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Thorium and Rare Earth Element Comprehensive Extraction Projects in Argentina: Assessment Using The United Nations Framework Classification For Resources (UNFC)

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INTRODUCTION

This case study looks explicitly into how integrated thorium and associated rare earth elements (REE) projects could contribute to thedevelopment of the minerals sector in Argentina[1-2].

Thorium could be used as fuel for low-carbon nuclear power generation, while REE is widely accepted as a critical material required for renewable energy technologies, among other uses[3].

For the accurate assessment and planning the progression of resources, United Nations Framework Classification for Resources (UNFC)is used in this case study. In particular, the specific guidelines for uranium and thorium resources in acomprehensive recoveryprojectswere used in this case study[4]. In general, UNFC uses a three-dimensional classification system with (i) Socio-economic viability (E); (ii) Technical feasibility (F) and; (iii) Geological knowledge (G) as the three major criteria for assessment.

Thorium resources in Argentina, as in most other countries, have not been subjected to systematic studies. Most of the existing anomalies, showings and deposits were discovered as a result of uranium exploration, where airborne radiometric surveys played a relevant role as a prospecting technique [5-6].Incidentally, REE potential was also estimated as part of the examination of high-Th radiometric records and field geological characterization.

More recently and due to the renewed worldwide interest in REEs and other critical materials, exploration companies have initiated different projects in Argentina, which have shown encouraging geological prospectivety for thorium and REE; additionally, thorium resources have been evaluated and reported.

In 2013, the CNEA carried out a plan for the expeditious reexamination of the radiometric anomalies related to Th and U in the Ambargasta and Sumampa Ranges in Santiago del Estero Province. This study allowed defining the sites with the most mining potential, where high radioactivity areas were mostly related to carbonatites [7].

The only reported production of REE-Th minerals in Argentina, was the recovery of 1,010 kg of monazite, without recovery of REE and Th from the Teodesia mine (Valle Fertil Range) during 1954 to 1956.

DESCRIPTION

The REE interest covers vast areas of the country in the Puna, Cordillera Oriental and Pampean Ranges regions, focused mainlyon Upper Jurassic-Cretaceous carbonatite rocks intruded in extensional geotectonic settings.The geological types of REE-Th deposits that have been found in Argentina are carbonatites, pegmatites and placers. Main projects of interest and their status in UNFC scheme can be described as follows:

Rodeo de los Molles REE (Th, U) Deposit/ Project: This deposit was discovered by the CNEA in the early 1980s while mapping and prospectingthe area identified by regional airborne radiometric anomalies.The deposit is hosted in 'fenitized'alkaline igneous rocks (Jurassic) of the Las Chacras igneous complex, and it is

LREE dominant. Rodeo de los Molles is the most significant undeveloped REE project in Argentina with a historicalgeologic resource of 5.6 Mt of mineral ore, containing an estimated 117,600 tREO and 950 tU. About 10,000 tTh were estimated with a lesser degree of confidence.The first resource estimate was prepared in 1992, including metallurgical test work that demonstrated the amenability of bastnasite to REErecovery; this estimate was based on approximately 6,000 m of rotary air blast drilling. [8].Significant quantities of uranium could be produced as by- or co-product from this project. About 15 tU in G2 and 950 tU in G3 categories are estimated in this project. The Th resources of Rodeo de losMolles project arealso considered as a potential by- or co-product of the project, but the quantities are estimated with a lower level of confidence. Hence they are assigned to a G4 category. In San Luis Province, where this project is located, the Law 634/2008 prohibits the use of chemicals in all forms and stages of metalliferous mining and processing. Under the UNFC, Rodeo de los Molles REE-U project is considered as a "Potentially Commercial Project"within the subclass "Development On Hold"with categories E2, F2.2, G2-G3.The Th quantities are at present classified separately as an "Exploration Project". With additional data availability, these quantities can be progressed to higher G categories and merged with the REE-U project.

Puna and Cordillera Oriental Thorium (REE) Deposits:These deposits are located in the Northwestern Region of Argentina in Salta and Jujuy Provinces. The depositsshow a complex mineralogical composition and are linked to Jurassic-Cretaceous alkaline magmatism that took place in anextensional geotectonic setting.Identified resources of 23,900 tTh at a grade of 0.37% Th and 35,300 tREO+Y (Rare Earth Oxides and Yttrium) at a grade of 0.58% REO+Y derive from nine mineral deposits [9-10].The quantities associated withthese deposits have been estimated with a low level of confidence.In the case of REO+Y resources, itis considered that economic viability of recovery cannot yet be determined due to insufficient information and the justification as commercial developments may be subject to significant delay. Th resources, even though currently considered as having no reasonable prospects for economic recovery, can be produced as a by- or co-product along with the primary REE production. Hence, Puna and the Cordillera Oriental projectsare classified as "Non Commercial Projects"with sub-class"Development Unclarified"(E3.2, F2.2, G3).

III River and V River Surveys:In the 1950s and 1980s, the CNEA addressed some specific thorium recognition studies on the detrital deposits along the III River (Cordoba Province) and V River (San Luis Province) [11-12]. Th resources in both sites and Th and REO resources in III River site were evaluated, based on raw material and monazite tonnages and monazite chemical compositions.The areas involved are densely cultivated and mining the resources may implicate access to large tracts of agricultural land. Because of these constraints, the projects had become unattractive, and no project was identified to potentially recover the resources. The quantities of 850 tTh and 15,500 tREO in III River and 260 tTh estimated in V River project are assumed tobe presently unrecoverable, as no development project has been identified. The quantities fall in the UNFC class of "Additional Quantities in Place", with UNFC criteria of E3.3, F4 and G4.

Exploration Projects:Several new REE (Th) projects are active today in Argentina such as Jasimampa, Susques, Cachi and Cueva delChacho [13-14].In these projects, economic viability and feasibility of recovery cannot yet be assessed due to insufficient information and limited technical data; eventualreported quantities associated with these mineralizations would be considered as undiscovered resources. Therefore, in the UNFC these projects are qualified as "Exploration Projects"(E3.2, F3, G4).

DISCUSSION AND CONCLUSIONS

Although the potential for mineral resources are very high in Argentina, the mining sector plays only a minor role in the socio-economic development of the country. Most of the mineral potential of the country is underdeveloped, which therefore offers a possible opportunity for future investments. Rare earth element potential of the country is significant,and its potential development in the future is one that may be worth serious consideration. This case studyspecifically looks into how integrated REE and associated thorium and other valuable materials projects could contribute to the solid mineral sector development in Argentina.

Argentina has no current plans to use Th as a nuclear fuel. However, it can be pointed out that all three existing HWR nuclear power plants offer potential capabilities for large-scale irradiation of naturalTh-232 to produce U-233.More recently, due to the renewed interest in REE worldwide, the private sector has set up different exploration projects, which exhibit encouraging geological prospectivety. As a result, thorium resources are started to be evaluated and reported. In the case of possible future production of REEs, Th and some other materials such as U, it can be assumed to be produced as a by- or co-product. While REE has crucial applications, especially in the renewable energy sector, the Th produced can be stored for future use.

Thorium resource assessment in the country is far from complete, and most thorium resource estimations correspond to undiscovered resources because specific exploration and comprehensive resource estimation of REE and thorium deposits have been conducted at a very preliminary level.

When mapping REE and thorium resources in the UNFC scheme,the Argentine projects currently have neither economic and social conditions nor technical feasibility that are sufficiently matured to indicate a reasonable potential for commercialrecovery and sale in the foreseeable future. Except for the Rodeo de losMolles project, which has been classified as a "Potentially Commercial Project"no other project has matured well for commer-

cial recovery in the near-future. However, when considered as comprehensive recovery projects, there are projects with significant potential for future development. Thorium and other valuable materials, in that case also become significant, andcould be produced without major additional investment as by- or co-products. This case study on the application of demonstrates the potential for assessing REE and Th as an integrated project, thereby increasing the project maturity of the combined project.

The application of UNFC contributes to a better understanding of the availability of reliable nuclear and associated critical material resources, especially for green energies in Argentina, and helps in understanding where the focus should be in future. The role of REE to contribute to Argentina's GDP could be reassessed with this in view.

This contribution is a summary of several studies that were conducted by the National Atomic Energy Commission (Argentina), the Argentine Geological Mining Survey and different exploration companies. The authors are grateful to many companies and institutions for allowing the information to be assessed and presented here.

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