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Title: GOLD RECOVERY FROM REFRAC TORY ORES AND CONCENTRATES

Abstract: A method for recovery of gold from a gold-containing refractory pyrite- rich ore or concentrate is disclosed. The method results in the production of a high grade, gold-containing solid intermediate concentrate. One embodiment comprises the steps of treating gold-containing material (100) rich in pyrite, arseno-pyrite or other iron sulphide to yield a gold-containing refractory concentrate (110) comprising a host mineral matrix rich in pyrite, arseno-pyrite or other iron sulphide, pressure oxidation (112) of the refractory concentrate (110) under acidic conditions to decompose the host mineral matrix and precipitate basic ferric sulphate (Fe(OH)SO4) to produce a pressure oxidation product (114), conditioning of the pressure oxidation product (114) under acidic conditions at atmospheric pressure to convert the basic ferric sulphate (Fe(OH)SO4) to soluble ferric sulphate (Fe2(SO4)3) to produce a conditioning product (120), solid/liquid separation of the conditioning product (120) to produce a high grade, gold-containing solid intermediate concentrate (124), and an acidic filtrate (126).

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Gold recovery from refractory ores and concentrates

Technical Field

[0001] The present invention relates to processes for enhancing gold recovery from refractory ores and concentrates with improved environmental outcomes.

Background

[0002] Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is solely for the purpose of providing a context for the present invention. It is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present invention as it existed before the priority date of each claim of this specification.

[0003] The commercial exploitation of gold-containing refractory ores and concentrates is often determined by developing and implementing processing techniques that overcome the mineralogical complexities of the feedstocks, while at the same time avoiding, or at least minimising, potentially negative outcomes that flow from either the non-valuable (gangue) components of the feedstocks and/or the actual processing conditions themselves, such as the use of cyanide as the gold leachant.

[0004] Because of the mineralogical nature of refractory gold-containing ores and concentrates, it is usually necessary to treat the feedstock in a manner that physically and/or chemically breaks down the structure of the gold host mineral(s), typically pyrite and/or arsenopyrite, before the gold particles are amenable to dissolution, usually by means of a suitable lixiviant, eg, an alkaline cyanide leachant.

[0005] At present there are four commercially exploited technologies for processing gold-containing refractory ores and concentrates that incorporate a pre-leach conditioning step. The pre-leach conditioning steps focus on oxidation of sulphur and include:

- roasting, which uses heat and air or oxygen to burn away the sulphur from the ore;
- pressure oxidation, which utilizes oxygen and temperature under pressure in an aqueous medium, to effect oxidation of sulphur by way of controlled chemical reaction(s). Pressure oxidation is typically performed in high pressure autoclaves and may be performed under alkaline or acidic conditions, depending on the specific process;
• bioleaching, which uses bacteria to oxidize iron and sulphur as part of their metabolic pathways (e.g., *Acidithiobacillus ferrooxidans*, *Acidithiobacillus thiooxidans*);

• ultra-fine milling, to reduce the particle size of the feedstock in order to expose gold-containing minerals to leachant.

[0006] In each case, the exposed gold is typically recovered by cyanide leaching.

[0007] Each of the above processes has its own inherent technological challenges including, for example, separation and recovery of any co-dissolved base metals, neutralisation of excess acid, precipitation of soluble iron, precipitation of soluble arsenic, processing sulphur dioxide containing off-gases, handling elemental sulphur, and the essential cyanide detoxification circuit. Various methods have been developed which attempt to at least partly overcome these technological challenges, although this typically adds to the overall capital and operating costs of the entire processing flowsheet, which adversely impacts commercial viability.

[0008] Considerable effort has been directed toward the development of various alternative methods for processing gold-containing refractory ores and concentrates. These include alternative methods of chemically breaking down the gold host minerals, for example, by nitric acid or chloride leaching technologies, as well as the use of alternative gold leachants such as thiosulfate and thiourea. However, to date none of these alternative methods has achieved commercial status, although several have been piloted on a continuous basis.

[0009] Although the chemistry of gold dissolution using an alkaline cyanide leachant, as well as the chemical destruction of both free and complexed cyanide in effluent streams, are well understood, there is a world-wide move to tighten the occupational health and safety regulations covering the use of cyanide. As a result, in many jurisdictions obtaining the necessary permits is both time consuming and costly. This applies to both brown field projects where cyanide leaching is already practised, but is more prevalent in green field projects where there is no history of cyanide leaching. In some instances there is a total ban on cyanide leaching. In such cases, processing of gold-containing refractory ores and concentrates is effectively excluded because there is no viable alternative to cyanide leaching.

[0010] There remains a need for alternative methods for improving extraction of gold and other valuable metals from refractory ores.
Summary of the Invention

[001] The present invention relates to an alternative approach to processing gold-containing material, such as ores and concentrates, as well as an alternative route for final gold recovery.

[0012] In a first aspect the invention provides a method for recovery of gold from gold-containing material rich in pyrite, arseno-pyrite or other iron sulphide, the method comprising the steps of:

- treating gold-containing material rich in pyrite, arseno-pyrite or other iron sulphide to yield a gold-containing refractory concentrate comprising a host mineral matrix rich in pyrite, arseno-pyrite or other iron sulphide;

- pressure oxidation of the refractory concentrate under acidic conditions to decompose the host mineral matrix and precipitate basic ferric sulphate \((\text{Fe(OH)}\text{S}_\text{0})\text{4}\) to produce a pressure oxidation product;

- conditioning of the pressure oxidation product under acidic conditions at atmospheric pressure to convert the basic ferric sulphate \((\text{Fe(OH)}\text{S}_\text{0})\text{4}\) to soluble ferric sulphate \((\text{Fe}_\text{2}(\text{S}_\text{0})\text{3})\) to produce a conditioning product;

- solid/liquid separation of the conditioning product to produce a high grade, gold-containing solid intermediate concentrate, and an acidic filtrate.

[0013] The gold-containing pyrite-rich material may be refractory ore, run-of-mine ore or flotation tailings where pyrite has been rejected as waste product.

[0014] The treatment step to yield a gold-containing refractory concentrate typically involves one or more steps selected from crushing, grinding and selective flotation of the ore. Any or all of these steps may be repeated as required. The treatment step will typically yield a high-grade gold-containing refractory concentrate. The host mineral matrix of the concentrate produced during or by this step will typically reject the majority of the gangue in the concentrate tailings.

[0015] In a second aspect the present invention provides a method for recovery of gold from a gold-containing refractory concentrate comprising a host mineral matrix rich in pyrite, arseno-pyrite or other iron sulphide, the method comprising the steps of:

- pressure oxidation of the refractory concentrate under acidic conditions to decompose the host mineral matrix and precipitate basic ferric sulphate \((\text{Fe(OH)}\text{S}_\text{0})\text{4}\) to produce a pressure oxidation product;

- conditioning of the pressure oxidation product under acidic conditions at atmospheric pressure to convert the basic ferric sulphate \((\text{Fe(OH)}\text{S}_\text{0})\text{4}\) to soluble ferric sulphate \((\text{Fe}_\text{2}(\text{S}_\text{0})\text{3})\) to produce a conditioning product, and
solid/liquid separation of the conditioning product to produce a high grade,
gold-containing solid intermediate concentrate, and an acidic filtrate.

[0016] The pressure oxidation step promotes precipitation of iron as basic ferric
sulphate (Fe(OH)SO₄). Typically, the pressure oxidation is performed in an autoclave at
a temperature in the range of from about 200-230°C for from about 30 minutes to about
2 hours, more preferably for about 45 minutes to about 1 hour. Typically, the
autoclave feed will have an initial free acidity of approximately 50-100 g/L H₂SO₄,
typically about 90-100 g/L H₂SO₄ or about 80-100 g/L H₂SO₄. Typically, the pressure in
the autoclave may range from about 2,500-3,000 kPaa (about 350-400 psia). Typically,
the pressure oxidation product is flash cooled before being conditioned.

[0017] Preferably the pressure oxidation product is conditioned at atmospheric
pressure and at a temperature in the range of from about 90-100°C, more preferably
about 95°C, for about 2-12 hours, for example, about 4-6 hours, under acidic conditions.
The acidic conditions for the conditioning of the pressure oxidation product may be
achieved by about 80-120 g/L H₂SO₄, more typically, about 90-100 g/L H₂SO₄, or about
100 g/L H₂SO₄.

[0018] The pressure oxidation step according to the invention is thought to minimise
the conditions under which iron precipitates, including hematite and jarosite, will form.
Processes of the prior art considered it desirable to produce hematite in significant
quantities. The pressure oxidation step of the present invention, by contrast, now seeks
to produce a basic iron sulphate precipitate and to reduce or eliminate hematite as part
of the overall process.

[0019] The conditioning step converts precipitated basic ferric sulphate
(Fe(OH)SO₄) to soluble ferric sulphate (Fe₂(SO₄)₃). This step thus minimises the
amount of basic ferric sulphate (Fe(OH)SO₄) that is present during downstream gold and
silver recovery, including for example, recovery by cyanide leaching. In this way, the
present invention allows the bulk of the iron to report to the liquid phase prior to
neutralization, while silica gangue, gold and a portion of the silver remain in the solid
phase.

[0020] The solid/liquid separation of the conditioning product may be achieved by
thickening and filtration using standard techniques known in the art to separate the solid
gold-containing intermediate concentrate from the acidic filtrate. Accordingly, the
soluble ferric sulphate (Fe₂(SO₄)₃) may be readily separated from the high grade,
gold-containing solid intermediate concentrate.

[0021] The method of the invention may further comprise neutralization of the acidic
filtrate using one or more alkalis or alkaline agents, such as alkaline earth(s). Typically,
this may be achieved by controlled multistage acid neutralisation to induce iron and
arsenic precipitation from the residual liquor using at least one alkali or alkaline agent, such as a source of limestone or lime or a combination thereof, to yield a mixture of gypsum/anhydrite, iron oxide/hydroxide (goethite and/or ferric hydroxide and/or hematite and/or jarosite and/or paragoethite) tailings and ferric arsenate suitable for final disposal or marketing as by-products. The neutralised solution will typically be recycled.

[0022] In accordance with the methods of the present invention, recovery of the soluble copper and silver content may be achieved by sulphide precipitation or solvent extraction/electrowinning, using conventional techniques known to those skilled in the art. Typically, the methods of the invention further include neutralization of the resultant copper-free residual liquor to an environmentally suitable pH using a combination of limestone and lime.

[0023] In preferred embodiments the present invention is directed to the processing of gold-containing refractory ores and concentrates in which the gold is intimately associated with pyrite and arsenopyrite, but it is equally applicable to other gold- and base metal-containing refractory ores and concentrates.

[0024] In the context of the present disclosure the term 'pyrite-rich' may be used to refer to material (eg, refractory ores, tailings or concentrates) rich in pyrite, arsenopyrite, any other iron sulphide mineral, or mixtures thereof.

[0025] The present invention is principally directed to methods of enhanced gold recovery. In alternative embodiments the refractory ores or concentrates may contain recoverable amounts of gold, silver, copper or other valuable metals and the invention is directed to methods of enhanced recovery of gold, silver, copper and other valuable metals.

[0026] In accordance with the present invention, the refractory gold-containing material (ie, gold-containing refractory ore or gold-containing refractory concentrate) may be processed in such a manner that a high proportion of the gold and the silver, if present, reports to a solid high-grade intermediate concentrate.

[0027] The overall recovery of gold into the solid intermediate concentrate is preferably at least about 75%, more preferably at least about 80%, more preferably at least about 85%, more preferably at least about 90%, and even more preferably at least about 95%. In various preferred embodiments the overall recovery of gold into the intermediate concentrate is about 75-95%, or about 80-95%, or about 85-95%.

[0028] Throughout this specification, percentages (%) refer to % by weight.

[0029] The overall recovery of silver into the solid intermediate concentrate is preferably at least about 50%, more preferably at least about 60%, more preferably at
least about 70%, more preferably at least about 80%, more preferably at least about 90%, and even more preferably at least about 95%.

[0030] The mass of the gold-containing solid intermediate concentrate will typically be about 5-30%, and more typically about 10-25% of the mass of the original gold-containing refractory concentrate. The substantial reduction in mass, more particularly a higher proportion of gold contained in the substantially reduced mass, offers a particular advantage with regard to handling and downstream processing. In addition, the substantial reduction in mass allows the solid intermediate concentrate to be economically transported to a different site for further processing for gold recovery.

[0031] Gold may be recovered from the solid intermediate concentrate by various conventional means. For example, in various embodiments gold recovery may be achieved by addition of some or all of the solid intermediate concentrate to the feedstock flux of a copper sulphide smelter, such as a flash smelter, that yields gold-containing blister copper and which may be subsequently electrorefined such that the gold may be finally recovered from the copper anode slimes by appropriate means.

[0032] In alternative embodiments, gold may be recovered from the solid intermediate concentrate by conventional cyanide leaching, where permitted, or recovered using alternative means such as the use of a non-cyanide leachant.

[0033] Methods of the present invention may be applied to a gold-containing pyrite-rich ore with a relatively low copper content of 0.5%-1.25% copper. Typically, the gold-containing, refractory pyrite-rich concentrate may comprise approximately 6-8 g/t gold and approximately 0.5-1.25% copper.

[0034] The solid intermediate concentrate will typically contain approximately 30-60 g/t gold and approximately 20-75 g/t silver.

[0035] The overall flowsheet of the present invention may include processes for recovering other base metals contained in the original refractory ore or concentrate.

[0036] In an alternative embodiment, gold may be recovered from the solid intermediate concentrate by conventional cyanide leaching, where permitted, or recovered using alternative means such as the use of a non-cyanide leachant, eg, thiosulfate.

[0037] The acidic filtrate, which contains the soluble copper content of the initial concentrate, may be subjected to an optional controlled acid neutralisation and iron and arsenic precipitation step, eg, using limestone/lime, to recover soluble copper content and to separately yield a final mixture of gypsum/anhydrite, iron oxide/hydroxide (goethite and/or ferric hydroxide and/or hematite and/or jarosite and/or paragoethite) tailings and ferric arsenate suitable for final disposal or marketing as by-products. In
one typical embodiment a portion of the residual liquor after the autoclave discharge may be clarified and recycled to the initial pressure oxidation step to maintain the initial free acid strength at a desired level. The remaining portion of the copper-free residual liquor may then be subjected to controlled acid neutralisation and iron and arsenic precipitation.

[0038] Copper sulphide precipitated from the filtrate derived from the conditioning product separation step may be combined with the high-grade intermediate concentrate.

[0039] The high gold content of the intermediate concentrate combined with the significant mass reduction are such that the present invention is thought to offer an economical means to transport this material to another site for further processing. This may be particularly advantageous in situations where the necessary extraction (ie, leaching) facilities are not available and/or permitted at the up-front mining, milling or pressure oxidation facility site.

[0040] Thus, in one or more preferred embodiments the method of the present invention enables the economic recovery of the gold and base metal contents of refractory ores and concentrates under conditions that incorporate conventional procedures, including the use of an alkaline cyanide for gold leaching where permitted, but also enables the use of an alkaline cyanide leach stage for gold recovery to be avoided where such a step is not permitted for environmental reasons.

Brief Description of the Drawings

[0041] Figure 1 is a flowsheet representing one presently preferred embodiment of the invention.

[0042] Figure 2 is a flowsheet representing a presently preferred embodiment of the invention including the water flows.

Detailed Description of Preferred Embodiments

[0043] A presently preferred embodiment of the invention includes the following steps:

Step 1. A pyrite-rich, gold-containing concentrate typically containing 6-8 g/t gold and 0.5-0.75% copper is subjected to pressure oxidation at 200-230°C for 0.75-1.0 h.

Step 2. The pressure oxidation product may be flash cooled and conditioned at 95°C and atmospheric pressure for 2-8 hours under acidic conditions to produce a conditioned product.
Step 3. A portion of the autoclave discharge liquor may be clarified and recycled to the initial pressure oxidation step to maintain the initial free acid strength of the slurry at the desired level.

Step 4. The conditioned product from step 2 is thickened and filtered to yield a gold-containing solid intermediate concentrate that typically contains 30-60 g/t gold and 20-75 g/t silver.

Step 5. The filtrate is subjected to an optional controlled acid neutralisation and iron and arsenic precipitation step, eg, using limestone/lime to yield a final mixture of gypsum/anhydrite, iron oxide/hydroxide (goethite and/or ferric hydroxide and/or hematite and/or jarosite and/or paragoethite) tailings and ferric arsenate suitable for final disposal or marketing as by-products.

Step 6. Soluble copper silver and other valuable metals contained in the intermediate concentrate filtrate are recovered via sulphide precipitation and/or solvent extraction and electrowinning in separate stages among the neutralisation steps. Alternatively, the pH may be further elevated to 10 by using lime to precipitate any magnesium built up in the circuit.

Step 7. The remaining portion of the copper-free residual liquor is subjected to final acid neutralisation to neutral pH using a combination of limestone and lime.

Step 8. The solid intermediate concentrate recovered from the conditioned product is further processed to recover the gold and silver contents. This can be achieved by various known processes, including (a) direct cyanidation, (b) gold dissolution using a non-cyanide leachant or (c) pyrometallurgical processing to yield a gold-containing blister copper suitable for copper electrowinning and anode slimes treatment. With respect to process (c), copper sulphide precipitated from the filtrate derived from the conditioning product separation stage optionally may be combined with the high-grade solid intermediate concentrate.

[0044] Preferred embodiments of the invention will now be described with particular reference to Figure 1 and Figure 2.

[0045] Figure 1 is a flowsheet illustrating the method of a presently preferred embodiment of the invention in which pyrite-rich, gold-containing refractory ore 100 is treated by one or more methods known in the art to produce a pyrite-rich, gold-containing refractory concentrate 110. Typical treatment methods include comminution of the ore 100, for example by crushing 102 and grinding 104, to reduce the particle size to facilitate liberation of gold-containing pyrite residues. Typically, selective flotation 106 may be used to further refine the ore 100 to produce pyrite-rich, gold-containing refractory concentrate 110. Selective flotation techniques are well known in the art. Selective froth flotation uses differences in physico-chemical surface properties of
particles to preferentially float certain minerals. Typically, this involves treatment of a feedstock with reagents that emphasise differences in surface properties between minerals within a flotation pulp, such as hydrophobic properties and hydrophilic properties. Air bubbles may then be sparged through the pulp to float hydrophobic particles. Flotation reagents and conditions may be selected to favour flotation of selected gold-containing sulphide minerals.

[0046] The pyrite-rich, gold-containing refractory concentrate 110 comprises a host mineral matrix rich in pyrite, arsenopyrite or other iron sulphides. In the preferred embodiment, the pyrite-rich, gold-containing concentrate 110 contains about 6-8 g/t gold and about 0.5-1.25% w/w copper. The breakdown and dissolution of pyrite, arsenopyrite and other iron sulphides is highly desirable for gold recovery by liberating the fine gold particles trapped within the sulphide matrix. Accordingly, the pyrite-rich, gold-containing refractory concentrate 110 is subjected to pressure oxidation 112 using oxygen from an oxygen plant 113 in an autoclave at a temperature in the range of from about 200-230°C for a period ranging from about 45 minutes to about 1.0 hour to produce pressure oxidation product 114. The free acidity of the autoclave medium during pressure oxidation 112 is typically about 50-100 g/L H₂SO₄. Typically, the pressure oxidation 112 is performed at a pressure in the range of from about 2,500-3,000 kPaa (about 350-400 psia).

[0047] Basic iron sulphate (Fe(OH)SO₄) forms under the acidic conditions of the pressure oxidation step 112 and, if not removed, can adversely affect downstream extraction of gold, for example, during cyanide leaching processes. Basic iron sulphate can be converted under highly acidic conditions to soluble ferric sulphate (Fe₃(SO₄)₂) in solution. Accordingly, the next stage in the process is flash cooling 116 of the pressure oxidation product 114 followed by conditioning 118 at 95°C and atmospheric pressure for 2-12 hours under acidic conditions to produce conditioning product 120 in which the basic iron sulphate precipitate has been converted to soluble ferric sulphate. A portion of the autoclave discharge liquor may be clarified and recycled to the pressure oxidation step 112 to maintain the initial free acid strength of the slurry at the desired level.

[0048] The conditioning product 120 is subjected to a thickening, washing, filtration and clarification step 122 to yield a gold-containing solid intermediate concentrate 124 that typically contains about 30-60 g/t gold and about 20-75 g/t silver.

[0049] The gold-containing solid intermediate concentrate 124 recovered from the conditioning product 120 undergoes further processing 128 to recover the gold and silver contents 132. This can be achieved by various known processes, including (a) direct cyanidation, (b) gold dissolution using a non-cyanide leachant or (c) pyrometallurgical processing to yield a gold-containing blister copper suitable for copper electrowinning and anode slimes treatment.
[0050] With respect to pyrometallurgical processing (c), copper sulphide precipitated from the overflow 142 optionally may be combined with the high-grade solid intermediate concentrate 124. Advantageously, the reduced overall mass and increased concentration of gold (and silver) in the gold-containing intermediate concentrate 124 allows the concentrate 124 to be readily transported off-site 130 for further processing 128, which is especially useful for sites that do not allow cyanide leaching.

[0051] The acidic filtrate 126 from the solid/liquid separation step 122, contains the soluble copper and other metal content of the initial refractory concentrate 110. In one embodiment the acidic filtrate 126 goes through Neutralization Phase 1, which incorporates a primary neutralization 136 and iron/arsenic precipitation phase 138, and the solids are subjected to thickening and filtration 139 and separated to yield a mixture of gypsum/anhydrite, iron oxide/hydroxide (goethite and/or feme hydroxide and/or hematite and/or jarosite and/or paragoethite) tailings and ferric arsenate (Fe-As) precipitation tailings 140. Metal solids (copper and other metals) 148 are then recovered from the overflow, Phase 1 142 via copper recovery stage 143 and a thickening/filtration stage 144. Liquor 146 is subjected to Neutralization Phase 2, 150, which is the final neutralization step, to yield a precipitate 152 containing gypsum/anhydrite and remaining constituents including arsenic, iron, aluminium, copper, zinc, cobalt, nickel, manganese and magnesium, which may be combined with the phase 1 tailings 140, and either stored separately or sold as a by-product.

[0052] The neutral pH filtrate from Neutralization Phase 2 150 may be returned as process water for cooling pressure oxidation autoclave 112 and thickener/filter/clarifier/washer 122.

[0053] Figure 2 is a flowsheet illustrating the method of another presently preferred embodiment of the invention in which a pyrite-rich, gold-containing refractory concentrate 200 is fed to a pressure autoclave 204 in a pressure oxidation step. The pyrite-rich, gold-containing refractory concentrate 200 comprises a host mineral matrix rich in pyrite, arsenopyrite or other iron sulphides. Typically, the pyrite-rich, gold-containing concentrate 200 contains about 6-8 g/t gold and about 0.5-1.25% w/w copper.

[0054] The pressure autoclave 204 receives an oxygen feed from an oxygen plant 202 and pressure oxidation is typically performed at a temperature ranging from 200-230°C for a period ranging from about 30 minutes to about 2.0 hours, typically 45 minutes to about 1.0 hour. The free acidity of the pressure autoclave medium is typically about 50-100 g/L H₂SO₄. Typically, the discharge product of the pressure oxidation undergoes flash cooling and thickening 206 before proceeding to hot acid cure tanks 208 for conditioning. In alternative embodiments, the product of the pressure autoclave 204 may be fed directly to hot acid cure tanks 208 for conditioning. A portion
of the autoclave discharge liquor may be clarified and recycled to the pressure autoclave 204 to maintain the initial free acid strength at the desired level.

[0055] During the hot curing conditioning step basic iron sulphate (Fe(OH)SO₄), which forms during the pressure oxidation in the pressure autoclave 204, is converted to soluble ferric sulphate (Fe₂(SO₄)₃) under highly acidic conditions at about 95°C and atmospheric pressure for 2-12 hours. The conditioning product is thickened and washed 210 then filtered in a filter press 212 to separate the high-grade solid gold-containing concentrate 214, which typically contains about 30-60 g/t gold and about 20-75 g/t silver. The total mass of the gold-containing concentrate 214 is substantially reduced and the proportion of gold is substantially increased, relative to the mass of the initial concentrate introduced to the feed system 200. For example, typically the mass of the gold-containing solid intermediate concentrate is about 5-30%, more typically 10-25% of the mass of the original gold-containing refractory concentrate. This enables the gold-containing concentrate 214 to be transported off-site for further processing if required. Alternatively, the gold-containing concentrate 214 may be processed in situ to recover the gold and silver content by standard processes.

[0056] The method includes controlled multistage acid neutralisation. The clarified overflow step 210, which contains soluble copper and other metals, is fed to neutralization tanks 216. Neutralization may be achieved using slaked lime, or using limestone fed from a limestone mill 218. The contents of neutralization tanks are thickened 222 and the overflow is fed to copper precipitation/pipe reactor 226 in which the soluble copper may be precipitated (and then followed by thickening 228) by the addition to reactor 226 of sulphidising reagents 230, for example sodium hydrogen sulphide (NaHS), to precipitate copper sulphide minerals, which are filtered 232 and the covellite concentrate 234 is recovered.

[0057] The copper-free filtrate from the copper sulphide filtration step may be fed to phase 2 neutralization tanks 236 in which neutralization may be achieved with slaked lime fed from lime silo 239 and then to lime slaker 240. Controlled acid neutralisation and iron and arsenic precipitation using slaked lime or limestone yields a mixture of gypsum/anhydrite, iron oxide/hydroxide (goethite and/or ferric hydroxide and/or hematite and/or jarosite and/or paragoethite) tailings and ferric arsenate which is thickened in filter press step 238. The filtrate may be returned as process water for cooling autoclave 204 and for washing thickeners, clarifiers 210. The solid residue tailings may be fed to a tailings management facility 242 and to concentrator 243 via tailings filters 241.

[0058] It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.
Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.
Claims:

1. A method for recovery of gold from gold-containing material rich in pyrite, arseno-pyrite or other iron sulphide, the method comprising the steps of:
   - treating gold-containing material rich in pyrite, arseno-pyrite or other iron sulphide to yield a gold-containing refractory concentrate comprising a host mineral matrix rich in pyrite, arseno-pyrite or other iron sulphide;
   - pressure oxidation of the refractory concentrate under acidic conditions to decompose the host mineral matrix and precipitate basic ferric sulphate \((\text{Fe(OH)}_2\text{S}_\text{O}_4)\) to produce a pressure oxidation product;
   - conditioning of the pressure oxidation product under acidic conditions at atmospheric pressure to convert the basic ferric sulphate \((\text{Fe(OH)}_2\text{S}_\text{O}_4)\) to soluble ferric sulphate \((\text{Fe}_2\text{(S}_\text{O}_4)_3)\) to produce a conditioning product;
   - solid/liquid separation of the conditioning product to produce a high grade, gold-containing solid intermediate concentrate, and an acidic filtrate.

2. The method of claim 1, wherein the gold-containing material rich in pyrite, arseno-pyrite or other iron sulphide is a gold-containing refractory ore.

3. The method of claim 1 or 2, wherein treating the gold-containing comprises one or more of crushing, grinding and selective flotation to yield the gold-containing refractory concentrate and to reject gangue.

4. A method for recovery of gold from a gold-containing, refractory concentrate comprising a host mineral matrix rich in pyrite, arseno-pyrite or other iron sulphide, the method comprising the steps of:
   - pressure oxidation of the refractory concentrate under acidic conditions to decompose the host mineral matrix and precipitate basic ferric sulphate \(\text{Fe(OH)}_2\text{S}_\text{O}_4\) to produce a pressure oxidation product;
   - conditioning of the pressure oxidation product under acidic conditions at atmospheric pressure to convert the basic ferric sulphate \(\text{Fe(OH)}_2\text{S}_\text{O}_4\) to soluble ferric sulphate \(\text{Fe}_2\text{(S}_\text{O}_4)_3\) to produce a conditioning product, and
   - solid/liquid separation of the conditioning product to produce a high grade, gold-containing solid intermediate concentrate, and an acidic filtrate.

5. The method of any one of claims 1 to 4, further comprising controlled neutralisation of the acidic filtrate with at least one alkali or alkaline agent to precipitate iron and/or arsenic residues.

6. The method of claim 5, wherein the alkali or alkaline agent is selected from a source of limestone or lime, and mixtures thereof.
7. The method of claim 5 or 6, wherein the iron and arsenic residues precipitate as a mixture of gypsum/anhydrite, iron oxide/hydroxide (goethite and/or ferric hydroxide and/or hematite and/or jarosite and/or paragoethite) tailings and ferric arsenate.

8. The method of any one of claims 1 to 7, further comprising recovering one or more of soluble copper and other metals from the acidic filtrate.

9. The method of claim 8, wherein the recovery of soluble copper and other metals comprises solvent extraction, electrowinning or sulphide precipitation.

10. The method of any one of claims 1 to 9, wherein the mass of the gold-containing solid intermediate concentrate is approximately 10-25% of the mass of the refractory concentrate.

11. The method of any one of claims 1 to 10, wherein the overall recovery of gold into the solid intermediate concentrate is at least about 75%.

12. The method of any one of claims 1 to 11, wherein the refractory concentrate contains about 6-8 g/t gold and about 0.5-1.25% copper.

13. The method of any one of claims 1 to 12, wherein pressure oxidation is performed at a temperature in the range of from about 200-230°C for about 45 minutes to one hour with a free acidity of autoclave medium of about 50-100 g/L H₂SO₄.

14. The method of any one of claims 1 to 13, wherein the pressure oxidation product is flash cooled, then conditioned at about 95°C and atmospheric pressure for about 2-12 hours under acidic conditions.

15. The method of any one of claims 1 to 14, wherein the gold-containing solid intermediate concentrate contains about 30-60 g/t gold.

16. The method of claim 15, wherein the gold-containing solid intermediate concentrate contains about 20-75 g/t silver.

17. The method of any one of claims 1 to 16, further comprising processing the gold-containing solid intermediate concentrate to extract the gold.
Figure 1

Substitute Sheet
(Rule 26) RO/AU
INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2013/001169

A. CLASSIFICATION OF SUBJECT MATTER

C22B 11/00 (2006.01)  C22B 3/00 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC...

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

Epodoc and WPI. IPC.CPC: C22B1 1/00/LOW, C22B3/00/LOW; Keywords: pyrite, ore, pressure, oxidation (with similar keywords). Google Patents. Esp@cenet Patent Lens: pyrite, ore, pressure, oxidation, (with similar keywords).

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Documents are listed in the continuation of Box C

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"*" Special categories of cited documents:

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Date of the actual completion of the international search: 2 January 2014

Date of mailing of the international search report: 02 January 2014

Name and mailing address of the ISA/AU

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End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

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