Geological, legal and environmental aspects of lithium brine projects, NW Argentina

Aspectos geológicos, legais e ambientais de projetos de lítio em salmouras, Noroeste da Argentina

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ABSTRACT
Lithium is crucial for the transition to green energy since Li-ion batteries are commonly used in consumer electronics, electrical vehicles and for storing electricity from renewable energy sources (wind and solar). In this scenery, the Li brine deposits located in Salta, Jujuy and Catamarca (NW Argentina) have a particular interest as they belong to the well-known “Lithium Triangle”. The issues related to the governance and sustainable development of Li resources are particularly challenging due to these Li brine deposits being constituted of dynamic fluids. Geological aspects of Li brine deposits are analyzed in the Argentinian legal framework that was conceived for solid ore deposits. The division of a salar into mining claims is very common in Argentina and this situation requires a specific definition of the boundaries of the mineralized body and the distribution of lithium grade. The understanding of the geological, legal, environmental and social aspects is crucial to address potential conflicts in simultaneous lithium extraction activities within one salar.

Keywords: lithium, brine, geology, legal, environment.

RESUMO
O lítio é fundamental para a transição para a energia verde, uma vez que as baterias de íon-lítio são comumente usadas em eletrônicos de consumo, veículos elétricos e para armazenar eletricidade de fontes de energia renováveis (eólica e solar). Nesse cenário, os
depósitos de salmoura de lítio localizados em Salta, Jujuy e Catamarca (noroeste da Argentina) têm um interesse especial, pois pertencem ao conhecido "Triângulo do Lítio". As questões relacionadas à governança e ao desenvolvimento sustentável dos recursos de lítio são particularmente desafiadoras, pois esses depósitos de salmoura de lítio são constituídos de fluidos dinâmicos. Os aspectos geológicos dos depósitos de salmoura de Li são analisados na estrutura legal argentina que foi concebida para depósitos de minério sólido. A divisão de um salar em reivindicações de mineração é muito comum na Argentina, e essa situação exige uma definição específica dos limites do corpo mineralizado e da distribuição do teor de lítio. A compreensão dos aspectos geológicos, legais, ambientais e sociais é fundamental para lidar com possíveis conflitos em atividades simultâneas de extração de lítio em um salar.

Palavras-chave: lítio, salmoura, geologia, legal, meio ambiente.

1 INTRODUCTION

Lithium is an essential metal for the transition to low-carbon green energy, and its demand will continue to grow steadily in the coming years. Production of metals such as graphite, lithium and cobalt should increase by almost 500% by 2050 to meet the growing demand for green energy technologies (World Bank, 2020) (Figure 1). Despite the strong global impact of the COVID-19 pandemic, this trend does not seem to be slowing down, as evidenced by the strong increase in demand for lithium (Li) in the second half of 2020 (USGS, 2021).


Source: own elaboration
From a geological point of view, lithium deposits can be divided into two main groups, the first consisting of hard rock deposits, such as Li deposits in pegmatites, rare metal granites, greinsen and hectorite. The second group includes those of a fluid nature, such as geothermal deposits, oil field wastewater, and brines contained in salt flats. The latter are widely distributed in South America, where Argentina, Chile and Bolivia constitute the recognized "lithium triangle" that encompasses more than 50% of the planet's lithium resources (USGS, 2023). This enormous proportion of global lithium resources has to do with the fact that the Central Andes region includes the world's largest evaporite complex, within which numerous salt flats contain significant proportions of Li, B, and K resources, among other elements (Alonso et al. 2006).

Mining activities encompass a series of complex economic, social and environmental scenarios which, in Argentina, have given rise to a specific regulatory framework established by the Mining Code. Few works have been devoted to the regulatory framework for lithium brine deposits, considering the intrinsic nature of these deposits, in which the host medium is a fluid and not a hard rock. In Argentina, there are approximately 60 lithium-in-brine projects, which are distributed in more than 25 salt flats located in the provinces of Salta, Jujuy and Catamarca. Only three projects are in production in Argentina. In a forward-looking situation where more projects reach their productive stage, the problem of the limits between the different mining properties in the same salt flat will be a real challenge in those salt flats operated by more than one mining company. Therefore, a comprehensive understanding of the geological, legal and environmental aspects is crucial to ensure proper governance and sustainable development of Li resources in brine in the national territory. Our work is a first analysis of this issue, considering the geological, legal and environmental aspects.

2 LITHIUM BRINE PROJECTS, GEOLOGICAL CONTEXT AND ITS SCENARIO IN ARGENTINA

The salt flats are formed in endorheic topographic depressions located in the Altiplano-Puna region, which constitutes an extensive uplifted plateau linked to the subduction of the Nazca plate beneath the South American plate. This zone correlates spatially and temporally with the Andean magmatic arc, which is one of the largest magmatic bodies on the planet (Allmendinger et al. 1997). The Puna region, formed by a chain of volcanoes to the west and a high mountain range to the east, hosts a large number of topographic depressions where a number of key features for the formation of high Li
salt flats converge, including an arid climate, an endorheic environment, Li source rocks, one or more aquifers, and sufficient time to concentrate brine (Bradley et al. 2013). However, not all salars have economic concentrations of this metal and each salar has a different geological setting, resulting in different geochemical characteristics of the brine.

Most lithium-bearing salars (Figure 2) are concessioned to more than one mining company, so the surface area of a given salar is subdivided into several mining properties belonging to different companies. To date, the projects in production are Livent’s Fénix project in the Hombre Muerto salt flat (Catamarca-Salta), and the Allkem and Minera Exar projects in the Olaroz-Cauchari salt flat (Jujuy). Projects under construction include projects belonging to Eramet in the Centenario-Ratones salt flat (Salta), Ganfeng in the Llullaillaco salt flat, Zijing Mining Group in the Tres Quebradas salt flat (Catamarca), and Posco, in the Hombre Muerto salt flat (Salta-Catamarca). In addition, more than 40 lithium projects in initial and advanced exploration are currently in operation in Argentina.

3 THE LEGAL FRAMEWORK FOR LITHIUM PROJECTS IN ARGENTINA, NATIONAL AND PROVINCIAL JURISDICTIONS

In Argentina, the original ownership of natural resources in general and of mines in particular, including lithium, belongs to the Provinces where they are located (National Constitution, Article 124°). This original ownership can be transferred to individuals, thus creating what is known as derivative ownership and, in fact, as far as mining property is concerned, it is usually transferred to them by means of the "legal concession", thus giving rise to civil ownership or property rights. By provision of Article 3 of the said Code, Li deposits are included in the first category of minerals, which comprises those mines to which the soil is accessory, belong exclusively to the State, and can only be exploited by virtue of a legal concession granted by a competent authority.
Although the Provinces are the original owners of the mineral resources, the jurisdiction, i.e. the power to dictate the rules regulating the mining activity, is distributed between the Nation and the Provinces and, sometimes, these powers are concurrent between both levels of government. This distribution of competences arises from the National Constitution, which grants the Congress of the Argentine Nation the power to dictate, in a uniform manner for all the provinces that make it up, the Argentine Mining Code, the minimum requirements for environmental protection, including those related to mining activity, national taxes and in general to regulate interjurisdictional issues, i.e. those involving more than one Province, such as interprovincial water basins, interjurisdictional transport of toxic or radioactive waste, etc.

Provinces are the original owners of the natural resources in their territory and have the competence to sanction procedural codes, including the mining procedures code and environmental laws complementary to national minimum requirements for environmental protection, and to legislate and organize, among other issues, everything related to the granting authority, enforcement and control authorities for mining and environmental activities, provincial taxes and fees.
4 DISCUSSION

From a geological point of view, the fluid nature of Li-bearing brine and the geological units containing such brine (aquifer reservoirs) require a particular and different approach to that usually associated with hard-rock hosted deposits. The assessment of Li resources in situ consists essentially of three elements: the volume of the host aquifer, the specific porosity value and the concentration (grade) of the elements of interest contained in the brine (Houston et al. 2011).

The Mining Code (CM) regulates lithium in the same way as minerals occurring in solid form. That is, it applies to this mineral the system of concession which is integrated by a certain number of “mining units” (a company can hold up to 35 “mining units” for each exploitation concession, and for Li the extension of each “mining unit” is up to 100 hectares), and grants the holder the right to exploit the minerals found within the concession: "the extension of the land within whose limits the miner can exploit his concession is called a “mining unit” (art 72 of the CM), the concession being determined "by straight lines and in depth by vertical planes indicated by these lines". In other words, the limits of the concession are projected in depth by vertical planes extending "to the center of the land".

Considering that Li in brine is a fluid and that in most salt flats the boundaries are permeable (Houston et al. 2011), the presence of an extraction well located on the confines of a mining property could draw brine from the neighboring property. The CM regulation does not provide any solution to this problem, as the fixed limits set by the CM when applying the concession per property were designed and work for minerals in solid media. From a geological point of view, this conflict scenario has been expressed initially by Houston et al. (2011) and later by Border and Sawyer (2015), who recommend the use of "barrier zones" between contiguous mining properties in the same salar, in which productive wells should not be developed without the explicit consent and agreement of the owners.

This problem also extends to environmental impacts, where the shared responsibilities of the owners of mining properties located in the same salar must be studied. The pumping of brine from wells generates a modification of the aquifer in which the brine is contained, and the wells must be sufficiently distanced so as not to cause significant depressions in the salar. Moreover, the brine extraction process generates a movement of fluids to replenish the volume removed by the extraction. In this scenario, the prevention of mixing of mineralized zones with freshwater bodies is of particular
interest, both from the point of view of dilution of recoverable lithium resources, and from the point of view of the contamination of freshwater areas which constitute a fundamental resource for local populations.

5 CONCLUSIONS

The study of Li deposits in brine presents its own characteristics that clearly differentiate them from deposits hosted in hard rocks. The definition of parameters such as specific porosity, distribution of Li concentrations, definition of deposit boundaries and interrelation of lithium-enriched brine with freshwater bodies are fundamental for an adequate evaluation of this type of deposit.

Argentina's regulatory framework presents difficulties when it comes to responding to potential conflict situations, such as that generated by the exploitation of a deposit compartmentalized in more than one mining property. In this respect, the study of these problems will be different depending on where the deposit is located, since, although there is a national regulation, each province has different complementary regulations. Detailed knowledge of the lithium deposit at the basin scale is essential both to allow the exploitation of the resource over a long period of time, and for the preservation of the drinking water aquifers.

The above leads to the question of whether a modification of the Mining Code and the existing regulatory framework at national and provincial level would be advisable. This issue has been addressed in a recent paper by Saravia Frias and Sanchez Rioja (2021), in which the authors point out the pros and cons of modifying the regulatory framework and warn against overlooking the fact that a modification of the regulatory framework may have an undesirable effect on foreign investments that allow the development of these mining resources. In this work, they mention some legal tools used in the oil field at the international level, such as well spacing, mandatory pooling and voluntary unitization contracts, as an aid to regulating conflict scenarios in lithium brine projects. As has been seen in the US oil regulations, it is advisable that regulations to problematic situations promote conflict resolution between parties, where state intervention is effective only in the case of failure to reach an agreement between the parties.

Given the technical complexity of the processes involved, interdisciplinary studies that address geological, hydrogeological, environmental and social issues are essential in the search for better strategies to help the governance and development of these valuable resources.
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