Journal of Cleaner Production xxx (2013) 1–6

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

A practical approach for the management of resources and reserves in Small-Scale Mining

Jacopo Seccatore [a,b,*], Tatiane Marin [a,b], Giorgio De Tomi [a,b], Marcello Veiga [c]

[a] Department of Mining and Petroleum Engineering, University of São Paulo, Brazil
[b] Research Center for Responsible Mining, University of São Paulo, Brazil
[c] Norman B. Keevil Institute of Mining Engineering, University of British Columbia, Canada

ARTICLE INFO

Article history:
Received 17 April 2013
Received in revised form
13 September 2013
Accepted 16 September 2013
Available online xxx

Keywords:
Small-Scale Mining
Artisanal mining
Mineral reserves
Sustainability

ABSTRACT

Artisanal (ASM) and Small-Scale Mining (SSM) are well-known sources of environmental, health and safety risk. Nonetheless, due to the massive increase in the price of gold in the last few years, ASM and SSM units have rapidly appeared and are operating in many remote locations around the world. This trend is bound to last, since there are no valid alternative livelihoods for the operators in the sector, and the attractiveness of the profit does not counterpoise any concern about the environment or safety. The most viable solution for such activities is a shift towards responsible operations. This can be done by turning an ASM operation into a sustainable and profitable SSM industrial extractive unit. For doing so capital investment is needed from external investors. The main task, therefore, is to make ASM attractive for investment. The approach proposed in this work is based on a main differential from large-scale mining: the attractiveness for external investment only lies in proving, in the early stages of the business, a minimum mineral reserve that is able to rapidly return the investment committed to upgrade the artisanal operation into a small-scale industrial one, plus an attractive profit. This is done by introducing the concepts of "minimal reserve to be proved" and "replication". The paper proposes a practical methodology for the evaluation of the minimal reserve to be proved, based on mining and processing CAPEX and OPEX. A portion of the profits of the operation on such minimal reserve is to be shared between the stakeholders of the business, and another is to be re-invested in future exploration. With this last share, the process of proving the reserve can be consequently replicated to the next portion of the mineral resource. This methodology is applied to prove viable a real SSM unit in Ecuador. The results are compared with large-scale reserve estimations: the order of magnitude of the volume that needs to be proved at the start to make the operation viable varies by 1/1000 in favor of SSM.

1. Introduction

The high investments associated with the installation of a mine requires the careful management of risks associated with the business (Singer and Kouda, 1999). This includes careful geological exploration research, detailed analysis, review and modeling of technical data on the indicated resources, and the study of alternative mining scenarios to exploit such resources in order to prove it as a reserve. An example of the process of "resource-to-reserve definition" can be found in Diering et al. (2013):

1) Reserves are based on a scheduled resource, ensuring that the planning discipline is integral to process
2) Appropriate mine design and layouts are applied to the resource areas as dictated by current mining methods and mine design criteria to derive a mineable resource
3) The mineable resource is scheduled according to production requirements to develop a scheduled resource
4) Only current operations (level 1), approved projects in execution (level 1e) and projects in feasibility study (level 2a) included in the business plan are defined as reserves (in Proved and Probable categories according to SAMREC)
5) The remaining scheduled area of the Life of Mine (LOM) plan is termed scheduled exclusive resource and includes projects from Level 2b, 2c, and Level 3 with the objective of optimally extracting the available resources

* Corresponding author. Department of Mining and Petroleum Engineering, University of São Paulo, Brazil Av. Prof. Mello Moraes, 2373, Butantã, CEP 05508-030, São Paulo, SP, Brazil.
E-mail address: jacopo.seccatore@usp.br (J. Seccatore).

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http://dx.doi.org/10.1016/j.jclepro.2013.09.031

6) Resource categories have been increased to cater for exclusions and confidence levels (e.g. mineral resources above the geothermal gradient cut-off are moved to mineral inventory)
7) The introduction of mining losses pertaining to resources left in pillars. The mineable resource excludes material locked up in mine-design related pillars
8) Uneconomic production plan 'tails' revert to mineral resource or mineral inventory (depending on position in plan) through a 'tail management' process
9) The application of modifying factors (technical, mining, geotechnical, processing and recovery, legal, market, and social/government factors) is implemented in three distinct phases:
   i. Mine design and scheduling-Those modifying factors that impact on dilution of the resource (i.e. stope width versus resource width, tertiary development and other waste mining done on the reef horizon etc.) and modifying factors that define mining losses (i.e. non-mineable pillars and RIH/RIF mining inefficiencies etc.) are applied to the criteria included in establishing the mine design and scheduling
   ii. Processing – Those modifying factors that influence the efficiency of processing and recovery are applied to the scheduled resource, and the result is a mineable reserve
   iii. Economic – The subsequent application of modifying factors that influence the economic aspects of the mining operation results in the tail management requirement.
10) The scheduled reserves are multi-discipline peer-reviewed and signed off by the competent person(s)

All this process is required for the disclosure of mining projects, and is mandatory to adhere to reference standards such as the Australian JORC (2004), the South-African SAMREC (2009) or the Canadian NI 43-101 (2011). Nevertheless, all this initial preparation work is highly costly. While being largely diffused in a standardized manner in Large-Scale Mining, with large investments applied and state-of-the-art technologies employed, when dealing with Small-Scale Mining (SSM) the exploratory and modeling phases are generally neglected due to a lack of capital (Hruschka and Echavarría, 2011).

SSM "has had unprecedented growth in developing economies over the past few decades. ASM is defined as the use of rudimentary processes to extract valuable minerals from primary and secondary ore bodies, and is characterized by the lack of long-term mine planning/control. It can be illegal or legal, formal or informal and can encompass everything from individual gold panners to medium-scale operations employing thousands of people" (Shena and Gunsonb, 2006). When approached as a business opportunity, SSM is quite critical: it is often related to poverty in remote areas, and is commonly seen as a problem due to its issues related to illegality and environmental pollution (Veiga, 1997, 2006, 2009; Shandro et al., 2009; Spiegel, 2010; Velasquez, 2010; Hintona et al., 2003). Nevertheless, Andrew (2003) highlights very clearly the positive potential of SSM: "Small-scale mining offers several potential benefits. It often allows the mining of otherwise uneconomic resources, since it is mobile, flexible, and requires little capital". This indicates that there is a positive return in overcoming the challenges related to SSM business. Seccatore et al. (2012) also indicate that "small-scale mining meets both the rapid customization with the necessities of the market and the technological and financial flexibility to adapt to the lower grades of the deposits to be exploited. These are all signals of a future development of small-scale mining in precious metals, especially gold, along the next decades". In the same study it is concluded that "efficiency in productivity is the main path to turn an ASM unit into a sustainable and profitable Small-Scale industrial extractive unit". In SSM the greatest challenge to achieving this is the availability of initial capital investment (Hentschel et al., 2002; Hruschka and Echavarría, 2011). Because of the high risk of the operation, due to little guarantee of return and financial success, the SSM scenario, for investors, is in general less attractive and not very encouraging. This creates a condition similar to a "gambling" scenario for the operators of ASM: with the limited economic resources available they invest directly in the operation, without previous geological exploration, restricting their operational planning on the available information, experience from previous operations and, often, simply on instinct. As Hruschka and Echavarría (2011) reported, "artisanal miners [...] usually skip the exploration phase and [...] proceed with extraction immediately after discovery". Such a lack of methodology creates the highest levels of uncertainty; hence a lack of credibility and a negative image for investors. A vicious circle is automatically triggered, a very common situation among SSM operators.

This research proposes a tool intended to "untrigger" the vicious circle and manage the evaluation of resources and reserves for SSM operations in a sustainable manner.

2. A practical approach to assess the viability of Small-Scale Mining

The main concept for approaching SSM in a sustainable way is the idea of converting an artisanal operation (ASM) into a small-scale responsible enterprise. This can be done by providing technical knowledge, based on geological exploration, engineering, mineral processing and more efficient equipment. As the owner of an ASM usually does not possess the necessary capital resources for such activities, the investment can be provided, through partnership, by an external investor.

The main differential of this new approach is to prove, during the early stages of the business, only a minimum mineral reserve that is able to return the investment committed to upgrading the ASM into a small-scale industrial one. This is done in opposition to traditional large-scale mining exploration, consisting in performing a thorough exploration, with large financial investment and long-term planning. Like any activity in mineral exploration, at a large or small scale, the investment committed for reserve estimation is at high risk. Therefore, the proposal for SSM is to only invest what is absolutely necessary in the mineral exploration phase, and then cyclically replicate the minimum reserve approach exploration process, committing part of the proceeds from the sale of the produced mineral to prove the viability of the continued operation.

In the following paragraphs this concept is presented through a system of equations to determine the required minimal reserve, including an example with actual values from a small-scale underground mine in Ecuador.

3. Methodology

Geological exploration for large-scale mining follows the concept of high investment to prove the largest amount of reserves possible, in order to estimate the life-of-mine NPV of the project. The proposed methodology differs greatly from the traditional approach. It considers that SSM is characterized by quick installation, rapid payback and high flexibility, and uses these aspects as its keystones. It is based on the concepts of:

- "minimum reserve to be proved" and
- "replication".

The two concepts are explained below.