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Case studies and testing of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009

Application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 to Rare Earth Elements and Thorium Comprehensive Extraction Projects in Argentina

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Summary

This report provides considerations related to the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009), and in particular, the specific Guidelines for Application of the UNFC-2009 for uranium and thorium resources to rare earth elements (REE) and thorium projects/resources in Argentina. Although the potential to develop mineral resources is very high in Argentina, the mining sector plays only a minor role in the country's socio-economic development. Most of the mineral potential of the country is under developed, which therefore offers a possible opportunity for future investments. Argentina's REE potential is significant and its possible development in the future is one that may be worth serious consideration. This case study demonstrates the potential for assessing REE and thorium as an integrated project, thereby increasing the project maturity of the combined project. The application of UNFC-2009 contributes to a better understanding of the availability of reliable nuclear fuel and associated critical material resources, especially for renewable energy in Argentina, and helps in understanding where the focus should be in the future.

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I. Introduction

1. This report was prepared by Mr. Luis López of the National Atomic Energy Commission of Argentina (CNEA) with technical inputs from Mr. Bradley Van Gosen of the United States Geological Survey (USGS) and Ms. Charlotte Griffiths and Mr. Harikrishnan Tulsidas of the United Nations Economic Commission for Europe (ECE).

2. The report provides considerations related to the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009), and in particular, the specific Guidelines for Application of the UNFC-2009 for uranium and thorium resources [1] to rare earth elements (REE) and thorium projects/resources in Argentina.

3. In 2014, the oil and mining industry in Argentina contributed US$ 15,200 million to Argentina's GDP (3.2 per cent), accounting a Compound Annual Growth Rate (CAGR) of 117 per cent since 2003. Between 80 per cent and 85 per cent of that contribution to GDP corresponds to the extraction of fuel, followed by non-metallic minerals, and metallic minerals (gold, copper, aluminium, copper, silver, lithium, iron ore). Additionally, mining contributes 6 per cent of the employment, 7.4 per cent of the exports and 1 per cent of the companies based in Argentina [2] [3].

4. It can be noted that the contribution to the economy of the mining sector in Argentina is considerably low in comparison to other countries of the region, such as Bolivia and Chile, and well below the world's average. However, it is expected that the industry will gain importance, especially from larger investments that may be attracted by changes in market conditions supported by strong incentives from the national government to the mining industry. In addition to the improvement in the market conditions, the mining sector offers many investment opportunities as it is considerably underexploited compared to other countries in the region. According to the National Chamber of Mining Companies (CAEM), only 15 per cent of the mining fields have been developed [3].

5. This case study specifically looks into how integrated REE and associated thorium projects could contribute to development of the solid minerals sector in Argentina. REE is widely accepted as a critical material required for renewable energy technologies [4], while thorium could be used as fuel for low-carbon nuclear power generation. A comprehensive extraction approach and application of UNFC-2009 contributes to a better understanding of such projects with co-production of commodities, and the potential contribution of such projects to the socio-economic development of Argentina.

II. Nuclear Power and Thorium Utilization

6. Similar to uranium (U), thorium (Th) can be used as a nuclear fuel. Although not fissile itself, Th-232, when loaded into a nuclear reactor, absorbs neutrons to produce U-233, which is fissile (and long-lived). Much of the U-233 will then fission in the reactor. The used fuel can then be unloaded from the reactor, and the remaining U-233 can be chemically separated from the thorium and reused as fuel [5] [6].

7. Argentina has three Heavy-water Reactors (HWR) in operation, namely Atucha I with a gross electrical power of 362 MW and fuelled with Slightly Enriched Uranium (SEU) (0.85 per cent U-235), and Embalse and Atucha II, both based on natural uranium fuel and with a generation capacity of 648 MW and 745 MW, respectively [7].

8. In connection with thorium fuel, the reactor power regulation system of the Embalse Nuclear Power Plant (NPP) has 21 adjuster rods, which are loaded with pencils of natural cobalt-59 (Co-59) powder producing cobalt-60 (Co-60) at an average rate of

3 million Curie/year. It has been proposed that in this reactor and other future Candu-6 nuclear power plants, some part or the whole of the absorbing load could be replaced by natural Th-232 to produce U-233.

9. A preliminary study on the feasibility and basic design for producing Co-60 in the Atucha I and Atucha II nuclear power plants has been conducted using a limited number of special fuel assemblies. These designs would have a few outer rods, where the tube would contain cobalt pencils similar to those used in Embalse NPP while the rest of the fuel assembly rods would contain slightly enriched uranium (U) fuel. In the same line, some part or the whole of the cobalt absorbing load could be replaced by natural Th-232 to produce U-233 [8].

10. It is important to note that beyond the potential irradiation capacities previously described, Argentina currently has no definite plans for using thorium as a nuclear fuel.

III. Rare Earth Elements

11. The REE group is composed of 15 elements that range in atomic number from 57 (lanthanum) to 71 (lutetium) on the periodic table of elements, and are officially referred to as the "lanthanoids," although they are commonly referred to as the "lanthanides". The rare earth element promethium (atomic number 61) is not included in discussions of REE deposits because the element is rare and unstable in nature. Yttrium (atomic number 39) is commonly regarded as an REE because of its chemical and physical similarities and affinities with the lanthanoids, and yttrium typically occurs in the same deposits as REEs. Scandium (atomic number 21) is chemically similar to, and thus sometimes included with, the REEs, but it does not occur in economic concentrations in the same geological settings as the lanthanoids and yttrium. Traditionally, the REEs are divided into two groups on the basis of atomic weight: the light REEs (LREE) are lanthanum through gadolinium (atomic numbers 57 through 64); and the heavy REEs (HREE) comprise terbium through to lutetium (atomic numbers 65 through 71) [4].

12. Due to their unusual physical and chemical properties, such as unique magnetic and optical properties, REEs have diverse applications that touch many aspects of modern life and culture. REEs are used as components in high technology devices, including smart phones, digital cameras, computer hard disks, fluorescent and light-emitting-diode (LED) lights, flat screen televisions, computer monitors, and electronic displays. Large quantities of some REEs are used in clean energy (for example, nickel-metal hydride batteries built with lanthanum based alloys as anodes, and the motors of wind turbines) and defense technologies [4].

13. In recent years, the aforementioned variety of high-tech applications of rare earth elements has burgeoned, especially in low-carbon technologies, and demand for them has grown rapidly. At the same time, there is international concern driven by the REE export restrictions of China, the world's primary producer of REEs. Since the late 1990s, China has provided 85–95 per cent of the world's REEs. In 2010, China announced its intention to reduce REE exports. Thus, China's reduction of REEs to the global market has caused concern about the security of the future supply of REEs, most notably the supply of HREE, as well as the costs and other product impacts this might have [4] [9].

14. Therefore, due to the renewed worldwide interest in REE and other critical materials, junior companies have set up different exploration projects in Argentina, such as Jasimampa, Susques, Cachi and Cueva del Chacho. These projects have shown encouraging geological prospectivety; additionally, thorium resources would be evaluated and reported.

15. In the past, exploratory studies of uranium and in particular thorium had already revealed the potential for rare earth minerals in Argentina. The REE interest covers vast areas of the country in the Puna, Cordillera Oriental and Pampean Ranges regions, focused mainly in Upper Jurassic-Cretaceous carbonatite rocks intruded in distensive geotectonic settings.

IV. Legal Framework for Nuclear Minerals and REE

16. Since the 1950s, uranium and thorium have had the same mining legal status in Argentina. On the one hand, the Legal Framework for Nuclear Minerals during 1956 to 1997 declared uranium, thorium, and plutonium as nuclear elements [10]. On the other hand, the Argentine Mining Code (AMC), in force since 1997, considers uranium and thorium as nuclear minerals; their associated resources belong to the Provincial States under the provisions of the National Constitution (1994) [11].

17. Among other considerations, the Argentine Mining Code under its Title XI “On Nuclear Minerals” specifies:

(a) Nuclear minerals can be explored and exploited under a legal license by a Competent Provincial Authority.

(b) The National Atomic Energy Commission (CNEA), like any other natural or artificial person, may prospect, explore and mine nuclear minerals under the general provisions of the Mining Code.

(c) The legal owner of mines containing nuclear minerals shall supply the State with information on the reserves and production of these minerals and concentrates.

(d) The National State shall have the first option to purchase, under usual market terms, nuclear minerals, concentrates and by-products produced in the country to meet domestic needs.

(e) Exports of uranium and thorium minerals, concentrates and by-products shall call for the prior consent of the State, and the internal supply and control of the final destination of export materials shall be guaranteed.

18. In general terms, under the Argentine Mining Code, mines are divided into three categories:

(a) Mines whose soil is an accessory and which belong exclusively to the State and which may only be tapped or exploited under a legal license which is granted by a competent authority.

(b) Mines which, based on their importance, are preferentially licensed to the owner of the soil; and mines which, as a result of the conditions of the deposits, are used on a shared basis.

(c) Mines which belong solely to their owner and which cannot be tapped or exploited by anybody without their owner´s consent, except in case of public benefit or good.

19. How metals are treated is important. According to the above classification, deposits of REE and Th associated with carbonatite rocks and pegmatites would fall into the first category, while placer deposits would fall into the second category. The eventual metal recovery from burrows and tailings of former mining works would also correspond to the second category. Under the provisions of the Mining Code, individuals are empowered to search for mineable deposits, operate mines and dispose of mines as owners.

20. Additionally, it should be noted that eight of the 23 Argentine provinces have legislation in place that restrict metal mining. Hence, this needs to be taken into account when studying the social viability of the projects. In connection with the location of thorium projects, in Cordoba Province, all activities related to metal mining and those specifically related to uranium and thorium production cycle are forbidden by Law 9526/2008 [12], whereas San Luis Province Law 634/2008 prohibits the use of chemicals in all forms and stages of metalliferous mining [13].

V. Comprehensive Extraction Approach

21. REE, Th and U, as well as niobium and tantalum, are often associated in mineral form and occur as oxides, silicates and phosphates. At the simplest level, REE and Th are found in four main types of deposits, which are placer, carbonatite-hosted, vein-type and alkaline rock hosted deposits [14].

22. Due to the current low demand for Th, it has rarely been a primary exploration target. Its common association with U and/or especially REE has meant that Th resources have been identified as a spinoff of exploration activities aimed at those commodities. In current market conditions, primary production of Th is not economically viable, and the extraction of Th as a by-product of REE recovery from monazite seems to be the most feasible source of Th production at this time [5] [6].

23. Comprehensive extraction approaches can manage the production of REE, Th and other critical material resources in an integrated, multi-targeted manner. This approach is likely to achieve considerably higher aggregate recovery rates than a management strategy that targets only a single resource and effectively treats all other co-occurring resources as if they were contaminants or wastes. Furthermore, on the sustainability side, the premise is simpler—once the decision to break ground is taken, the ethical imperative to maximize the return from that activity is apparent according to the well-established fundamentals of sustainable development [1].

VI. REE and Thorium Resources and Application of UNFC-2009

24. Thorium in Argentina, as with the majority of the world, has not been as a general rule the subject of 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 (Figures 1 [15] and 2 [16]). REE potential was also estimated as part of the examination of high-Th radiometric records and field geological characterization.

25. The geological types of REE-Th deposits that have been found in Argentina are carbonatites, pegmatites and placers; the main examples can be listed as follows (for locations, see Figure 3):

(a) Carbonatites, associated veins and altered zones:
- Deposits in Puna and Cordillera Oriental (Salta and Jujuy Provinces)
- Rodeo de los Molles deposit (San Luis Province)
- Jasimampa mineralizations (Santiago del Estero Province)
- Susques mineralizations (Jujuy Province)
- Cueva del Chacho mineralizations (La Rioja Province)

(b) Pegmatites:
- Cachi mineralizations (Salta Province)
- Valle Fertil Range mineralizations, Teodesia mine (San Juan Province)

(c) Placers:

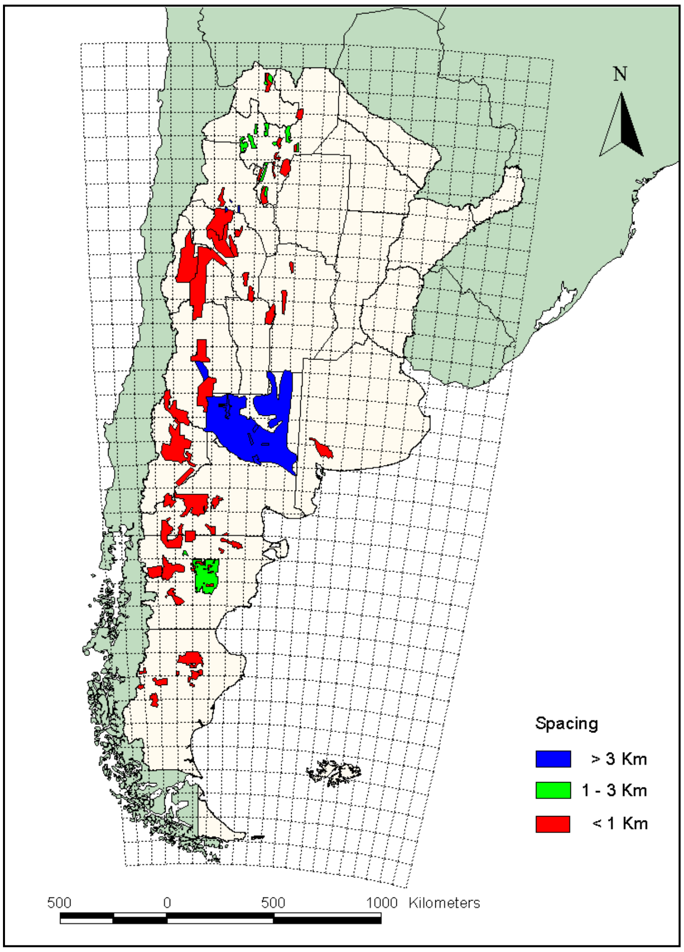
- III River monazite sands (Cordoba Province)
- V River monazite sands (San Luis Province)

26. In 2013, 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 [17].

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

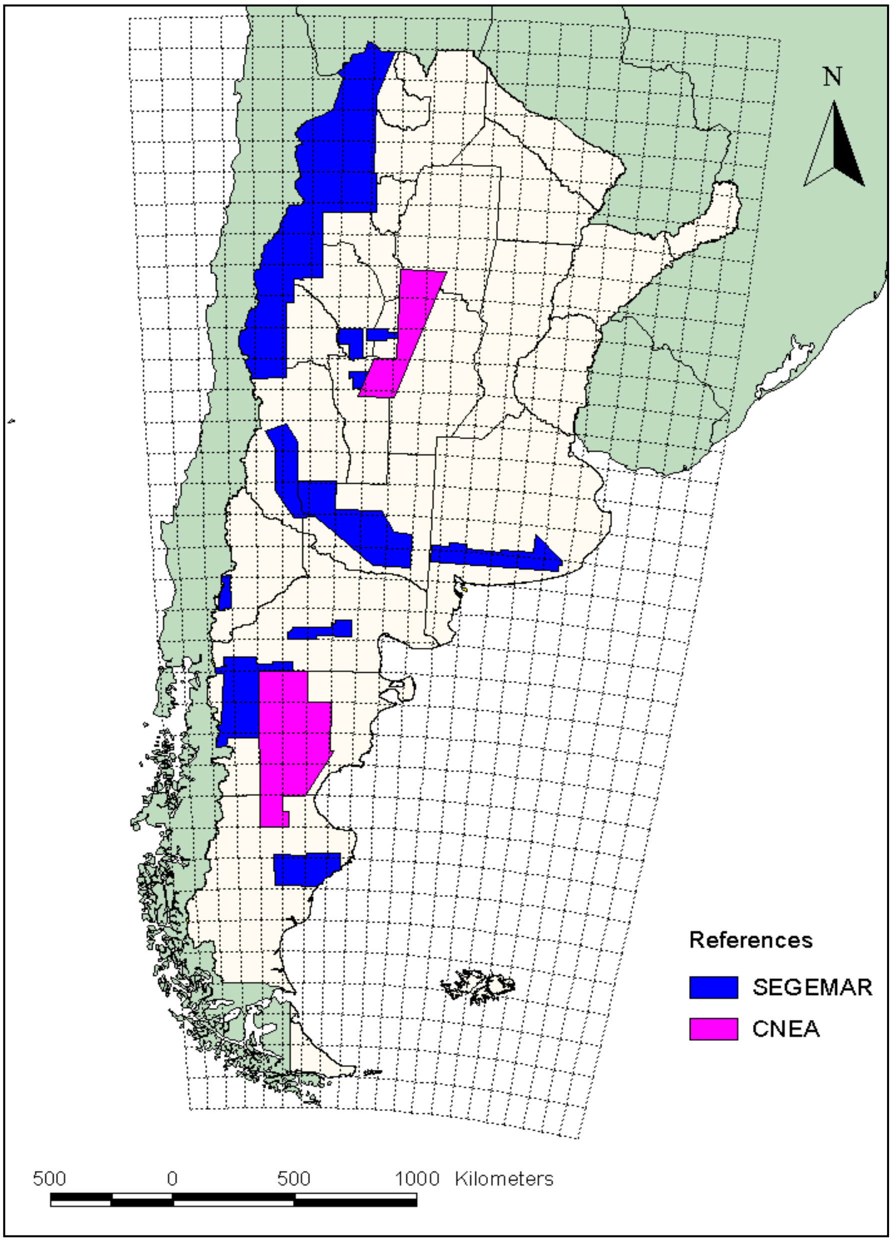
Figure 1

Airborne gamma-ray total count surveys carried out by CNEA (1950-1970) [a]



[a] Different colours indicate the spacings of the survey flight lines [15].

Figure 2
Airborne gamma-ray spectrometry surveys (1978-1995) [a]



[a] Blocks in fuchsia were surveyed by CNEA, while blocks in blue were surveyed by SEGEMAR. Survey flight line spacing was 1 kilometre [16].

Figure 3
Location of REE-Th projects in Argentina

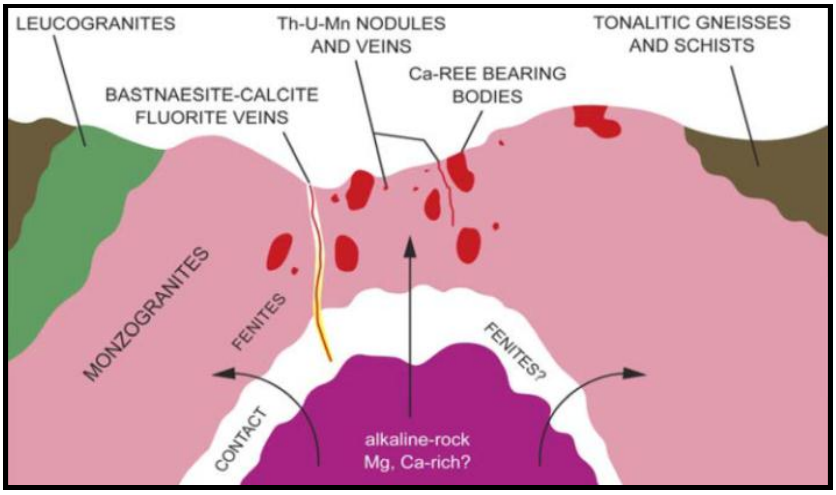
A. Rodeo de los Molles REE (Th, U) Deposit/Project

28. This deposit was discovered by CNEA in the early 1980s while mapping and prospecting the area identified by regional airborne radiometric anomalies. The deposit is hosted in 'fenitized' alkaline igneous rocks (Jurassic) of the Las Chacras igneous complex. The deposit is LREE dominant. Mineralization is primarily bastnasite-synchisite, britholite and minor allanite. The geologic model is presented in Figure 4.

29. Rodeo de los Molles is the largest undeveloped REE project in Argentina with an historical geologic 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.

30. The first resource estimate was prepared in 1992, including metallurgical test work that demonstrated the amenability of bastnasite to REE extraction; this estimate was based on approximately 6,000 m of rotary air blast drilling. However, the resource assessments are historical in nature. Furthermore, historical exploration at the Rodeo deposit has only tested REE mineralization exposed on the surface and to very shallow depths, typically less than 35 m of depth; the limited indicated resources that have been evaluated account for 2,270 tREO at an average grade of 2.1 per cent Rare Earth Oxides (REO) [18] [19] [20]. Figure 5 exhibits a general view of the mineralized area.

Figure 4
Schematic geologic model of Rodeo de los Molles deposit [18]



31. Significant quantities of uranium could be produced as a by- or co-product from this project. About 15 tU in G2 and 950 tU in the G3 category of UNFC-2009 are estimated in this project.

32. The Th resources of Rodeo de los Molles project are also 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 the G4 category. Further sampling and analytical studies are required to assign the Th quantities to higher G categories.

33. 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. Therefore, there are no active metal mining projects currently in this province. However, the mineralization is primarily refractory in nature. Hence, it could be possible to mine the ore and undertake some physical beneficiation to prepare pre-concentrates, which could be

shipped elsewhere for processing and recovery of REE, U and Th. Nevertheless, this possibility has not yet been discussed or tested. Further studies are required to test the robustness of this model. The mining laws could also be amended as necessary if critical materials for clean energy projects become a priority for Argentina. Such a proposal is not currently under consideration, however that does not preclude such a change happening in the future.

34. Therefore, under UNFC-2009, Rodeo de los Molles REE-U project is considered as a “Potentially Commercial Project” within the sub-class “Development On Hold” with categories E2, F2.2, G2-G3. Application of UNFC-2009 makes it very clear that if follow-up exploration activities can increase the geological knowledge of the existing inferred resources, and if detailed studies on extraction are conducted, the project could move to a higher UNFC-2009 Class.

35. The Th quantities are at present classified separately as an “Exploration Project”. With the availability of additional data these quantities can be transferred to higher G categories and merged with the REE-U project. In case of eventual REE production, the Th resources can be produced in the same process flow and could be stored for future use or sold in the market as required.

Figure 5
General view of mineralized area at Rodeo de Los Molles [18]

B. Puna and Cordillera Oriental Thorium (REE) Deposits

36. These deposits are located in the north-western region of Argentina in the Salta and Jujuy Provinces. The deposits are linked to Jurassic-Cretaceous alkaline magmatism that took place in a distensive geotectonic setting. Both magmatic carbonatites (calcite, dolomite, ankerite, magnetite, iron oxides, hypersthene, potassium feldspar, serpentine, chlorite) and metasomatic-hydrothermal carbonatites (pyrite, chalcopyrite, galena, sphalerite, magnetite, hematite, ilmenite, thorite, fluorite, monazite, strontianite, vanadinite, limonite, cerussite, thorogummite, goethite, bastnasite, parisite) can be found. All of them show a complex mineralogical composition.

37. In the area, at least six magmatic alkaline centers have been distinguished:

(a) Fundicion Stock (194 ± 6 Ma): syenitic facies

(b) Agua del Desierto Formation (155 ± 6 Ma): syenitic bodies

(c) Rangel Complex Laccolith (120-140 Ma): syenitic and granitic facies; radial and ring dykes

(d) Santa Julia Alkaline Complex (Cretaceous): syenite-monzonite stock; radial and ring dykes

(e) Hornillos Complex (Cretaceous): complex laccolith; subvolcanic rocks

(f) Alkaline lamprophires and phonolitic dykes (Cretaceous).

38. Identified resources of 23,900 tTh at a grade of 0.37 per cent Th and 35,300 tREO+Y (Rare Earth Oxides and Yttrium) at a grade of 0.58 per cent REO+Y derive from nine mineral deposits, listed in Table 1 [21] [22]. The quantities associated with these deposits have been estimated with a low level of confidence. For the REO+Y resources, economic viability of extraction 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 not having reasonable prospects for economic extraction, can be produced as a by- or co-product along with the primary REE production. Hence, the Puna and Cordillera Oriental projects are classified as “Non Commercial Projects” with sub-class “Development Unclarified” (E3.2, F2.2, G3).

Table 1
Main features of Puna and Cordillera Oriental Th-REE deposits [22]

Deposit	*Width (m)*	*Depth (m)*	*Length (m)*	*Th %*	*Resources tTh*	*REE+Y %*	*Resources tREO+Y*
Rangel	0.7	70	200	0.22	58	0.45	119
El Ucu	0.3	70	200	0.08	9	0.25	28
Plateria South	0.6	130	400	0.004	4	0.03	25
Plateria North	1.0	80	250	0.02	9	0.09	49
La Barba	1.0	130	400	0.37	518	0.60	842
La Aurelia	1.1	700	2000	0.46	19001	0.65	27027
Curaca	1.0	300	1000	0.40	3203	0.60	4860
Estr. Oriente	1.0	165	500	0.40	881	0.60	1337
Isis - Osiris	1.6	300	1000	0.02	228	0.08	1037

C. III River and V River Surveys

39. In the 1950s and 1980s, CNEA undertook a number of specific thorium recognition studies on the detrital deposits along the III River (Cordoba Province) and V River (San Luis Province) [23] [24]. 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. Table 2 shows the main characteristics of these projects.

40. III River and V River projects can essentially be considered as orientation surveys and quantities are estimated based on the analytical results of 24 samples along 135 km of

the river and 4 samples along 46 km of the river, respectively. Hence these quantities are assigned to the G4 Category.

41. The areas are densely cultivated and mining the resources may involve access to large tracts of agricultural land. Because of these constraints, the projects were deemed unattractive and a project was not 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 to be currently unrecoverable, as a development project has not been identified. The quantities fall in the UNFC-2009 class of "Additional Quantities in Place", with UNFC-2009 criteria of E3.3, F4 and G4.

Table 2
Thorium and Rare Earths studies of the detrital material of III River and V River [23 [24]

Study Areas	*III River*	*V River*
Length Along River	135 km	46 km
Number of Samples	24	4
Raw Material Tonnage	46.2 Mt	3.58 Mt
Monazite Tonnage	25,480 t	6,260 t
Th Grade	0.0018%	0.0072%
REO Grade	0.0335%	---
Th Resources	850 t	260 t
REO Resources	15,500 t	---

VII. Exploration Projects

42. Several new REE (Th) projects are active today in Argentina. In these projects, the economic viability and feasibility of extraction cannot yet be assessed due to insufficient information and limited technical data; eventual reported quantities associated with these mineralizations would be considered as undiscovered resources. Therefore, according to UNFC-2009 these projects are qualified as "Exploration Projects" (E3.2, F3, G4).

A. Jasimampa REE (Th) Project

43. The Jasimampa Property covers 60,000 ha (hectares) of ground in the Jasimampa area in the Sierra Norte de Cordoba (Santiago del Estero Province). The property lies directly east of some known small rare earth deposits.

44. This new project is considered highly prospective for rare earth mineralization related to Jurassic carbonatites and associated alteration, plus hydrothermal precious and base metal mineralization [25].

B. Susques REE (Th) Project

45. The Susques Property covers 41,500 ha in southern Jujuy Province, north-west Argentina. Susques is known to be prospective for a variety of rare earths elements, yttrium, and also thorium (>1000 parts per million). The economically desired higher ratio of HREE to LREE is also encouraging.

46. The local geology is dominated by Ordovician sediments, and Tertiary intrusives and carbonatites. Little detailed exploration has been conducted here. Rare earth mineralization that has been observed thus far is hosted in stockwork veins, which are up to 10 m wide and occur over a strike length of 6 km.

47. The preliminary exploration results are important first indicators of potential mineralization considering the broader geological environment in which they are hosted. More detailed work is needed to ascertain the extent and economic potential of mineralization [25].

C. Cachi REE (Th) Project

48. The Cachi property covers over 55,000 ha in Salta Province, northwest Argentina, and offers excellent opportunities for discovery, based on very favourable geology.

49. The geology is prospective for pegmatite-related rare earth mineralization associated with extensive granitoid intrusions, which extends for over 40 km along the strike, as well as large (up to 300 m wide) pegmatite dykes intruding Neo-Proterozoic gneiss. Worldwide, many pegmatites have been economically valuable as sources of clays and feldspars, as well as bismuth, lithium, molybdenum, rare earths, tantalum-niobium, thorium, tin, tungsten, and uranium minerals.

50. Reconnaissance work has been completed with stream sediment sampling and mapping completed, which identified three targets based on surface alteration halos. The sampling identified geochemical anomalies of tantalum, niobium, cesium, uranium, thorium and hafnium in the south part of the property, whereas lead and zinc were identified in the north part of the property [25].

D. Cueva del Cacho REE (Th) Project

51. The Cueva del Chacho property comprises 6000 hectares in the semiarid valley that flanks the Sierra de Paganzo in La Rioja Province. A reconnaissance sampling of 39 slightly radioactive zones found highly anomalous REE values in massive arkosic grits, phyllites and an alaskite intrusive.

52. Total REE values ranged to over 0.25 per cent REO, or over 0.33 per cent if yttrium is included. Unlike many deposits, there has been little or no depletion in the HREE with respect both to chondrite and normal crustal ratios, with the exception of europium. HREE comprise an average of 29 per cent of the total REEs with a high of 71 per cent if yttrium is included, and 14 per cent of the total REEs with a high of 44 per cent if yttrium is not included. An area of anomalous uranium (as much as 551 ppm) in carbonaceous phyllites was encountered. Thorium is also present in carbonaceous shales and phylites, but is not closely associated with rare earth mineralization.

53. A programme of further work has been recommended, on the one hand to delineate better and evaluate the known rare earth concentrations, and on the other to determine the regional extent of these anomalies [26].

VIII. Conclusions

54. 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 under developed, which therefore offers a possible opportunity for future investments. The REE potential of the country is significant and its

potential development in the future is one that may be worth serious consideration. This case study specifically looks into how integrated REE and associated thorium and other valuable materials projects could contribute to the development of the solid minerals sector in Argentina.

55. Argentina currently has no plans to use Th as a nuclear fuel. However, all three existing Heavy-Water Reactor (HWR) nuclear power plants offer potential capabilities for large-scale irradiation of natural Th-232 to produce U-233. More recently, due to the renewed interest in REE worldwide, the private sector has started a number of exploration projects. These have shown encouraging geological prospectivity. As a result, evaluation and reporting of thorium resources is starting. In the event of possible future production of REEs, Th and some other materials such as U, it can be assumed they will 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.

56. During the 1950s and 1980s, CNEA conducted a number of reconnaissance studies on thorium deposits that defined very limited resources, and therefore related projects were not developed. Nevertheless, 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 (Table 3).

57. Based on the UNFC-2009 assessment conducted on a number of the deposits, such as Rodeo de Los Molles and those located in the Cordillera Oriental and Puna regions, there is potential for further development. REE resources in these deposits show a higher ranking, and Th can be produced as a by- or co-product. More studies are required for firming up the resources and progressing the projects along the project maturity pipeline. Moreover, some of the projects classified as “Exploration Projects” could have breakthroughs in discovering new additional resources.

58. Therefore, when classifying REE and thorium resources according to UNFC-2009, the Argentine projects currently have neither economic and social conditions nor technical feasibility that are sufficiently matured to indicate reasonable potential for commercial recovery and sale in the foreseeable future, with the exception of the Rodeo de los Molles project which has been classified as a “Potentially Commercial Project”. However, when looking from the perspective of comprehensive extraction projects, there are projects with significant potential for future development. Thorium and other valuable materials, in that case also become significant, and could be produced without major additional investment as by- or co-products. This case study on the application of UNFC-2009 demonstrates the potential for assessing REE and Th as an integrated project, thereby increasing the project maturity of the combined project.

59. The application of UNFC-2009 contributes to a better understanding of the availability of reliable nuclear and associated critical material resources, especially for renewable energy in Argentina, and helps in understanding where the focus should be in the future. The role that REEs could contribute to Argentina’s GDP in the future could be reassessed with this in mind.

Table 3
REE-Th-U projects of Argentina classified according to UNFC-2009

Project	*UNFC-2009 Class*	*UNFC-2009 Sub-class*	*UNFC-2009 Category*	*Resources*
Rodeo de los Molles (REE-U)	Potentially Commercial Project	Development On Hold	E2, F2.2, G2	2,270 tREO 15 tU
			E2, F2.2, G3	117,600 tREO 950 tU
Cordillera Oriental and Puna (REE-Th)	Non Commercial Project	Development Unclarified	E3.2, F2.2, G3	35,300 tREO+Y 23,900 tTh
III River (REE-Th)	Additional Quantities In Place	---	E3.3 F4 G4	15,500 tREO 850 tTh
V River (Th)	Additional Quantities In Place	---	E3.3 F4 G4	260 tTh
Rodeo de los Molles (Th)	Exploration Project	---	E3.2 F4 G4	10,000 tTh
Jasimampa (REE-Th)	Exploration Project	---	E3.2, F3, G4	Not Available
Susques (REE-Th)	Exploration Project	---	E3.2, F3, G4	Not Available
Cachi (REE-Th)	Exploration Project	---	E3.2, F3, G4	Not Available
Cueva del Chacho (REE-Th)	Exploration Project	---	E3.2, F3, G4	Not Available

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