$).

B. Lime - Burnt lime - calcium oxide.

These abbreviations are used in reporting the reagent consumptions and conditions employed in Tests 13 (Graphitic ore) and Test 4F (Fels ore).

KAUTOKEINO KOBBERFELTER-BIDJOVAGGE ORE-GRAPHITE TYPE-

A Possible outline flowsheet for the two stage grinding and Bulk flotation treatment of the graphitic shale type ore.



DJO/8th July '61.

MINING & MINERAL TECHNOLOGY DEPT.

22nd August, 1961.

K. Ingvaldsen, Esq.,
Kautokeino Kobberfelter,
Sverres gt. 4.,
TRONDHEIM,
Norway.

Dear Mr. Ingvaldsen,

Enclosed herewith is an Appendix to our Report giving results and treatment conditions of all other tests carried out on samples of Bidjovægge ore. A second copy has been sent under separate cover.

We would appreciate any comments you may wish to make in due course.

Yours sincerely,



D. J. OTTLEY.

A P P E N D I X

APPENDIX C

RESULTS AND TREATMENT CONDITIONS - ALL OTHER TESTS

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

Tests are reported in the order in which they were conducted.

TEST 1.

Summary: Batch grinding in a rod mill for 20 minutes at 50% solids without reagents was followed by incremental flotation of the graphite by drop-wise additions of pine oil only. After raising the 'pH' to 10.5 using burnt lime, attempts were made to float the chalcopyrite selectively from pyrite by stage additions of potassium ethyl xanthate.

Metallurgical results:

Product	% wt.	Assay % Cu	Cu % Distribution
Graphite conc 1	11.1)	0.63	2.2
" " 2	12.3)	0.62	2.4
" " 3	17.9) 45.4	1.96	11.3
" " 4	4.1)	9.10	12.0
Sulphide conc.1	6.5)	14.90	31.2
" " 2	11.2) 22.5	8.50	30.5
" " 3	4.8)	1.12	1.7
Final Tailing	32.1	0.84	8.7
Calculated Head	100.0	3.12	100.0
Measured Head	-	3.03	-

Comments: A voluminous froth resulted in the first two stages of the graphite flotation. These products consisted almost entirely of very fine free graphite with a little slimed free sulphide minerals. Coarser graphite, some locked with quartz and a little locked with sulphides, was floated in graphite concentrate 3.

An abundance of fine and coarse free chalcopyrite with some pyrite was found in graphite concentrate 4 as well as both coarse locked and free graphite. The first sulphide concentrate contained appreciable quantities of coarse graphite, some fine graphite and a significant amount of graphite - gangue particles. There was very little pyrite present. The second and third sulphide concentrates still contained significant amounts of locked graphite - quartz particles and increasing amounts of pyrite.

The tailing was largely clean gangue with some locked graphite - gangue particles and several free coarse chalcopyrite grains. The grind was in excess of that considered necessary for economic liberation of the sulphides.

Reagent additions and treatment conditions:

Stage	Lime	P.O.	KEX	pH	
				Start	End
Mill	-	-	-	-	-
Grind	20	-	-	-	-
Graphite float	-	0.5	-	8.2	-
Cond.	-	2	-	-	-
Flotn.	-	2	-	-	8.2
Sulphide float	1.25	0.25	0.05	10.5	-
Cond.	4	1	3	-	-
Flotn.	-	-	4	-	9.2

The four graphite concentrates were floated each for half a minute after the addition of 0.125 Kg./ton of pine oil (half minute conditioning for each stage). The sulphide concentrates were floated for 1, 1.5 and 1.5 minutes respectively after the stage addition of 0.016 Kg./ton of xanthate. Pine oil was added before sulphide floats 2 and 3.

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 2.

Summary: Batch grinding in a rod mill as in Test 1 was followed by the flotation of the graphite in three stages using methyl isobutyl carbinol, after conditioning with sodium silicate. The selective flotation of chalcopyrite was attempted as before on the graphite float tailing at a 'pH' of 11.4 again by stage additions of potassium ethyl xanthate.

Metallurgical results:

Product	% wt.	Assay % Cu	Cu % Distribution	
Graphite conc.	1	14.0)	0.29	1.6
	2	13.5) 45.9	0.36	1.8
	3	14.4)	1.90	10.4
Sulphide conc	1	9.1	13.50	46.6)
	2	5.1	14.40	27.8) 74.4
	3	3.4	2.50	3.2)
Tailing	40.5	0.56	8.6	
Calculated head	100.0	2.64	100.0	
Measured head	-	3.03	-	

Comments: Results were similar to Test 1 but less sulphide reported in the first two graphite concentrates due probably to the more brittle frother used and its lower collecting properties. The sodium silicate might also have contributed to this. A slightly longer flotation time was necessary during the graphite flotation. The selectivity and recovery of copper in the sulphide flotation stage was essentially the same as in Test 1. The calculated head assay was low indicating possibly, poor sampling or sample preparation with the regular distribution of the chalcopyrite in the ore. Pine oil was used in the final sulphide flotation because of the brittle froth produced using MIBC.

A coarser grind might have removed many of the difficulties caused by slimes and consequently improved the results generally. Screen analysis showed 100% minus 100 mesh virtually and 81.4% minus 200 mesh BSS.

Reagent additions and treatment conditions:

Stage	Lime	MIBC	F.O.	KEX	Sod. Silic.	'pH'	
						Start	End
Mill	-	-	-	-	-	-	-
Grind	20	-	-	-	-	-	-
Graphite float.	-	0.3	-	-	1.0	8.0	8.1
cond.	-	2.5	-	-	10	-	-
flotn.	-	5	-	-	-	-	8.1
Sulphide float.	2.5	0.06	0.13	0.05	-	11.4	-
cond.	5	-	1	3	-	-	-
flotn.	-	-	-	4.5	-	-	10.9

MIBC and xanthate were added in equal increments at each stage of the graphite and sulphide flotation.

Screen analysis - flotation tailing:

Mesh B.S.S.	% wt.	Cum. % wt.
Plus 52	0.1	0.1
72	0.3	0.4
100	1.0	1.4
150	3.8	5.2
200	13.4	18.6
- 200	81.4	100.0
Total	100.0	-

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE 'FELS TYPE' ORE

TEST 1F (Fels Ore).

Summary: A sample of the Fels type ore was treated under essentially the same conditions as were used in Test 2 with the graphitic ore, except that no collector was added until the flotation of concentrate 3.

Metallurgical results:

Product	% wt.	% Cu Assay	% Distribution Cu
Copper conc. 1	7.9	22.00	87.1
2	1.3	6.70	4.4
3	0.9	6.90	3.1
Tailing	89.9	0.12	5.4
Calculated head	100.0	2.00	100.0
Measured head	-	1.93	-

Comments: The chalcopyrite floated readily with only the addition of frother. Xanthate was added only for scavenging. This test indicated that unless the chalcopyrite could be readily depressed in this ore without detriment to its later flotation, then the removal of the graphite prior to the recovery of the sulphide using frother as a method for treating the graphitic ore would be unsuitable since both ore types would probably have to be treated together.

A screen analysis of the flotation tailing showed the Fels ore to be very much softer than the graphitic ore (98% minus 200 mesh BSS and all minus 150 mesh). The grind employed here was obviously much too fine.

Reagent additions and treatment conditions:

Stage	Lime	MIBC	KEX	Sod. Silic.	'pH'	
					Start	End
Mill	-	-	-	-	-	-
Grind	20	-	-	-	-	-
Sulphide float. 1 & 2 cond. flotn.	-	0.3	-	1.0	7.4	8.1
	-	1	-	-	-	-
	-	2.5	-	-	-	8.1
Sulphide float 3 cond. flotn.	2.5	-	0.07	-	-	-
	5	-	1	-	11.0	-
	-	-	-	-	-	-

Extra xanthate was added in stage 3 but very little mineral was floated.

No extra frother was needed in this test.

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE 'FELS TYPE' ORE

TEST 2F (Fels Ore).

Summary: Similar to Test 1F except that a coarser grind was employed and a higher 'pH'. Unsuccessful attempts were made to depress the chalcopyrite in a cleaning operation using a 'pH' of 11.0 and additions of sodium cyanide. Products were not assayed since a visual examination showed them to be similar to Test 1.

Metallurgical results:

Product.	% wt.	Assay % Cu	% Distribution Cu
Copper conc. 1	6.0	-	-
2	3.0	-	-
Tailing	91.0	-	-
Calculated head	100.0	-	-

Comments: Microscopic examination of the concentrates showed them to be comparable in grade to those from Test 1 F, with an equivalent or possibly better, recovery. The copper still floated readily without the addition of collector. Virtually all copper mineral had floated before the addition of xanthate was made. The shorter grind (15 minutes) resulted in a tailing containing 2.6% plus 150 mesh size material and 92.5% minus 200 mesh BSS, still much finer than the graphitic tailing ground for 20 minutes. Cleaning was carried out in an 800 ml. beaker cell but the concentrates were not collected separately.

Reagent additions and treatment conditions:

Stage	Lime	MIBC	KEX	NACN	'pH'	
					Start	End
Mill	-	-	-	-	-	-
Grind	15	-	-	-	-	-
Copper float	1.25	0.15	0.02	-	10.4	-
cond.	5	1	1	-	-	-
flotn.	-	2	1	-	-	9.5
Cleaner float	0.2	-	-	0.2	11.0	9.5
cond.	5	-	-	-	-	-
flotn.	-	-	-	-	-	-

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 3

Summary: Batch grinding of the ore as in Test 1 was followed by conditioning with sodium silicate and reagent 610 (American Cyanamid) at a high 'pH', in an attempt to selectively depress the graphite. Flotation was conducted using stage additions of frother and a little potassium ethyl xanthate. The two rougher concentrates were re-treated separately after further additions of reagent 610 and sodium silicate.

Product	% wt. %	Assay % Cu	Cu % Distribution
R. conc.1) Froth	8.5) 11.8	1.34	4.3) 8.4
) Tailing	3.3)	3.30	4.1)
R. conc.2) Froth 1	7.5)	21.20	59.9)
) Froth 2	5.0) 17.0	6.00	11.3) 73.4
) Tailing	4.5)	1.32	2.2)
Rougher Tailing	71.2	0.69	18.2
Calculated Head	100.0	2.66	100.0
Measured Head	-	3.03	-

Comments: The addition of reagent 610 with sodium silicate was quite effective as a depressant for the coarser graphite grains but also appeared to have some inhibiting influence on the flotation of chalcopyrite. The rough concentrate cleaner froth was virtually all slimed graphite. The rougher concentrate 2 - Froth 1 contained a lot of both slime and coarse graphite as well as graphite-quartz middling grains.

Desliming to remove the fine graphite, a coarser stage grind and the use of other graphite depressants should be investigated.

Reagent additions and treatment conditions:

Stage	Lime	'610'	Sod. Silic.	MIBC	KEX	'pH'	
						Start	End
Mill	-	-	-	-	-	-	-
Grind	20	-	-	-	-	-	7.9
Rougher flotn.	2.5	.10	0.63	0.20	0.05	10.9	-
cond.	5	5	-	2	2	-	-
flotn.	-	-	-	-	4	-	10.2
Cleaning R conc.1	-	.12	1.25	0.10	-	8.6	-
cond.	-	5	5	1	-	-	-
flotn.	-	-	-	2	-	-	8.6
Cleaning R conc.2	-	0.12	1.25	0.10	0.04	9.0	-
cond.	-	5	5	1	2	-	-
flotn.	-	-	-	-	1	-	8.6

Xanthate and frother were added in equal increments for each of the two roughing stages.

Cleaning of rougher concentrates 1 and 2 was effected in the same Fagergren cell.

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 4

Summary: 3 stage grinding for 2.1/2, 4 and 5.1/2 minutes to a much coarser size than was used previously was followed by desliming in a small glass hydrocyclone in an attempt to selectively remove the troublesome graphite slimes, prior to flotation. After rougher flotation at a high 'pH' (11.6) with ehyl xanthate and MIBC an attempt was made to depress the graphite as in Test 3 using reagent 610 and sodium silicate.

Metallurgical results:

Stage	% wt.	Assay % Cu	% Distribution Cu
R. conc) - Froth 1	8.5	11.20	31.5
) - Froth 2	5.5	3.80	6.9
) - Tailing	6.3	0.46	0.9
Rougher tailing	70.3	2.31	53.7
Primary slime	9.4	2.24	7.0
Calculated head	100.0	3.03	100.0
Measured head	-	3.03	-

Comments: Desliming in the hydrocyclone under the conditions employed was not successful, since slime graphite remained in the pulp and copper losses in the hydrocyclone overflow were high.

In both the roughing and the cleaning stages selectivity and recovery of copper were poor. There were appreciable amounts of both fine and coarse graphite in the final copper concentrate and many free grains of coarse and fine chalcopyrite in the rougher tailing.

The grind would appear to be perhaps a little too coarse. A screen analysis of the tailing shown later gave approximately 72% minus 100 mesh and 25% minus 200 mesh.

Reagent additions and treatment conditions:

Stage	Line	'610'	Sod. Silic.	MIBC	KEX	'pH'	
						Start	End
Mill	-	-	-	-	-	-	-
Grind	12 (S)	-	-	-	-	-	-
Rougher flotn.	2.5	-	-	0.2	0.05	11.6	-
cond.	-	-	-	2	2	-	-
flotn.	-	-	-	-	4	-	11.3
Cleaner flotn.	-	0.10	1.0	0.1	0.01	-	-
cond.	-	5	5	1	1	-	-
flotn.	-	-	-	2	1	-	8.6

MIBC and xanthate added in two equal increments for the rougher flotation. MIBC only was added for the first cleaning stage, the xanthate being added to produce cleaner concentrate 2.

Screen analysis - flotation tailing

Mesh BSS	Direct % wt.	Cum % wt.
Plus 52	0.5	0.5
72	4.0	4.5
100	23.7	28.2
150	33.2	61.4
200	13.3	74.7
Minus 200	25.3	100.0
Total	100.0	-

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE 'FELS TYPE ORE.

TEST 3F (Fels ore)

Summary: A much coarser grind in the rod mill was followed by additions of reagent 610 and sodium silicate which successfully inhibited the flotation of chalcopyrite unless a collector was added. Flotation was conducted at a natural 'pH' using potassium ethyl xanthate and MIBC frother.

Metallurgical results:

Product	% wt.	Assay % Cu	% Distribution Cu
Rougher conc. 1	5.4	24.8	71.5
2	3.2	11.5	19.7
Tailing	91.4	0.18	8.8
Calculated head	100.0	1.87	100.0
Measured head	-	1.93	-

Comments: The tailing was slightly higher than in Test 1 which could be attributed to the coarser grind, the brittle froth or some slight depression effect of the '610' reagent. Chalcopyrite also floats more slowly than in Test 1. No chalcopyrite floated until xanthate was added. 2.5 Kg./ton of sodium sulphide added to the rougher concentrate showed that the chalcopyrite could be effectively and almost completely depressed. This part of the test was qualitative only.

Reagent additions and treatment conditions:

Stage	Lime	'610'	Sod. Silic.	MIBC	KEX	'pH'	
						Start	End
Mill Grind	- 10	- -	- -	- -	- -	- -	- -
Rougher flotn.1. cond.	- -	0.13 5	1.25 5	0.1 1	0.03 1	7.7 -	- 8.4
Rougher flotn.2. cond.	- -	- -	- -	- -	0.03 1	- -	- -
flotn.	-	-	-	-	1.5	-	8.4

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 5

Summary: Three stage grinding at 100 mesh as in Test 4 but for 2.1/2, 4.1/2 and 6.1/2 minutes, was followed by conditioning with reagent '610' and sodium silicate and stage flotation of the graphite with MIBC frother at a 'pH' of 8.0 (conc.1). Ethyl xanthate and pine oil were added and the sulphides and coarse graphite floated off in two separate fractions (conc. 2 and 3). Concentrate 2 was treated with sodium sulphide to depress the sulphides and the graphite floated.

Metallurgical results:

Product	% wt.	Assay % Cu	% Distribution Cu
Rougher conc.1	19.9	0.56	3.6
Rougher conc.2) froth) tails.	12.7) 14.3 1.6)	5.7 21.1	23.4 10.9
Rougher conc.3	7.5	7.7	18.7
Rougher tailing	58.3	2.30	43.4
Calculated head	100.0	3.10	100.0
Measured head	-	3.03	-

Comments: Sodium sulphide depression was not good under the conditions employed. Reagent '610' appears to have a strong inhibiting effect on the chalcopryrite. A stronger collector should be tested. The grind employed would appear to be satisfactory for the liberation of the copper mineral. A screen analysis of the rougher tailing gave 7.6% plus 100 mesh and 42.2% minus 200 mesh BSS.

Reagent additions and treatment conditions:

Stage	Lime	'610'	Sod. Silic	MIBC	KEX	Na ₂ S 9H ₂ O	'pH'	
							Start	End
Mill	-	-	-	-	-	-	-	-
Grind	13.5 (st)	-	-	-	-	-	-	-
Rougher conc.1	-	.13	0.63	0.2	-	-	8.0	-
cond.	-	5	5	2	-	-	-	-
float	-	-	-	4	-	-	-	8.3
Rougher conc 2&3	-	-	-	*0.13	0.05	-	-	-
cond.	-	-	-	1	2	-	-	-
float	-	-	-	-	2.5	-	-	-
Cleaning conc.2	-	-	-	-	-	2.5	-	-
cond.	-	-	-	-	-	5	-	-
float	-	-	-	-	-	1	-	-

1.1/2 and 1 minute flotation times for Rougher concentrates 2 and 3 respectively. The xanthate was added as one dose. * Pine oil was used for this stage of flotation.

Screen analysis - Rougher tailing:

Mesh BSS	Direct % wt.	Cum. % wt.
Plus 72	1.4	1.4
100	6.2	7.6
150	35.6	43.2
200	14.6	57.8
Minus 200	42.2	100.0
Total	100.0	-

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 6

Summary: Stage grinding as in Test 5. Dowfroth 250 was added with MIBC in the graphite flotation stages. The sulphide flotation was conducted at a higher 'pH' (with lime) using stage additions of potassium ethyl xanthate. No cleaning of the concentrates was attempted.

Metallurgical results:

Products	% wt.	Assay % Cu	% Distribution Cu
Rougher conc. 1	24.0	0.67	5.7
2	8.5	16.2	49.2
3	8.2	8.7	25.3
Tailing	59.3	0.94	19.8
Calculated head	100.0	2.81	100.0
Measured head	-	3.03	-

Comments: Dowfroth '250' gave a very poor froth alone but together with MIBC more coarse graphite grains were floated resulting in a higher grade copper concentrate.

Tailing losses of copper were mostly in the 100/150 mesh fraction. These were seen to be present largely as clean free grains (See screen analyses and fraction assays reported later). The sulphides in the plus 100 mesh tailing fractions were 50% liberated, below 100 mesh all sulphides were essentially free. There were a few middling sulphide-graphite grains in the 100/150 mesh range.

Reagent additions and treatment conditions:

Stage	Lime	'610'	Sod. Silic.	DOW 250	MIBC	KEX	'pH'	
							Start	End
Mill Grind	-	-	-	-	-	-	-	-
	13.5 (st)	-	-	-	-	-	-	-
Graphite flotn.	-	.061	0.63	0.10	0.20	-	8.2	-
cond. flotn.	-	2	2	1	2	-	-	-
	-	-	-	-	3	-	-	8.1
Sulphide flotn.	1.8	-	-	-	0.05	0.05	10.5	-
cond. flotn.	5	-	-	-	1	4	-	-
	-	-	-	-	-	2.5	-	10.2

Ethyl xanthate was added in three equal increments, two in the concentrate 2 flotation stage. Flotation times were 1.1/2 and 1 minutes respectively.

Screen analyses and fraction assays - Tailing.

Mesh BSS	% wt.	Assay % Cu	% Distribution Cu
Plus 52	0.2)	0.55	5.5
72	0.9)		
100	7.7)		
150	37.8	1.33	56.7
200	16.3	0.60	11.0
Minus 200	37.1	0.64	26.8
Total	100.0	0.89	100.0

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 7

Summary: Batch, single stage grinding for 13.1/2 minutes was followed by conditioning with lime and sodium silicate and stage flotation using ethyl xanthate and pine oil. The first rougher concentrate containing the graphite and most of the copper mineral was cleaned after treatment with sodium sulphide at a 'pH' of 10.2 (sodium carbonate), the graphite being floated off in 3 separate concentrates.

Metallurgical results:

Product	% wt.	Assay % Cu	% Distribution Cu
) conc.1	12.7)	0.90	4.0
) 2	7.4)	1.30	3.2
R. conc.1) 3	6.0) 27.1	17.90	36.6
) Tailing	1.0)	6.00	2.0
Rougher conc. 2	6.2	6.40	13.6
Rougher tailing	66.7	1.77	40.6
Calculated head	100.0	2.92	
Measured head	-	3.03	-

Comments: Rougher tailing still high. Since no '610' reagent was used this must be attributable to other causes. Sodium sulphide separation not very effective under the conditions used.

Reagent additions and treatment conditions.

Stage	Lime	Sod. Silic.	P.O.	KEX	Na ₂ CO ₃	Na ₂ S 9H ₂ O	'pH'	
							Start	End
Mill Grind	- 13	- -	- -	- -	- -	- -	- -	- -
Rougher flotn.1 cond. float	1.8 5 -	0.63 5 -	0.20 2 -	0.04 3 2	- - -	- - -	7.7 - -	- 10.2 -
Rougher flotn.2 cond. float	- - -	- - -	0.20 2 -	0.02 2 2	- - -	- - -	- - -	- - 8.6
Cleaner flotn.1 cond. float	- - -	- - -	* 0.20 1 -	- - -	3.8 5 -	5.0 5 1	9.8 - -	10.4 - 10.2

Xanthate and pine oil were stage added in three equal increments in the rougher 1 stage and in 2 increments for the 'rougher 2' flotations.

* MIBC and Dowfroth 250 were used in the cleaning stages not pine oil. Sodium carbonate and sodium sulphide were added in two increments before and after the removal of the first cleaner concentrate.

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITE ORE

TEST 8

Summary: Batch, single-stage grinding for 13.1/2 minutes was followed by flotation of the graphite at a natural 'pH' using stage additions of MIBC after conditioning with reagent 610 and sodium silicate. After raising the 'pH' to 10.2 with lime and adding a little sodium cyanide, the copper was floated in two separate concentrates by stepwise additions of ethyl xanthate. The rougher concentrate was cleaned with sodium sulphide at a high 'pH' (10.6).

Metallurgical results:

Product	% wt.	Assay % Cu	% Distribution Cu
Graphite conc. 1	15.7	0.63	3.4
Sulphide conc. 1 ²	5.4	0.52	1.0
Sulphide conc. 1) froth) tails	12.5) 20.6	0.81	3.5
	8.1)	18.9	52.8
Sulphide conc. 2	3.2	8.8	9.9
Tailings	55.1	1.54	29.4
Calculated head	100.0	2.89	100.0
Measured head	-	3.03	-

Comments: The sulphides floated sluggishly and the primary tailing assay was high. Ethyl xanthate was neither selective nor strong enough to effectively float the copper mineral. Chalcopyrite was depressed also by sodium cyanide. A screen analysis of a sample of the rougher flotation tailing and fraction assays again showed the losses to be largely in the 100/150 mesh size. Microscopic examination showed this copper to be present as free grains of chalcopyrite. Microscopic examination of the cleaner tailing (copper concentrate) showed very little pyrite to be present. The principal impurities were coarse grained graphite, both free and locked with gangue minerals and slimed graphite.

Reagent additions and treatment conditions.

Stage	Lime	'610'	Sod. Silic	MIBC	KEX	Na ₂ S 9H ₂ O	Na ₂ CO ₃	'pH'	
								Start	End
Mill Grind	13.5	-	-	-	-	-	-	-	-
Graphite float	-	.02	0.63	0.25	-	-	-	8.2	-
cond.	-	5	5	2.5	-	-	-	-	-
float	-	-	-	-	-	-	-	-	8.0
Sulphide float	1.3	-	NaCN	Dw 25	0.15	-	-	10.2	-
cond.	5	-	0.05	0.10	3	-	-	-	-
float	-	-	10	1	3.5	-	-	-	9.5
Cleaner 1	-	-	-	0.10	-	7.0	2.5	10.6	-
cond.	-	-	-	1	-	5	5	-	-
float	-	-	-	-	-	-	1	-	10.5

MIBC was stage added in four increments during the graphite float. Ethyl xanthate was stage added during the sulphide flotation.

Screen analysis and fraction assays - Rougher tailing.

Mesh BSS	% wt.	Assay % Cu	% Distribution Cu
Plus 52	-	-	-
72	3.5	0.9	7.6
100	8.8		
150	30.1	2.28	46.7
200	14.4	1.97	19.3
Minus 200	43.2	0.90	26.4
Total	100.0	1.47	100.0

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 9

Summary: Batch grinding in a rod mill for 13.1/2 minutes was followed by conditioning with reagent '610' and sodium silicate. After further conditioning with lime ('pH' - 10.3) and a little sodium cyanide, ethyl xanthate and pine oil were added stage-wise and the graphite and sulphide floated in three separate concentrates. The second concentrate containing the bulk of the copper minerals was retreated using sodium sulphide and sodium carbonate ('pH' 10.2). The float fractions (graphite) was recleaned after further additions of sodium sulphide and carbonate ('pH' 9.8).

Metallurgical results:

Product	% wt.	Assay % Cu	% Distribution Cu
Rougher conc. 1 (graphite)	19.8	0.50	3.2
R. conc. 2 cleaner tailing	9.4	21.95	66.6
R. conc. 2 cleaner froth-conc	21.2	0.89	6.1
R. conc. 2 cleaner froth-tail	0.9	5.10	1.5
Concentrate 3 (scavenger)	3.0	7.31	7.1
Primary tailing	45.7	1.05	15.5
Calculated head	100.0	3.10	100.0
Measured head	-	3.03	-

Comments: Very little copper mineral floated until the graphite (mostly slimes) had been removed and the quantity of xanthate added had exceeded 0.04 Kg/ton.

Sodium sulphide depression of the sulphide minerals was reasonably effective and recleaning of the froth indicated that good recovery and grade of copper concentrate should be achieved once the right condition had been found.

Primary tailings assay was again high. The copper minerals floated sluggishly in the bulk roughing stages. Coarse graphite, both free and locked with gangue, and slime graphite, were the principal impurities present in the copper concentrate. Very little pyrite was ~~seen~~ present in this product.

Reagent additions and treatment conditions.

Stage	Lime	'610'	Sod. Silic.	NaCN	P.O.	KEX	Na ₂ S 9H ₂ O	Na ₂ CO ₃	'pH'	
									Start	End
Mill Grind	- 13.5	-	-	-	-	-	-	-	-	-
R. conc. 1	1.3	0.06	0.63	0.03	0.10	.04	-	-	7.8	-
cond.	10	5	5	10	1	2	-	-	-	10.3
float.	-	-	-	-	-	1.5	-	-	-	-
R. conc. 2	-	-	-	-	0.10	.04	-	-	-	-
cond.	-	-	-	-	1	2	-	-	-	-
float.	-	-	-	-	-	3	-	-	-	-
R. conc. 3	-	-	-	-	-	0.20	-	-	-	-
cond.	-	-	-	-	-	1	-	-	-	-
float.	-	-	-	-	-	1	-	-	-	-
2 cleaner	-	-	-	-	0.10	-	3.8	1.3	10.2	-
cond.	-	-	-	-	1	-	10	10	-	-
float.	-	-	-	-	-	-	2	-	-	10.2
2 recleaner	-	-	-	-	-	-	2.5	1.3	9.8	-
cond.	-	-	-	-	-	-	5	5	-	-
float.	-	-	-	-	-	-	1.5	-	-	9.6

The standard Fagergron cell was used for cleaning the rougher concentrate 2 and for recleaning the 1st cleaner froth.

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 10

Summary: Batch grinding for 13.1/2 minutes with lime added to the mill was followed by bulk flotation of the graphite and sulphides using stage additions of potassium ethyl xanthate and pine oil (pH 11.2). No cleaning of the concentrates was attempted.

Metallurgical results:

Product	% wt.	Assay % Cu	% Distribution Cu
Bulk conc.1	38.6	6.70	88.0
" " 2	12.0	1.42	5.8
Bulk tailing	49.4	0.37	6.2
Calculated head	100.0	2.94	100.0
Measured head	-	3.03	-

Comments: Grinding in lime appeared to improve the recovery of copper. This could also have been explained partly by the omission of depressants from the cell and by the low grade of bulk concentrate produced.

Reagent additions and treatment conditions.

Stage	Lime	KEX	P.O.	pH	
				Start	End
Mill	2.5	-	-	-	-
Grind	13.5	-	-	-	-
Bulk conc.1	-	.04	0.20	11.2	-
cond.	-	2	2	-	-
float	-	-	3	-	-
Bulk conc.2	-	.02	0.10	-	-
cond.	-	1	1	-	-
float	-	-	2	-	8.6

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 11

Summary: Identical treatment to that used in Test 10 except that a Bessemer cell was employed instead of the Fagergren cell. This was done to determine principally whether the losses of coarse free chalcopyrite in the tailing might, in any way, be attributable to the cell agitation.

Metallurgical results:

Product	% wt.	Assay % Cu	% Distribution Cu
Bulk conc. 1	34.8	6.70	80.6
" " 2	3.8	2.86	3.8
Bulk tailing	61.4	0.74	15.6
Calculated head	100.0	2.90	100.0
Measured head	-	3.03	-

Comments: Results were similar to those of Test 10 except for the higher tailing. This cell, which gave more violent agitation than the Fagergren, appeared to be slightly inferior. The tailing losses of free coarse grains of chalcopyrite were not considered to be attributable to the cell.

Reagent additions and treatment conditions.

The same as those used in Test 10.

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 12

Summary: Batch grinding as in Test 9 with lime was followed by flotation of the graphite using MIBC only. The copper mineral was floated by stage additions of potassium amyl xanthate. The rougher sulphide concentrate was cleaned in a small R.S.M. cell using sodium sulphide and lime (pH 11.2) instead of sodium carbonate.

Metallurgical results.

Product	% wt.	Assay % Cu	% Distribution Cu
Graphite conc.	11.3	0.58	2.0
R. conc - cleaner froth	13.0)	4.41	17.6
cleaner tail	14.4)	14.60	64.6
Scavenger conc.	15.7	2.36	11.5
Primary tailing	45.6	0.31	4.3
Calculated head	100.0	3.25	100.0
Measured head	-	3.03	-

Comments: Amyl xanthate appeared to give very much better results than ethyl xanthate in the rougher flotation stage but might have partly caused the poor depression of copper during cleaning with sodium sulphide. Microscopic examination of the primary tailing showed the losses of copper to be almost entirely as locked mineral (with quartz and graphite). One free grain of chalcopyrite of approximately 36 mesh BSS was seen however, which was clearly too coarse to float anyway.

Reagent additions and treatment conditions.

Stage	Lime	'610'	MIBC	P.O.	KAX	Na ₂ S 9H ₂ O	'pH'	
							Start	End
Mill	2.0	-	-	-	-	-	-	-
Grind	13.5	-	-	-	-	-	-	-
Graphite float cond. flotn.	-	.06	0.40	-	-	-	10.5	-
	-	5	1	-	-	-	-	-
	-	-	2	-	-	-	-	9.5
R.Sulphide float cond. flotn.	0.5	-	-	0.2	0.02	-	-	-
	5	-	-	1	2	-	-	11.2
	-	-	-	-	2.5	-	-	-
Scavenger float cond. flotn.	-	-	-	-	0.02	-	-	-
	-	-	-	-	2	-	-	-
	-	-	-	-	2	-	-	-
Sulphide cleaner cond. flotn.	1.25	-	-	0.10	-	5.0	11.2	-
	10	-	-	1	-	10	-	-
	-	-	-	-	-	3	-	11.2

Xanthate added as two equal increments in each stage. Cleaning with sodium sulphide was conducted in an 800 ml. R.S.M. cell with a metal bowl.

KAUTOKEINO KOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 14

Summary: Similar to Tests 12 and 13 except that 0.5 Kg/ton of reagent 633 was added to the mill along with lime. Bulk flotation of the graphite and copper mineral was followed by cleaning in the same cell using sodium sulphide and lime.

Metallurgical results:

Products	wt.	Assay % Cu	% Distribution Cu
Bulk rougher conc froth	29.1)	3.8	37.2)
tail	8.5)	18.2	52.3)
	37.6		89.5
Scavenger concentrate	6.4	1.49	3.2
Primary tailing	56.0	0.39	7.3
Calculated head	100.0	2.97	100.0
Measured head	-	3.03	-

Comments: Repeated cleaning of the cleaner froth and tailings should give improved recovery and copper concentrate grade. Sulphide depression was however, less effective where KAX was used. Flotation of the copper mineral was sluggish due to the addition of reagent 633 to the mill. This depressant had but little influence on the fine graphite which was added with the intention of selective depression of the graphite.

Reagent additions and treatment conditions.

Stage	Lime	633	P.O.	KAX	Na ₂ S 9H ₂ O	'pH'	
						Start	End
Mill	2.5	0.5	-	-	-	-	-
Grind	13.5	-	-	-	-	-	-
Bulk flotation	-	-	0.30	.04	-	10.7	-
cond.	-	-	1.5	3	-	-	-
flotn.	-	-	3	-	-	-	-
Scavenger flotn.	0.75	-	0.10	0.02	-	11.1	-
cond.	5	-	1	2	-	-	-
flotn.	-	-	0.5	-	-	-	-
			<u>MIBC</u>				
Cleaner 1	1.25	-	0.2	-	5.0	11.4	-
cond.	5	-	2	-	5	-	-
flotn.	-	-	2	-	-	-	11.2

Potassium amyl xanthate and pine oil were stage added in three equal increments in the bulk flotation stage and in two equal doses to the scavenger (one addition of pine oil only)

KAUTOKEINO HOBBERFELTER - BIDJOVAGGE GRAPHITIC ORE

TEST 15

Summary: Similar to Test 14 but with stage grinding of the ore on 100 mesh. Lime was added to the mill for each period of grinding. The bulk concentrate was cleaned using sodium sulphide and sodium carbonate followed by recleaning of the cleaner froth with lime and more sodium sulphide.

Metallurgical results:

Products	% wt.	Assay % Cu	% Distribution Cu
1st cleaner froth-recleaned	24.8)	4.00	34.8)
" " -tailing	5.3) 38.2	17.90	33.3) 94.8
1st cleaner tailing	8.1)	9.40	26.7)
Scavenger conc.	8.6	0.85	2.6
Primary tailing	53.2	0.14	2.6
Calculated head	100.0	2.85	100.0
Measured head	-	3.03	-

Comments: A very high recovery of copper was achieved in the bulk rougher stage (94.8). Depression of the sulphide minerals with sodium sulphide appeared to be less effective with sodium carbonate, added for 'pH' control than with lime. Stage grinding was no doubt responsible in part for the improved bulk recovery.

A screen analysis of the primary flotation tailing contained approximately 12% plus 100 mesh and 39.5% minus 200 mesh BSS. Microscopic examination of the screen fractions indicated that this grind might be suitable for economic liberation of the ore. This clearly could only be established after consideration of the many economic aspects. Two stage grinding with flotation between each or regrind or a middling fraction after an initial coarse grind could prove to be economic in practice.

Reagent additions and treatment conditions.

Stage	Lime	Sod. Silic	P.O. Dow 250	MIBC	KAX	Na ₂ S 9H ₂ O	Na ₂ CO ₃	'pH'	
								Start	End
Mill Grind	x 3.8 13.5(st)	-	-	-	-	-	-	-	-
Bulk floatn. cond. float.	0.25 5 -	0.5 5 -	0.40 2 2.5	- - -	0.2 2 -	- - -	- - -	10.4 - -	- 10.9 10.2
Scav. floatn. cond. float.	0.25 5 -	- - -	0.10 0.5 1	- - -	.01 0.5 -	- - -	- - -	- - -	- 10.7 10.2
Cleaner stage cond. float.	- - -	0.5 8 -	- - -	0.10 1 2.5	- - -	3.75 8 -	1.25 8 -	11.1 - -	- - 11.0
Recleaner stage cond. float.	1.25 5 -	- - -	- - -	0.1 1 2	- - -	5.0 5 -	- - -	- - -	- - 11.5

x 0.5 gm. of lime was added to the mill for each grinding stage.

Screen Analyses - primary tailing

Mesh BSS	Direct % weight	Cum. % weight
Plus 52	0.2	0.2
72	1.3	1.5
100	10.4	11.9
150	30.4	42.3
200	18.2	60.5
Minus 200	39.5	100.0
Total	100.0	-