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THE EFFECT OF ALIZARIN RED S IN DEPRESSING SILICEOUS GANGUE MINERALS IN THE FLOTATION OF PYRITE

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Abstract

A low-grade pyrite sample from Ingaldhal, Chitaldrug District, Mysore, assaying 44·55 per cent Fe, 27·83 per cent S and 16·13 per cent SiO_2 together with some insolubles was received from the Mysore Geological Department for beneficiation tests. The gangue minerals present were chlorite, quartz, hematite and magnetite and were intimately associated with pyrite. Straight flotation using potassium amyl xanthate yielded a concentrate assaying 46·5 per cent S with a recovery of 90·28 per cent. The use of alizarin red S for depressing the silica and other gangue minerals showed slight improvement in the grade of the concentrate and the concentrate assayed 47·82 per cent S with a recovery of 90·67 per cent. Artificial mixtures containing 5 per cent S did not respond well to the alizarin red S treatment and the dye has a limited use in the depression of siliceous gangue in pyrite flotation.

Introduction

It is known that in flotation, organic compounds capable of forming chelate complexes have been used as collectors as well as depressants for minerals. A compound that can function as a depressant in flotation, should be capable of reacting with the metallic ions commonly encountered in flotation pulps resulting in the closure of the ring on the mineral surface and the inner complex formed should be hydrophilic in character. Alizarin red S, a substituted hydroxy anthraquinone, $C_{14}H_5O_2(OH)_2SO_3Na \cdot H_2O$ has been used as a depressant for cassiterite in fluorite flotation,[1] for beryl in the flotation of quartz,[2] and for quartz in the flotation of monazite, zircon, ilmenite and rutile[3] and chromite.[4] The dye has not been tried in depressing siliceous and other gangue in sulphide flotation and

hence a study has been made on the effect of alizarin red S in depressing siliceous gangue in the flotation of pyrite.

EXPERIMENTAL

Assay.—The pyrite sample used in this investigation was from Ingaldhal, Chitaldrug District, Mysore, and consisted of lumps of $\frac{1}{8}''$–$1\frac{1}{2}''$. Chemical tests[5] revealed that the sample consisted of pyrite and marcasite and assayed 44·55 per cent. Fe, 27·83 per cent. S, and 16·13 per cent. SiO_2 together with some insolubles. The pyrite content based on the sulphur content of the sample would be 52·5 per cent. The gangue minerals found associated with pyrite were chlorite, quartz, hematite and magnetite. The lumps were stage-crushed in a rolls crusher to pass through 10 mesh (B.S.S.) and ground in a ball mill for flotation experiments. The screen analysis of the ground product is represented in Table I.

TABLE I

Screen analysis

Size fraction		Weight per cent.
+ 60 mesh	..	5·6
− 60/+100 mesh	..	0·8
−100/+150 mesh	..	1·7
−150/+200 mesh	..	4·1
−200 mesh	..	87·8

Preliminary experiments revealed that deslimed pulps yielded concentrates of higher sulphur assay than the ground ore in natural state and consequently experiments reported herein were carried out with deslmed ore. It may be added that about 5 per cent. of slimes were formed during grinding, the slimes assaying 19·6 per cent. sulphur. Flotation tests were carried out for determining the amenability of the ore to straight flotation and the role of depressants as alizarin red S and sodium silicate in pyrite flotation.

Straight Flotation.—In the tests, the Fagergren laboratory flotation cell was used and the conditioning and flotation time were maintained at 6 minutes each. Potassium amyl xanthate and pine oil were used as collector and frother respectively. Copper sulphate was used as an activator for pyrite in all the tests and sodium sulphide was used in the alkaline circuit only. Straight flotation yielded a concentrate of 46·5 per cent. sulphur with 90·28 per cent. recovery in acid circuit at pH 4·5, while a concentrate assaying 42·02 per cent. sulphur was obtained in alkaline circuit at pH 8·0 with 87·6 per cent. recovery. The results are shown in Table II.

TABLE II

Flotation of Ingaldhal pyrites

Head Assay 27·83 per cent. S

Expt No.	pH	Reagents lb./ton						Flotation products	Weight per cent.	Assay per cent. S	Recovery per cent. S
		Pot. amyl xanthate	Pine oil	Copper sulphate	Sod. sulphide	Alizarin Red S	Sod. silicate				
1	4·5	0·25	0·35	0·5	..	0·05	..	Concentrate	51·8	47·9	89·10
								Tailing	44·0	6·28	9·92
2	4·5	0·25	0·35	0·5	..	0·1	..	Concentrate	52·6	47·29	89·33
								Tailing	44·2	6·01	9·55
3	8·0	0·25	0·35	1·0	2·0	0·1	..	Concentrate	59·0	42·84	90·76
								Tailing	38·2	6·02	8·45
4	4·5	0·25	0·35	0·5	..	0·25	..	Concentrate	52·8	47·82	90·67
								Tailing	43·2	5·63	8·74
5	4·5	0·25	0·35	0·5	..	1·0	..	Concentrate	52·4	47·51	89·41
								Tailing	44·2	6·08	9·65
6	4·5	0·25	0·35	0·5	..	0·1	0·1	Concentrate	52·4	47·48	89·35
								Tailing	43·0	6·75	10·42
7	4·5	0·10	0·35	0·5	..	0·1	0·1	Concentrate	53·0	47·31	90·06
								Tailing	41·4	5·63	8·38
8*	4·5	0·25	0·35	0·5	..	..	..	Concentrate	56·5	42·5	86·32
								Tailing	41·4	9·0	13·38
9*	8·0	0·25	0·35	1·0	2·0	..	..	Concentrate	59·5	37·9	81·06
								Tailing	38·4	12·19	16·83
10	4·5	0·25	0·35	0·5	..	..	..	Concentrate	54·0	46·5	90·28
								Tailing	41·0	6·46	9·52
11	8·0	0·25	0·35	1·0	2·0	..	..	Concentrate	58·0	42·02	87·60
								Tailing	37·8	7·45	10·13
12	4·5	0·5	0·35	0·5	..	..	..	Concentrate	51·6	47·34	87·78
								Tailing	44·0	5·76	9·10
13	8·0	0·5	0·35	1·0	2·0	..	..	Concentrate	56·0	44·66	89·91
								Tailing	40·6	6·3	9·19
14	4·5	0·25	0·35	0·5	..	..	0·25	Concentrate	51·6	47·39	88·0
								Tailing	43·6	6·12	9·6
15	8·0	0·25	0·35	1·0	2·0	..	0·5	Concentrate	54·0	45·44	88·14
								Tailing	41·0	6·42	9·45

* Ore with slimes.

Depressants.—The effect of the depressant alizarin red S has been studied with change in concentration of the dye both in itself, and in combination with sodium silicate. In general, the acid dye has shown slight improvement both with regard to the grade of the concentrate and the recovery of the value as revealed by data embodied in Table II.

Tailings.—The tailings from the first flotation tests were reground to 98·9 per cent. −200 mesh and floated using the same reagents as mentioned earlier in suitable concentrations. Since the response was rather poor, in one case the tailings from the second flotation were reground and floated again to better the overall recovery. Results of the tests are shown in Table III. However, it was soon found that the nature of the locking of pyrite with the gangue was responsible for the poor flotation results. Ore microscopic studies with the reground tails mounted in bakelite, revealed that pyrite was in close association with chlorite and hematite. The latter was identified by its dark grey colour, weak anisotropism and dark brown polarisation colour and pyrite showed brass yellow colour with high relief and isotropic character.[6] However, chlorite was identified separately in transmitted light through its light green colour, pale to dark green pleochroism and polarisation colours yellow and green.[7]

The photomicrographs reproduced reveal that pyrite as veins and also blebs is locked in binary particles primarily with chlorite. Photomicrograph 1 records a typical reground tail sample showing bright patches of pyrite in several particles. Some particles show less bright patches and others show only streaks which appear submerged. It is believed that in the tails all the particles are not oriented in the same direction or depth with reference to pyrite and hence wherever pyrite has been exposed and polished, bright spots appear. In other particles the (appearance of pyrite) colour and intensity are dull depending on the area of pyrite vein, orientation and the depth at which it is embedded[8] in the chloritic gangue. Photomicrograph 2 shows a particle which is under focus. It should be added that this particle, which is thin and long, reveals pyrite as interspersed by chlorite and also completely covered by it. Therefore it is easy to discern that the pyrite surface would never be free to react to the flotation reagents and hence the loss of the value in the tails.

Lean Ores.—In view of the fact that flotation tests with alizarin red S were not significant, it was felt that this might be due to the low siliceous content of the ore. Therefore an attempt was made to ascertain whether larger amounts of gangue in lean ores would considerably alter flotation results. Experiments were tried with low grade synthetic pyrite ore containing quartz as gangue, assaying 14·0 and 5·0 per cent. sulphur respectively. The flotation tests were performed under the same conditions as mentioned earlier and the results showed that improvement was again small, as an increase of 0·26 per cent. in sulphur assay of the concentrate was obtained with the use of the dye. The results of the flotation of lean ores are represented in Table IV.

TABLE III

Flotation of reground tails

Expt. No.	pH	Reagents lb./ton						Flotation Products	Weight per cent.	Assay per cent .S	Recovery per cent. S
		Pot. amyl xanthate	Pine oil	Copper Sulphate	Sod. sulphide	Alizarin Red S	Sod. silicate				
1	4·5	0·12	0·16	0·25	..	0·025	..	Concentrate	9·2	14·70	4·86
								Tailing	34·8	4·05	5·06
2	4·5	0·12	0·16	0·25	..	0·050	..	Concentrate	6·8	17·30	4·23
								Tailing	37·4	3·96	5·32
3	8·0	0·12	0·16	0·50	1·0	0·050	..	Concentrate	7·6	15·26	4·17
								Tailing	30·6	3·72	4·09
4	4·5	0·12	0·16	0·25	..	0·125	..	Concentrate	5·40	18·98	3·68
								Tailing	37·8	3·72	5·05
5	4·5	0·12	0·16	0·25	..	0·50	..	Concentrate	8·0	16·42	4·72
								Tailing	36·2	3·79	4·92
6	4·5	0·12	0·16	0·25	..	0·05	0·05	Concentrate	8·0	19·71	5·65
								Tailing	35·0	3·78	4·75
7	4·5	0·05	0·16	0·25	..	0·05	0·05	Concentrate	5·4	17·19	3·34
								Tailing	36·0	3·9	5·04
*8	4·5	0·12	0·16	0·25	..	..	..	Concentrate	13·4	18·76	9·1
								Tailing	28·0	4·32	4·24
*9	8·0	0·12	0·16	0·5	1·0	..	..	Concentrate	12·60	27·56	12·53
								Tailing	25·8	4·7	4·31
10	4·5	0·12	0·16	0·25	..	..	..	Concentrate	5·7	15·3	3·13
								Tailing	34·60	3·69	4·59
11	8·0	0·12	0·16	0·5	1·0	..	..	Concentrate	5·04	17·56	3·18
								Tailing	33·5	4·39	5·29

TABLE IV

Flotation of artificial low-grade pyrite

Sample No.	pH	Reagents lb./ton				Flotation products	Wt. per cent.	Assay per cent. S	Recovery per cent. S
		Pot. amyl xanthate	Pine oil	Copper sulphate	Alizarin red S				
1	4·5	0·25	0·35	0·5	..	Concentrate 1	30·6	43·1	94·21
		0·12	0·16	0·25	..	do. 2	3·84	8·34	2·28
						Tailing	63·6	0·49	2·23
2	4·5	0·25	0·35	0·5	0·25	Concentrate 1	31·0	43·30	96·01
		0·12	0·16	0·25	0·12	do. 2	3·7	7·27	1·92
						Tailing	63·3	0·30	1·63
3	4·5	0·25	0·35	0·5	..	Concentrate 1	10·44	41·12	85·84
		0·12	6·16	0·25	..	do. 2	2·5	7·66	3·84
						Tailing	84·2	0·44	7·4
4	4·5	0·25	0·35	0·5	0·25	Concentrate 1	10·6	41·31	87·56
		0·12	0·16	0·25	0·12	do. 2	3·24	6·42	4·16
						Tailing	82·7	0·37	6·12

Note.—The head assay of samples 1 and 2 was 14 per cent. S. while that of 3 and 4 was 5 per cent. S.

DISCUSSION

It is well known that quartz and other granular silicates are easy to depress in sulphide flotation.[9] In straight flotation of pyrite, it was better in the acid range at pH 4·5 than in the alkaline range at pH 8·0. In a single stage flotation, 90·3 per cent. sulphur was recovered in a concentrate assaying 46·5 per cent. sulphur. The increase in pH lowered the flotability of pyrite and also lowered the possibility of its activation by copper salts as has been reported.[10] Reflotation of the tails after grinding yielded a concentrate assaying 15·3 per cent. sulphur and by this operation the overall recovery was raised to 94 per cent. These results are similar in nature to those reported recently[11] on a sample of pyrite from Chitaldrug District, Mysore, which assayed 40·92 per cent. Fe and 34·69 per cent. S. The flotation concentrate assayed 47·9 per cent. sulphur with a recovery of 86·5 per cent. In the present work, the overall recovery has been calculated on the total sulphur present in the feed including the slimes. From several experiments conducted. it was observed that the slimes accounted for 1·0–1·5 per cent of sulphur and the remaining 4·5–5·0 per cent. of the total sulphur as pyrite was found to be in close association with gangue minerals, though the tails from the second flotation were reground to 98·9 per cent. — 200 mesh. Microscopic studies of the flotation tails revealed that the pyrite occurred in the form of small veins and blebs locked in binary particles primarily with chlorite. The non-liberation of pyrite from the gangue minerals prevented proper collector attachment on the pyrite sur-

face and this accounted for the loss of value in the tails. In the soap flotation of quartz using oleic acid, and barium chloride as activator, the mineral was non-floatable when 0·25–0·5 pound per ton of alizarin red S was used.[1] It is known that there is no flotation of quartz below pH 7·0 in the presence of the dye. The depression of cassiterite by alizarin red S was aided by barium ions as the latter act as depression sensitizer while in the case of quartz, the amount of dye required for depression increased with the concentration of barium ions present in the pulp. In the present work carried out at a pH of 4·5, copper sulphate in excess of the stoichiometric proportion to amyl xanthate and the concentration of the dye has been varied from 0·05–1·0 pound per ton of ore. It was observed that the use of varied concentration of alizarin red S had very little effect on the depression of the gangue minerals. There was an improvement of 1·32 per cent. in the grade of the concentrate and in recovery by 0·4 per cent. with the use of the dye. The concentrations of the dye used in the flotation tests were sufficient to depress the gangue minerals but still the improvement in the grade of the concentrate was not significant with the use of the dye.

In the case of the flotation of artificial low-grade pyrite samples also, it has been observed that the grade and recovery have only been slightly bettered, *i.e.*, by 0·26 and 1·8 per cent. respectively. Though there is some improvement, it should be conceded that it is only slight. Therefore from the above results, it would appear that alizarin red S does not seem to have a markedly pronounced effect on the depression of siliceous gangue in the flotation of pyrite.

Conclusions

Pyrite sample from Ingaldhal, Chitaldrug District, Mysore, assaying 44·55 per cent. Fe, 27·83 per cent. S and 16·13 per cent. SiO_2 together with some insolubles was beneficiated by flotation.

The gangue minerals present were chlorite, quartz, hematite and magnetite.

The use of the dye alizarin red S in the depression of gangue minerals resulted in slight improvement to the grade of the concentrate and recovery.

The best flotation concentrate that was obtained assayed 47·82 per cent. sulphur with a recovery of 90·67 per cent.

By refloating the tails the overall recovery could be raised to about 94 per cent. with a slight lowering in the grade; further recovery was not possible due to the close association of gangue with pyrite as revealed by ore microscopic studies.

Artificial mixtures of pyrite carrying as low as 5 per cent. sulphur did not respond especially to alizarin red S treatment.

The dye appears to have a limited use in the depression of siliceous gangue in pyrite flotation.

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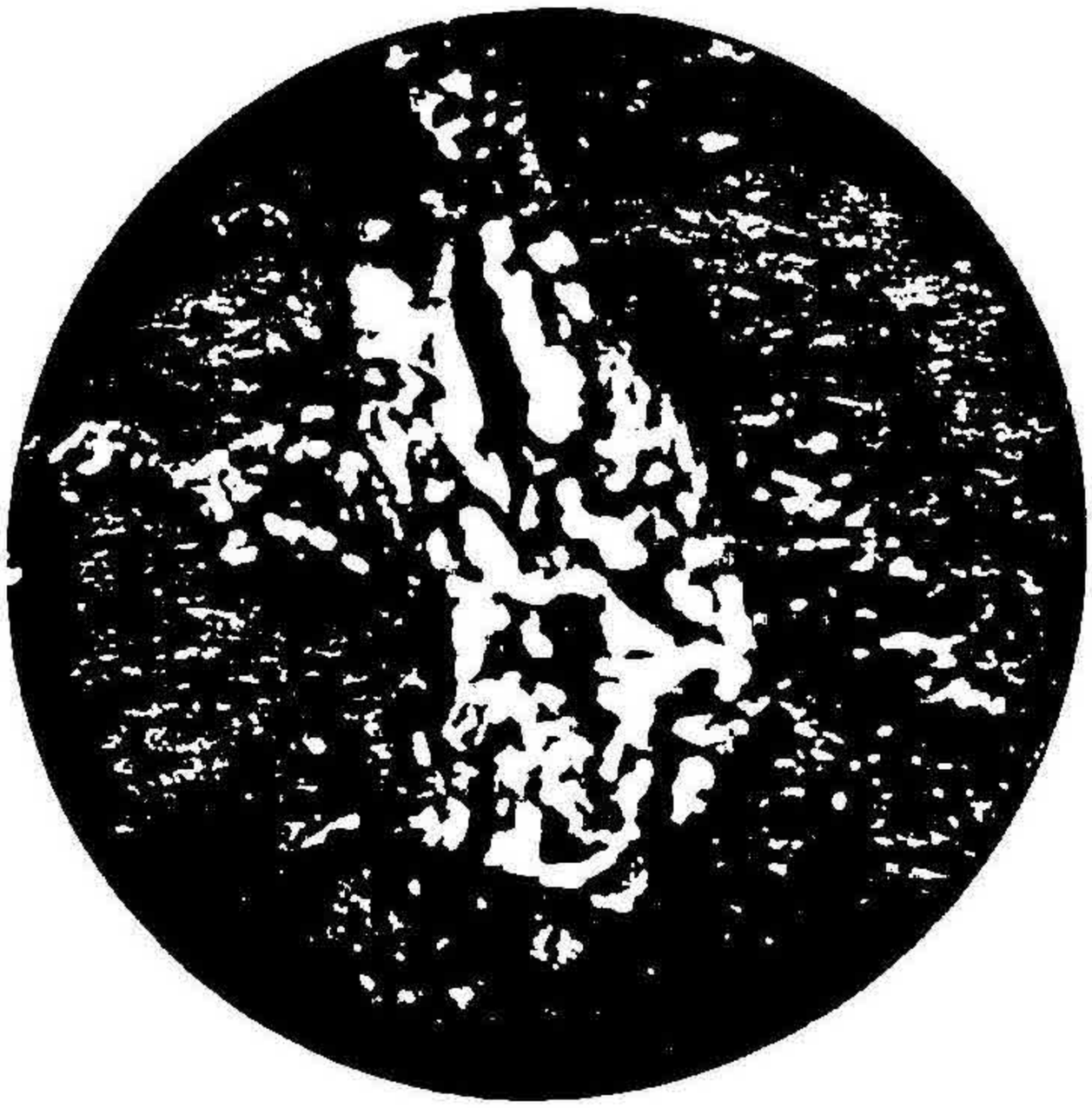
PHOTOMICROGRAPH 1. Locked pyrite particles, − 200 mesh. Reflected light, 500×.



PHOTOMICROGRAPH 2. Locked pyrite particle, − 200 mesh. Reflected light, 500×.

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