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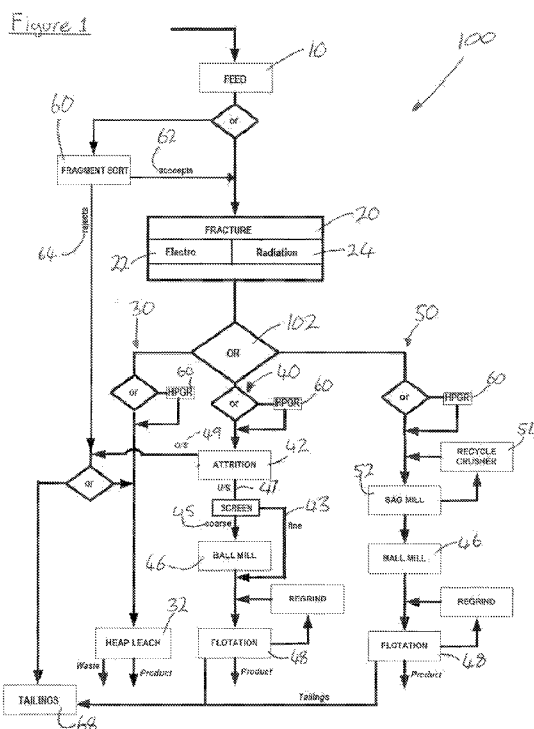
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(54) Title: A RECOVERY PROCESS



(57) **Abstract:** A recovery process for valuable components in mined material includes fracturing ore fragments by one of an electro fracturing technique or electromagnetic radiation technique at a fracture station and treating fractured ore fragments in a treatment process selected from heap leaching or flotation processes and recovering valuable components from the fragments.

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A RECOVERY PROCESS

TECHNICAL FIELD

5 The present invention relates to the recovery of valuable components, such as metals or minerals, from mined material. In particular, the present invention relates to process flows for the efficient recovery of the valuable components from ore fragments.

BACKGROUND ART

10

Extraction of copper and other valuable minerals/metals from ores usually involves a number of unit operations e.g. crushing, SAG milling, ball milling, froth flotation etc. It is well known that the energy consumption in such processes is very high. There is a continuous need to improve the efficiency of each unit operation or recovery process as a whole.

15

SUMMARY OF THE DISCLOSURE

20 The present invention provides a recovery process for valuable components, such as metals or minerals, in mined material that includes:

- (a) fracturing ore fragments by one of an electro fracturing technique or electromagnetic radiation technique at a fracture station; and
 - (b) treating the fractured ore fragments in a treatment process selected from heap leaching or flotation processes and recovering valuable components
- 25 from the fragments.

30 The term “mined” material is understood herein to include metalliferous material and non-metalliferous material. Copper-containing ores, iron-containing ores, nickel-containing ores, and uranium-containing ores are examples of metalliferous material. Coal is an example of a non-metalliferous material. The term “mined” material is understood herein to include, but is not limited to, (a) run-of-mine material and (b) run-of-mine material that has been subjected to at least primary crushing or

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similar size reduction after the material has been mined and prior to being sorted. The term “mined” material includes mined material that is in stockpiles. The term “mined” material includes geological core samples.

- 5 The recovery process may include fragment sorting of run of mine material into an “accepts” category and a “rejects” category and transferring accepted ore fragments only to the fracture step (a).

 The sorting step may be a dry sorting step.

10

 The dry sorting step may include exposing fragments to electromagnetic radiation and assessing the composition of the fragments based on the response of the fragments to the electromagnetic radiation.

15

 The dry sorting step may include exposing fragments to an alternating magnetic field which results in induction heating of fragments and assessing the composition of the fragments based on the response of the fragments to the alternating magnetic field.

- The treatment step (b) may include treating the fractured ore fragments in one
20 only of the heap leaching or flotation processes.

- The treatment step (b) may include treating the fractured ore fragments in more than one of the heap leaching or flotation processes, with a part of the fractured ore fragments being treated in one of the processes and another part of the fractured ore
25 fragments being treated in another one of the processes.

- The treatment step (b) may include a high pressure grinding roll step wherein the ore fragments are crushed by compression between two or more pairs of crushing rolls.

30

 The heap leaching step may be any suitable heap leaching step.

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The flotation treatment step may be any suitable flotation step.

5 The flotation treatment step may include an attrition milling step that abrades valuable components from the surface of fragments, for example from the high pressure grinding roll step, and produces an oversize category and an undersize category of fragments.

10 The flotation treatment step may include flotation processing of fragments in the undersize category to recover valuable components.

The flotation treatment step may include a semi-autogenous milling step of fragments, for example from the high pressure grinding roll step.

15 The flotation treatment step may include flotation processing of fragments from the semi-autogenous milling step to recover valuable components.

BRIEF DESCRIPTION OF THE DRAWINGS

20 Notwithstanding any other forms which may fall within the scope of the method as set forth in the Summary, a specific process flow embodiment will now be described, by way of example only, with reference to the accompanying drawing in which Figure 1 shows a flow diagram of a number of process flows for recovering valuable components, such as metals or minerals from ore fragments.

DESCRIPTION OF EMBODIMENT(S)

25 Referring to Figure 1, one embodiment of a recovery process 100 having a number of optional process flows is shown. The process flows of the recovery process 100 are designed for the efficient recovery of valuable components from a feed material.

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Mined material, in the form of ore fragments of any suitable size and size distribution, is received at feed point 10. The ore fragments are run-of-mine material. The run-of-mine material is optionally subjected to at least primary crushing or similar size reduction after the material has been mined and prior to being sorted. The ore
5 fragments can be sourced from feed stockpiles.

The ore fragments flow from the feed point 10 to a fracture station 20. Any one of a number of techniques may be employed at the fracture station 20 to fracture the ore fragments. Specifically, the ore fragments may be fractured using either an electro
10 fracturing technique 22 or an electromagnetic radiation technique 24 such as microwave or radio frequency induced fracturing.

Electro fracturing 22 uses electrical energy to cause the cracking, including micro-cracking, and then fracturing of ore fragments. An example electro fracturing
15 technique 22 is described in the Applicant's PCT International Application WO2010/065988, incorporated herein by reference.

Radiation induced fracturing 24 includes exposing ore fragments in an applicator to high power density electromagnetic energy thereby causing structural
20 alteration of the ore fragments. The electromagnetic radiation fracturing may operate with any suitable electromagnetic radiation. For example, the radiation may be any one or more of X-ray, microwave and radio frequency radiation. The structural alteration of the ore fragments is a result of differences in thermal expansion of minerals/metals within the ore fragments as opposed to the thermal expansion of the remainder of the
25 ore fragment. As a consequence of exposure to electromagnetic energy, regions of high stress/strain are created within the ore fragments and thus cracking within the ore fragments. An example microwave induced fracturing is described in the Applicant's PCT International Application WO2003/102250, incorporated herein by reference. The operating conditions, including frequency, residence time, power density, etc., are
30 selected so that the selected fragments are structurally altered to facilitate downstream recovery processing of the fragments. In situations where a valuable metal is a very small concentration in fragments and a large amount of fragments that have no or very

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low concentrations of the valuable metal, the electromagnetic radiation fracture 24 may not be a viable option from an energy (cost) viewpoint. The recovery process 100 may then include a fragment sorter 60 as described herein below.

5 Fractured fragments from the fracture station 20 are processed in either a heap leaching process 30 or one of two flotation processes 40, 50 in this embodiment of the invention. Decision block 102 indicates the optional use of one of the three downstream treatment processes 30, 40, 50. It is noted that the invention is not limited to this selection or combination of heap leaching and flotation processes and extends to
10 any suitable selection and combination of the processes.

 Each of the downstream treatment processes 30, 40, 50 includes an optional high pressure grinding roll (HPGR) step 60. The fragments optionally proceeding to the HPGR step 60 are crushed by compression of the fragments between two or more
15 pairs of crushing rolls. An example HPGR step 60 is described in the Applicant's PCT International Application WO2006/042378, incorporated herein by reference.

 The recovery process 100 takes advantage of exposing minerals/metals at a high bulk particle size (at fracturing station 20) and thus requires less mechanical
20 comminution energy input for the treatment processes 30, 40, 50.

 The fractured fragments received from fracture station 20 may be heap leached in accordance with downstream heap leaching process 30 to recover valuable components from ore fragments. The fractured fragments may first be ground in
25 HPGR step 60 before heap leaching 32 as discussed. Heap leaching is a well-known treatment process to extract valuable minerals and metals from ore fragments. The fracturing of the ore fragments at fracturing station 20 exposes the minerals/metals in the ore fragments to improve access of a leach solution to the valuable components. From a copper leaching perspective a major challenge in this ore type is the mass
30 transfer of solution to the copper through the very hard quartz matrix. This problem is alleviated as the copper minerals are exposed without significant energy input at

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fracturing station 20. An example leaching process 30 is described in the Applicant's PCT International Application WO 2009/000037, incorporated herein by reference.

5 The fractured fragments received from fracture station 20 may be processed in one of two flotation processes 40, 50.

10 In downstream treatment process 40, attrition milling station 42 is used to abrade the minerals/metals, such as copper, from the surface of the ore fragments. The minerals/metals after fracture 20 are beneficially located at or close to the surface of the ore fragments making milling at attrition station 42 highly effective. The treatment process 40 avoids use of a highly expensive SAG mill. Significant grinding energy is saved as a result of exposing or moving the copper sulphide minerals to the surface during fracturing 20 to be removed by attrition in attrition station 42.

15 After attrition milling station 42, the undersized ore particles 47 removed during attrition are screened in screen 44. Particles which are fine 43 are sent directly to flotation unit 48. Coarse particles 45 are milled in a ball mill 46 before being sent on to the flotation unit 48.

20 Oversized ore particles 49 from the attrition milling station 42 are transported to either heap 32 for heap leaching or the tailings pond 68 for disposal.

25 The downstream treatment process 50 is similar to the treatment process 40, with the only difference being that a SAG mill 52 with a recycle crusher 54 replaces the attrition milling station 42. Steps in the treatment process 50 which are the same as the steps in the treatment process 40 are referenced by the same reference numerals.

30 The feed material at feed point 10 is optionally fragment sorted, typically dry fragment sorted, at fragment sorting step 60 before being received at the fracture station 20. The fragment sorting step 60 comprises a fragment sorter.

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In one example, the fragment sorter utilizes either a radio frequency or a microwave applicator combined with an infrared camera to identify individual ore fragments having relatively high mineral/metal content. This technique includes assessing the composition of the fragments based on the response of the fragments to the electromagnetic radiation. An example of a radio frequency based fragment sorter that may be utilized is described in Applicant's PCT International Application WO 2011/075768, which is incorporated herein by reference. An example of a microwave based fragment sorter that may be utilized is described in PCT International Application WO 2007/051225, which is also incorporated herein by reference.

10

Another example of a fragment sorter utilizes an alternating magnetic field which results in induction heating of fragments. Valuable material in mined material is often more electrically conductive material than non-valuable material and therefore directly or indirectly assessing the electrical conductivity of mined material can provide an indication of whether there is valuable material in the mined material. This technique includes and assessing the composition of fragments based on the response of the fragments to the alternating magnetic field.

15

Accept fragments 62 having relatively high content of valuable mineral/metal continue to the fracture station 20. Reject fragments 64 which have relatively low content of valuable mineral/metal proceeds to either heap leaching 32 or a tailings pond 68. The fragment sorting step 60 is logically included when energy and/or cost savings due to relatively higher content valuable mineral/metal fractured fragments entering the treatment processes 30, 40, 50 outweighs the cost of the fragment sorting step 60.

25

The recovery process 100 describes improved efficiency recovery processes including a fracture station 20 and optional fragment sorting 60 prior to treatment processes 30, 40, 50.

30

The applicant is interested particularly in copper-containing ores in which the copper is present in the ore fragments as a sulphide, such as chalcopyrite or chalcocite. The applicant is also interested in nickel-containing ores in which the nickel is present

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in the ore fragments as a sulphide. The applicant is also interested in uranium-containing ores. The applicant is also interested in iron-containing ores.

Many modifications may be made to the embodiment of the present invention
5 described above without departing from the spirit and scope of the present invention.

By way of example, whilst the fractured fragments from the fracture station 20 are processed in either a heap leaching process 30 or one of two flotation processes 40, 50 in the described embodiment of the invention, it can readily be appreciated that the
10 invention is not limited to processing fractured fragments in only one downstream process and the invention extends to embodiments in which the fractured fragments are separated into different streams that are processed in two or more than two process options.

15 By way of further example, whilst the described embodiment includes processing fractured fragments in heap leaching and flotation processes, the present invention is not limited to these processes and extends to any processes that can extract valuable components from fractured fragments.

CLAIMS

1. A recovery process for valuable components in mined material that includes:
 - (a) fracturing ore fragments by one of an electro fracturing technique or
5 electromagnetic radiation technique at a fracture station; and
 - (b) treating fractured ore fragments in a treatment process selected from heap
leaching or flotation processes and recovering valuable components from the
fragments.
2. The recovery process defined in claim 1 includes fragment sorting run of mine
10 material into an “accepts” category and a “rejects” category and transferring accepted
ore fragments only to the fracture step (a).
3. The recovery process defined in claim 2 wherein the sorting step includes a dry
sorting step.
15
4. The recovery process defined in claim 3 wherein the dry sorting step includes
exposing fragments to electromagnetic radiation and assessing the composition of the
fragments based on the response of the fragments to the electromagnetic radiation.
- 20 5. The recovery process defined in claim 3 wherein the dry sorting step includes
exposing fragments to an alternating magnetic field which results in induction heating
of fragments and assessing the composition of the fragments based on the response of
the fragments to the alternating magnetic field.
- 25 6. The recovery process defined in any one of the preceding claims wherein the
treatment step (b) includes treating the fractured ore fragments in one only of the heap
leaching or flotation processes.
7. The recovery process defined in any one of claims 1 to 6 wherein the treatment
30 step (b) includes treating the fractured ore fragments in more than one of the heap
leaching or flotation processes, with a part of the fractured ore fragments being treated

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in one of the processes and another part of the fractured ore fragments being treated in another one of the processes.

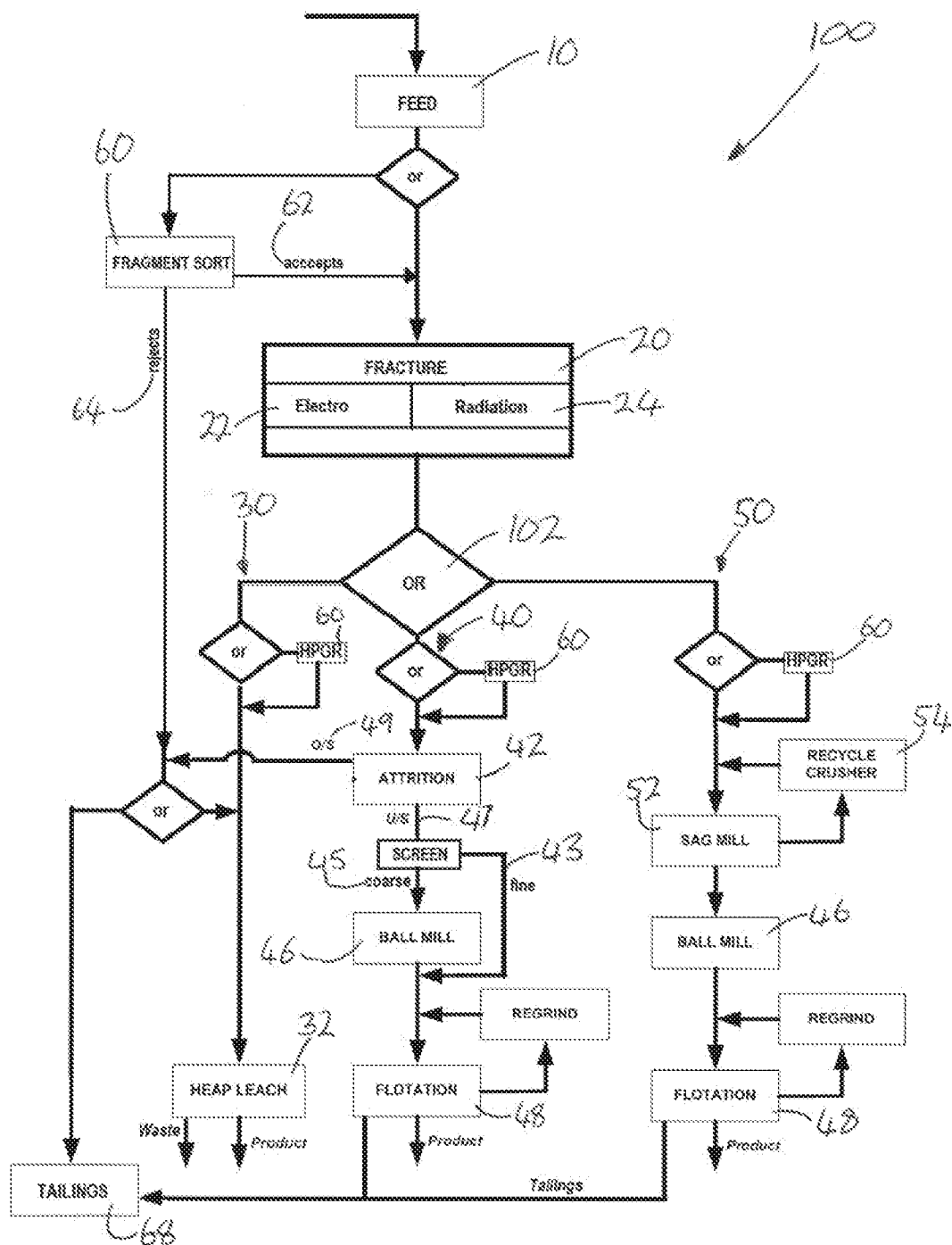


Figure 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2013/001494

A. CLASSIFICATION OF SUBJECT MATTER

B02C 19/18 (2006.01) B01J 19/12 (2006.01) B01J 19/08 (2006.01) C22B 1/14 (2006.01) B07C 5/34 (2006.01)
G01N 23/00 (2006.01) H05B 6/64 (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 data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI and EPODOC; IPC and CPC marks: B02C19/18, B02C23/00/LOW, B02C25/00, B02C21/00, B01J19/12, B01J19/08, C22B1/14/LOW, C22B9/14, H05B6/70, H05B6/78, H05B6/80, H05B6/784, C22B4/00, C22B1/08, B07C5/34, B07C5/344, B07C5/368, C22B1/00, G01N23/00, G01N33/00 using keywords such as: ore, electromagnetic radiation, sort, heap leaching, fracture and their similar keywords. Also Google Patents, Espacenet were searched using keywords such as: ore, electromagnetic radiation, sort, heap leaching, fracture and their similar keywords.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

☒ Further documents are listed in the continuation of Box C ☒ See patent family annex

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 20 March 2014	Date of mailing of the international search report 20 March 2014
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INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2013/001494
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2003/102250 A1 (Technological Resources Pty. Limited) 11 December 2003 (Abstract; claims; figure 1; page 9, line 15-page 11, line 14)	1 and 6
Y	(Abstract; claims; figure 1; page 9, line 15-page 11, line 10)	2-5 and 7
Y	WO 2012/016286 A1 (Technological Resources Pty. Limited) 09 February 2012 (Abstract; claims; figure 1; page 9, line 15-page 11, line 10).	2-5 and 7

Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2013/001494	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
WO 2003/102250 A1	11 Dec 2003	None	
WO 2012/016286 A1	09 Feb 2012	None	
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			