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Strategic evaluations and mining process optimization towards a strong global REE supply chain

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ABSTRACT

Rare earth elements (REE) have turned from an inconspicuous group of raw materials to critical commodities in the last decade. The insatiable and continuously growing demand for rare earths combined with their small and opaque market has resulted in a global exploration boom that has led to the delineation of extensive resources on every continent. Nevertheless, the special boundary conditions that govern the REE industry require second thoughts and careful evaluations when it comes to the potential exploitation of such resources. Past mistakes, with respect to environmental impacts and uncertain investments, have resulted in an overall uncertainty whether the mining and beneficiation of rare earth elements can be a viable industry in a free market context. This paper attempts to record the erroneous practices of the past and use them as guidelines to strengthen the global REE supply-chain. Moreover, the paper focuses on the assessments that need to be made in order to optimize the mining process and reinforce the growth prospects of the market. An overall assessment tool for the mineability of rare earth deposits is also used to consolidate these evaluations and answer the question, if REE mining can be sustainable.

1. Introduction

It has been five years since the rare earth element crisis and price spike of 2011 when REE gained tremendous publicity and visibility to the general public (Massari & Ruberti, 2013). It was the time that China imposed export restrictions and the world became alarmed that the global high-tech market may suffer from supply restrictions. The crisis was intense but short-lived and the prices have decreased rapidly. Nevertheless, the world was startled, especially in REE importing countries which were and are still totally dependent on Chinese production and exports. Various studies published during the time of crises predicted supply chain disruption (Alonso et al.,

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2012; Humphries, 2012), thus initiating discussions and consultations.

Despite the fact that special market analysts had forecasted that demand may exceed supply (Alonso et al., 2012; Moss, Tzimas, Kara, Willis, & Kooroshy, 2011), we are already in 2016 and actual supply has not been short. Conversely, the forecast for the upcoming years indicates that there will be sufficient supply of rare earth elements to satisfy demand (Roskill, 2015). There is, of course, a disproportion in supply of the individual rare earth elements, not to mention the high demand for some critical rare earths. Neodymium demand, for example, could grow by as much as 700% over the next 25 years, while the respective demand for dysprosium could increase by 2.600% (Alonso et al., 2012). It should be mentioned that REE consist of 16 metallic elements which are generally divided into the Light Rare Earth Elements (LREE) and the Heavy Rare Earth Elements (HREE) with the HREE being much less abundant and far more critical. The attributions to these groups are not distinct but in general lanthanum to gadolinium are called LREE while terbium to lutetium are called HREE. With respect to criticality, a third classification is often introduced; the Critical Rare Earth Elements (CREE), taking into consideration the perspective of their individual supply and demand, as well as the cruciality of their applications and end uses (U.S. Department of Energy, 2011). At the time being, the list of CREE consists primarily of neodymium and dysprosium for which demand will remain in high levels or increase even more and secondarily of terbium, yttrium and europium (Binnemans & Jones, 2015).

The aforementioned crisis was sufficient to inflate a global treasure hunt by way of exploration for REE deposits, but despite the discovery of more than 400 potential projects worldwide and the fact that non-Chinese rare earth producers have entered the market, little has really changed. On the contrary, in mid-2015, the biggest REE mining company outside China, Molycorp, filed for bankruptcy within less than three years after having re-started operations. Hence, it has become apparent that the REE-industry is governed by a set of special boundary conditions which can determine the feasibility of any potential REE mining project. And thus, a sequence of questions was generated. Why non-Chinese suppliers cannot gain a significant market share? How is China dominating the REE market? Is this situation reversible?

The true meaning of the REE crisis was misconceived and wrong actions were taken. Without any doubt the market of rare earth elements is neither open nor transparent. Given the size of the market, only a few of the exploration projects will actually become rare earth mines over the next decade; which ones will go into production is difficult to predict. Many experts tried and still do try to find ways to break the Chinese monopoly. Some analysts express the opinion that there is not a problem in the mining of rare earths rather than in their refining process (Kennedy, 2015). Alternatively, many researchers and REE experts adopt the solution of urban mining and recycling of end-of-life products (Binnemans et al., 2013; ERECON, 2015). Moreover, solutions to the supply problem could be also found on the recovery of rare earths as by products from other kinds of deposits (Emsbo, McLaughlin, Breit, du Bray, & Koening, 2015) or from a multitude of industrial process residues (Binnemans, Jones, Blanpain, Van Gerven, & Pontikes, 2015). These secondary sources could ease the bottleneck of REE global supply, especially in countries that do not have economical and/or operational primary deposits on their territories.

In any case the primary mining sector remains the basic source of rare earth elements and plays a major role within the supply chain of the rare earth industry and thus its optimization shall contribute to strengthening the global REE sector. Hence, a thorough evaluation is made in this paper and an optimization of the rare earth mining process is introduced.

2. Methodology

To be able to solve the issues that aggravate the situation we need to find out what the real problems are. In this paper an attempt is made to spot and analyze past erroneous practices in order to find the answers to the aforementioned questions. Our conceptual approach involves the evaluation of former and current mistakes as well as an analysis of the status quo of the rare earth supply chain. The research is based on empirical and quantitative analysis of information, data and literature which are collected from various sources and are cross-checked. On the occasion of the problems that the REE industry is facing, data from active and future rare earth mining projects are utilized and analyzed with respect to the mining feasibility and environmental impact assessment of these projects. Furthermore, tangible criteria are defined that should be taken into account moving forward and strategic evaluations are made in this direction. These evaluations are thereafter combined with a set of standardized parameters and methodologies in order to optimize the mining process and strengthen the REE global supply chain. Finally, an assessment tool for the optimization of REE mining is illustrated with respect to the defined criteria and the necessity for a secure evaluation method for potential rare earth element mining projects. The structure of the assessment tool is described in detail and how it will contribute to the optimization of the overall REE mining process.

3. Past and current erroneous practices

3.1. *Misinterpretation of the crisis*

A critical assessment of the so-called rare earth crisis reveals a number of important lessons. To begin with, when the prices for any commodity increase by a factor of 10 or even higher in just a few months it is unlikely for these prices to hold there for a long time or even go up again (Knittel & Pindyck, 2013; Pindyck, 2004). Furthermore, there is no secure prediction model for if and when the prices will increase again. During the crisis and while the prices were high, investments appeared to be temptingly easy. This resulted in an exploration boom that multiplied the global rare earth resources and reserves. Speculators bought the stocks of many small mining companies that were fueled by inexperienced investors and that promised to develop new sources of rare earths around the world. In other words, China did try to exercise its