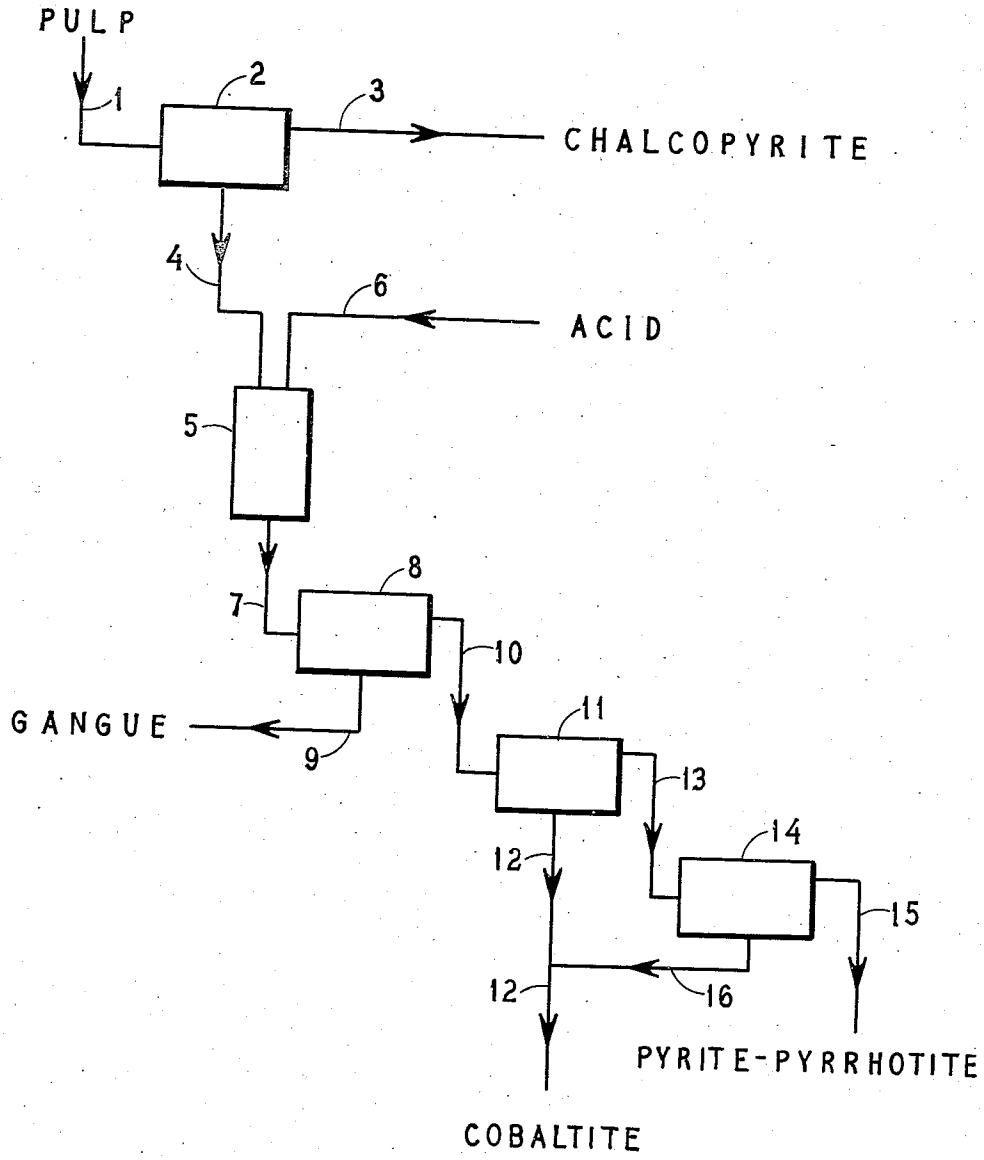
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SEPARATION OF COBALTITE

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SEPARATION OF COBALTITE

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1 Claim. (Cl. 209—167)

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This invention relates to the separation of cobaltite from minerals containing it.

Cobaltite, a mineral of the approximate composition CoAsS, is an available cobalt mineral from which the pure metal or its compounds can be economically produced, provided, however, the cobaltite can be separated in concentrated form from other minerals associated therewith. Among the minerals frequently associated with cobaltite are pyrite and pyrrhotite. Chalcopyrite is also frequently found in association with cobaltite.

Separation of minerals by flotation methods has advanced to the point where almost any mineral or group of minerals can be separated from any other mineral or group of minerals of distinctly different floatability and flotation characteristics. The difficulty arises in separating minerals of very similar floatability and flotation characteristics.

In the instant case, cobaltite is found associated with gangue (earthy matter of little or no mineral value), pyrite and pyrrhotite and, frequently, with chalcopyrite. The separation of the group cobaltite-pyrite-pyrrhotite from both the gangue and the chalcopyrite is easy and straightforward. The gangue can be separated by floating the minerals in an acid or neutral circuit, employing the usual flotation agents for flotation of sulfide minerals, whereby the cobaltite-pyrite-pyrrhotite are floated and the gangue is rejected. Also, chalcopyrite can be readily separated by floating it in a basic circuit. The separation of cobaltite from the pyrite and pyrrhotite is, however, a problem of wholly different magnitude. The floatabilities and flotation characteristics of these three minerals are so similar that, heretofore to my knowledge, they have not been separated except by cumbersome and expensive methods.

It is an object achieved by the present invention to effect a facile, economical separation of cobaltite from ores, concentrates and the like containing it in association with pyrite, pyrrhotite, or other iron sulfide minerals of similar flotation characteristics.

It is a further and particular object achieved by this invention to separate cobaltite from ores, concentrates and the like containing it in association with pyrite or pyrrhotite, or both, together with chalcopyrite.

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Other objects achieved by this invention will be apparent from the following description and the appended claim.

I have found that cobaltite can be readily and efficiently separated from pyrite or pyrrhotite, or from both if present together, by subjecting the mineral mixture to treatment with lime, and thereafter subjecting the mixture to flotation in a system of pH not greater than about 7 in the presence of a xanthate collector and a depressant for the cobaltite, and floating the pyrite and/or pyrrhotite away from the cobaltite in this system of controlled pH with the aid of the said flotation agents.

Without embarking upon any detailed scentific explanation of the phenomena involved, or in any way limiting the invention to a theory, I believe that the delicate separation of cobaltite from pyrite and/or pyrrhotite thus effected is due in large part to pre-liming the mineral mixture, which depresses the cobaltite more effectively and more durably than it depresses the pyrite and pyrrhotite, so that when the system is subsequently neutralized or acidified, the cobaltite is still depressed but the pyrite and pyrrhotite are not depressed or are not as fully depressed as the cobaltite. Upon flotation treatment in a system of pH not greater than about 7 in the presence of a xanthate collector (a known class of collectors suitable for use with sulfide minerals) and a depressant for the cobaltite (of which many well-known examples are available as hereinafter described), the cobaltite is still substantially non-floatable but the pyrite and pyrrhotite are flotable, especially in the presence of an activator.

If the mineral mixture consists of cobaltite plus pyrite and/or pyrrhotite, and no more, only the single flotation step described is necessary, and this step may be repeated, subjecting the cobaltite reject and the pyrite-pyrrhotite floated mixture each to a further similar flotation treatment.

However, if, as is usually the case, gangue is present, or if, as is often the case, chalcopyrite is present, in the mineral mixture, a preferred modification is employed. A single illustration with respect to a chalcopyrite-gangue-cobaltite-pyrite-pyrrhotite ore will suffice to illustrate this preferred modification.

In such case the ore, suitably comminuted, will first be limed, as by mixing with lime water, mix-

ing dry lime with the ground ore and adding water, or otherwise making an alkaline pulp containing lime. The chalcopyrite is then floated. Any other mineral flotable in a basic circuit may likewise be floated. This flotation step may be accomplished in the usual way, as by the use of pine oil as frothing agent and potassium ethyl xanthate as collector. The reject of gangue, cobaltite, pyrite and pyrrhotite, in pulp condition, is then rendered approximately neutral to acid and the mixture is subjected to flotation in the presence of a xanthate collector to float the cobaltite, pyrite and pyrrhotite away from the gangue. It will be noted that in this step the cobaltite is also floated. This is possible because the cobaltite depressant has not been used. The next step involves the use of a xanthate collector and a cobaltite depressant, whereby the cobaltite is depressed and rejected and only the pyrite and pyrrhotite are floated, as described above with reference to a simple cobaltite-pyrite-pyrrhotite mixture.

In the more complex separation of cobaltite from an ore containing it in association with chalcopyrite, gangue, pyrite and pyrrhotite, as just described, the order of steps is highly important. It is important that the chalcopyrite be floated first in a basic circuit and that gangue be subsequently separated. I have found that if the gangue is first separated and the chalcopyrite or other like mineral is then separated, the flotation products and tailings in subsequent separation steps are contaminated with chalcopyrite. This difficulty is avoided by following the order of steps as described above.

Of course, if chalcopyrite and gangue are separated by other means, or if a mineral mixture is available which does not contain chalcopyrite or gangue, the procedure of the invention may be suitably modified or simplified.

The process of my invention will be more fully understood by reference to the accompanying diagrammatic drawing representing a process of separating cobaltite from an ore containing it in association with chalcopyrite, gangue, pyrite and pyrrhotite.

Referring to the single figure of the drawing, an ore comprising chalcopyrite, pyrite, pyrrhotite, cobaltite and gangue, suitably ground and made into a pulp (about 20–30% solids) and made alkaline with lime solution, is introduced through a conduit 1 into a flotation cell 2 and is therein subjected to flotation in the presence of a frothing agent such as pine oil and a collector such as potassium ethyl xanthate. The frothing agent and collector may be added separately to the flotation cell or may be incorporated in the ore or pulp before it is introduced into the flotation cell. Preferably, the frothing agent is added to the pulp in the flotation cell. The flotation step carried out in cell 2, and subsequent flotation steps hereinafter described, may be carried out in accordance with standard procedure, such, for example, as that described in "Principles of Mineral Dressing" by A. M. Gaudin (McGraw-Hill), 1939 edition, pages 402–423. The chalcopyrite is floated in cell 2 and is removed through a conduit 3. The reject or tailings, containing the cobaltite along with pyrite, pyrrhotite and gangue, is withdrawn through a conduit 4 and introduced into a conditioning vessel 5 to which an acid, such, for example, as sulfuric acid or hydrochloric acid, is added through a conduit 6 in quantity sufficient to adjust the pH of the pulp to about 4 to 7. The material is preferably held in conditioning vessel 5 long enough to clean and brighten the surface of the sulfide particles. The pulp, thus adjusted as to pH, is withdrawn through a conduit 7 and introduced into a flotation cell 8 where it is subjected to flotation in the presence of suitable quantities of a frother, such as pine oil, and a xanthate collector, such as amyl xanthate, or potassium amyl xanthate, whereby all of the sulfide minerals, that is, pyrite, pyrrhotite and cobaltite, are floated and the gangue is rejected. The reject or tailings of gangue is withdrawn through a conduit 9 and suitably disposed of, and the floated sulfides are withdrawn through a conduit 10 and introduced to a flotation cell 11. Suitable quantities of a frother, such as pine oil, a xanthate collector, such as amyl xanthate, a depressant for cobaltite, such as mono calcium aryl sulfonate, and an activator, which may be a heavy metal salt, such as ferric sulfate, along with sufficient water to form a suitable pulp, are added and the mixture is subjected to flotation, whereby the pyrite and pyrrhotite are floated and the cobaltite is rejected. If need be, more acid may be added to adjust the pH of the pulp to 7 or less. Maintenance of the pH in this and the following flotation step at 7 or less, preferably from 7 to 4, is especially important because the difference in floatability between cobaltite on the one hand and pyrite and pyrrhotite on the other hand is small. By means of careful control of pH and proper selection of flotation agents, I am able successfully to float the pyrite and pyrrhotite away from the cobaltite despite this small difference in floatability. The cobaltite reject or tailings is removed through a conduit 12 and the floated pyrite and pyrrhotite are removed through a conduit 13 and introduced into a flotation cell 14. Suitable quantities of the same reagents as used in cell 11, and of water and/or acid if need be, are introduced into cell 14 and the pyrite-pyrrhotite concentrate is subjected therein to a second flotation similar to that carried out in cell 11, thus producing a further quantity of cobaltite as reject or tailings and floating a purer pyrite-pyrrhotite concentrate. The latter concentrate is removed through a conduit 15 and the recovered cobaltite is removed through a conduit 16 and joined with the first portion of cobaltite concentrate removed through conduit 12.

In the preferred embodiment illustrated by the drawing and described above, the pyrite-pyrrhotite-cobaltite concentrate resulting from the separation of gangue in flotation cell 8 is subjected to a double flotation as shown, but instead of this, a single flotation step, or three or even more flotation steps, may be employed. Thus the cobaltite concentrate may be subjected to further flotation to separate any residue of pyrite or pyrrhotite therein and the pyrite-pyrrhotite concentrate may likewise be subjected to further flotation to recover any residue of cobaltite therein.

The lime used in pretreating the mineral mixture, or in the chalcopyrite separation may be pure or impure lime. For example, it may be a dolomitic lime. The acid used in the neutralizing or acidifying steps is preferably sulfuric acid, but other acids capable of producing the desired pH, such as hydrochloric and phosphoric acids, may be used.

Following are specific examples of suitable frothing, collecting, activating and depressing agents capable of use in accordance with my invention, these specific examples belonging to recognized classes of flotation agents, many of which are set forth in Gaudin's "Principles of

Mineral Dressing," referred to supra, at the pages indicated below:

Frothing agents (page 363):
- Pine oil
- Higher alcohols
- Fusel oil
- Cresylic acid
- Eucalyptus oil
- Camphor

Collectors (page 371):
- Amyl xanthate
- Butyl xanthate
- Propyl xanthate
- Ethyl xanthate
- Sodium and potassium salts of the above xanthates
- Sulfonated petroleum sludge

Activators (pages 395 and 396):
- Ferric sulfate
- Lead nitrate
- Lead chloride
- Copper sulfate
- Copper chloride

Cobaltite depressants (pages 393 and 394):
- Mono calcium aryl sulfonate
- Mono sodium aryl sulfonate
- Sodium sulfide
- Sodium cyanide
- Sodium silicate

The amounts of such agents that may be used may vary considerably. However, in floating pyrite, pyrrhotite and cobaltite away from the gangue, in floating pyrite and pyrrhotite away from cobaltite, and in refloating the pyrite-pyrrhotite concentrate, I prefer to use the agents in the following approximate proportions:

	Lb./ton of ore
I. Flotation of pyrite, pyrrhotite and cobaltite away from gangue:	
Frother, such as pine oil	0.3 to 0.2
Xanthate collector, preferably amyl xanthate	0.25 to 0.75
II. Flotation of pyrite and pyrrhotite away from cobaltite:	
Frother, such as pine oil	0.5 to 0.1
Xanthate collector preferably amyl xanthate	0.25 to 0.5
Depressant for cobaltite, such as mono calcium aryl sufonate	0.25 to 0.5
Activator, such as ferric sulfate	1 to 2

	Lb./ton of ore
III. Reflotation of pyrite-pyrrhotite concentrate:	
Frother, such as pine oil	0.5 to 0.1
Collector, preferably amyl xanthate	0.1 to 0.25
Depressant for cobaltite, such as mono calcium aryl sulfonate	0.25 to 0.5
Activator, such as ferric sulfate	0.5 to 2

The depressants used in accordance with my invention are of the type of non-floating dispersing agents. Their function, as stated, is to depress the cobaltite. They accomplish this result by selectively wetting the surface of the cobaltite particles, thereby inhibiting bubble attachment to and flotation of the cobaltite particles. The activators, which are preferably heavy metal salts, have the effect of promoting the action of the collecting agents. They appear to effect this result by preferential adsorption of the heavy metal ion, e. g. ferric ion, on the pyrite and pyrrhotite particles, and forming heavy metal xanthate, e. g. ferric xanthate.

I claim:

In a method of effecting separation of cobaltite from a pulp mixture thereof with chalcopyrite, gangue, and from iron sulfide minerals of similar floatability to the cobaltite; that sequence of steps which consists in first rendering the pulp mixture alkaline with lime; adding a frother and a collector comprising a xanthate, and subjecting said pulp to a first froth flotation to float said chalcopyrite from said gangue, iron sulfide minerals and said cobaltite; then adding acid to adjust the pH of the reject of gangue, iron sulfide minerals and cobaltite to a value not greater than about 7 and a collector comprising a xanthate; then subjecting the pulp thus formed to a second froth flotation to float the cobaltite and iron sulfide minerals from the gangue; then adding to the cobaltite and iron sulfide a depressant for the cobaltite a collector comprising a xanthate, and an activator for the iron sulfide minerals comprising a heavy metal salt; and subjecting the pulp thus formed to a third froth flotation to float said iron sulfide minerals from said cobaltite in the presence of said depressant.

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