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# The Strategic Importance of the Lithiniferous Deposits of Gonçalo (Guarda, Portugal) in Sustainable Development of Low Density Regions — The Lithium Project

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**Abstract:** The growth of the world population and the increasing amounts of energy and raw materials demanded by the modern societies are facts of the last decades. The increasing global carbon emissions and the constant pollution situations in the great world cities are raising a growing ecological awareness of the society. According to the Goldman Sachs report (2015), the path must be a bet on low-carbon technology (LCT) and less "global warming" technologies. One of the low-carbon technologies with a big impact on green technology are hybrid vehicles (Hvs) and electric vehicles (Evs). Nowadays, special attention is placed on the exploitation of an important and scarce geological resource in Europe, but abundant in Portugal, especially in the area of Gonçalo (Guarda), the lithium. In the Iberian Peninsula, there is one of the largest lithium mineralization zones of Europe. These deposits are mostly lithiniferous pegmatites veins that outcrops metasedimentary rocks and Variscan granitoids in the zones of the Galicia-Trás-os-Montes Zone (GTMZ) and Central Iberian Zone (CIZ). With increasing prices of lithium carbonate and lithium hydroxide, pegmatites deposits are now cost-effective sources of Li. The concerns of the societies with the environment questions and the sustainability is a priority issue to avoid that the exploitation of the lithium can be carried out without the environmental concerns. There is a need now to prove the existence of mineral resources and reserves according to the best international codes to bring Europe with a new raw material.

Key words: Lithium, Portugal, Aplite pegmatites, sustainability, geotourism

## 1. Introduction

The growing global carbon emissions and the constant pollution situations in major cities worldwide are waking up a growing ecological awareness of the society. What the UN Climate Conference in Kyoto (1992) seemed more policy measures than real environmental concerns, became the UN Climate Conference in Paris (2015), the VW scandal trailer and the effects of smog in China, real environmental concerns the issue of global warming. According to the report from Goldman Sachs [1] the path should be increasingly bet on low-carbon technologies and less focused on the theme of policy "global warming".

Low carbon technologies, and with significant impact in this policy of green technologies, are the hybrid cars (Hvs) and trams (Evs), without forgetting the potential for large energy storage complexes (grid energy storage). Pressed by environmental awareness, the recent scandals of car pollution and green savings policies (greening economies), the big car companies want a piece of this market. The Tesla is a good example of this. At an European level the Mercedes,

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BMW, Renault, Volvo, Audi and VW, shows more than 20 models Hvs and Evs in production or in development. About the production of lithium batteries, Europe has an installed capacity of 1.798 MWh [2] and some European policies and the EUROBAT want to promote the construction of new production facilities and technological development (e.g., Batteries2020, € 8.4 M). German Chancellor Angela Merkel announced a program of €1200 M with the aim of reaching in 2020 1 million of Evs in German roads [3].

Thus developed modern technologies, whether in storage or in the lithium extraction of ores which led to the reduction of their costs of extraction, treatment and production especially in pegmatites lithiniferous deposits.

## 2. Framework

Lithium is an alkaline metal and atomic number three. It is the lightest metal on Earth, as well as the less dense solid element. Lithium is a rare metal in the Earth's crust and never occurs freely in nature being the main sources the lepidolite, the petalite and the spodumene minerals. Lithium is commercialized as a concentrated mineral, in various chemical compounds (particularly in the form of carbonate or hydroxide). Lithium applications are diverse: ceramic and glass production, metallurgy of aluminum, in synthetic rubber, in lubricants, in the process of purification of air in confined environments, in batteries (for vehicles, cell-phones and grid energy storage), being the lithium bromide and lithium carbonate used in the pharmaceutical industry for the treatment of depressions [4, 5]. With the increase in demand, and the consequent increase in the price of lithium, especially of the compounds used in the manufacture of lithium batteries, lithium carbonate (LCE) and lithium hydroxide (LH), pegmatite deposits are now cost-effective sources of lithium.

If historically spodumene deposits were the only economically competitive, the optimization of the processes of metal beneficiation and extraction of lithium pegmatite deposits of lepidolite and zinnwaldite became currently in a non-traditional source of lithium, with production costs comparable to those of spodumene.

After having secured the best pegmatite deposits in their countries, Australian and Canadian prospecting and research companies (P&P) began trying to ensure other deposits of lithiniferous pegmatites, being Europe and particularly Portugal one of their P&P base. The year 2016 was the year of excellence to the emergence of numerous “young companies” around the world, which together with traditional industrial companies operated not only from hard rock, but also from lithium exploration of salar brines.

The latter is a market traditionally deployed in the so-called South American triangle which encompasses: Chile, Argentina and Bolivia. Australia should be considered as, the largest lithium production, allied to strategic patents that allow the diversification of sources of lithium.

## 3. Lithium in Portugal

### *3.1 State of art of Lithium in Portugal*

In the Iberian Peninsula, there is one of the largest lithium deposits belts in Europe (Fig. 1). These deposits are essentially lithiniferous pegmatite bodies, that outcrops in metasedimentary rocks and granitoids from Variscan ages, along a zone of NNO-SSE direction in Galicia-Trás-os-Montes Zone (GTMZ) and Central Iberian Zone [6]. At least 25 locations have been identified and studied, some of them being mining in recent decades [7]. In the past, mining areas of Almendra-Barca de Alva [8-15], Argemela [16-19], Barroso-Alvão [14, 18, 20-31], Seixo Amarelo-Gonçalo [6, 7, 12, 18, 32-41], and the Arga mountains [7, 12, 42-44] have given their valuable contribution to the knowledge of the geology of these lithiniferous deposits in Portugal.

An agreement recently concluded between an Australian company and a Portuguese Group traditionally focused in solutions for the ceramic industry, shows the Portuguese business dynamics and their concern in energy savings. Effectively, the presence of lithium pegmatite allows to take advantage of their funding characteristics, during the cooking of the ceramic slurry, reducing the energy bill in the final production costs.

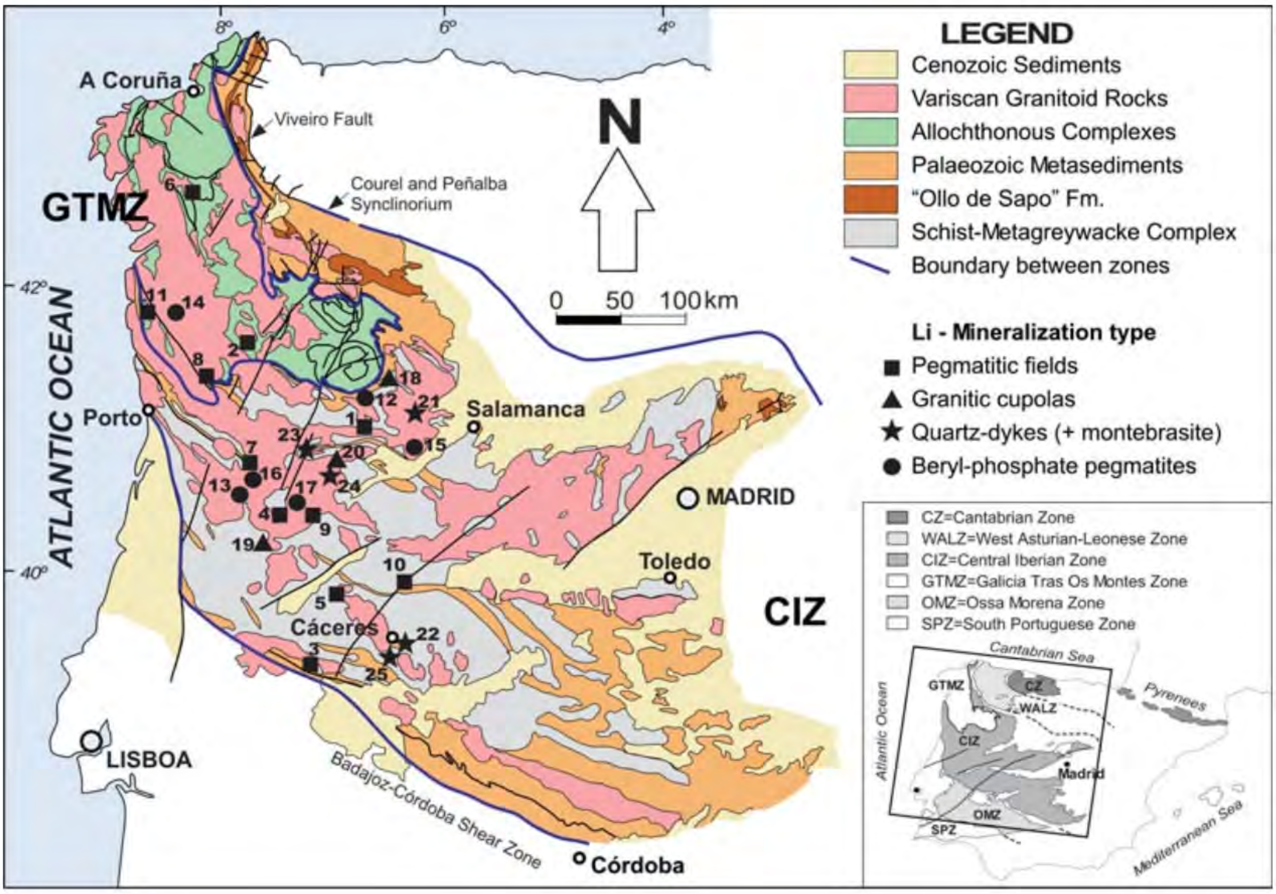


**Fig. 1 Schematic geological map of the Central Iberian Zone (CIZ) and the Galicia-Trás-os-Montes Zone (GTMZ) (Spain and Portugal) with the location of the different Li mineralization areas. 4- Gonçalo Mine Concession. From [7].**

The biggest business group that explores various mines in Portugal, including mines where lithium appears in different mineralogical and chemical formulas, don't give it up to continue to supply the needs of the ceramic industry. In its factories, it is made a physical pre-concentration of 2.5% $Li_2O$, traditionally destined to the supply the ceramic industry needs, not only national but also for exportation. The Government is aware of the potential existing in the country and, at the end of 2016, announced the constitution of a working group (Declaration No. 15040/2016 of 13 December 2016), with the mission of identify and characterize all the lithium deposits in Portugal, as the possibilities of their prospecting and exploitation. This group has produced a report formally displayed in March 2017 [45]. This report identified 9 geological zones with lithiniferous potential in Portugal (Fig. 2).

### *3.2 Pegmatitic Field of Gonçalo*

The pegmatitic field of Gonçalo (Guarda) is situated in a large granitic zone of center Portugal where outcrops granites from Variscan ages appears. Outcrops of the pegmatite sills are located on the slope of the granite massif of Serra da Estrela, at elevations between 450 and 850 m, over an area of more than 100 $km^2$ that comprises Gouveia, Fornos de Algodres, Celorico da Beira, Guarda, Belmonte and Sabugal counties.


**Fig. 2 Formations with lithiniferous potential in Portugal [45].**

They are mainly sub-horizontal veins, with thicknesses generally < 3.5 m. In the area, it is possible to observe the gradual evolution of a pegmatitic magma from less to more differentiated stages, as we reach higher structural and topographic levels [6]. This evolution became registered not only inside each sill (internal differentiation) but also from one vein to another

The veins exhibit an aplite - pegmatite structure, with a main composition of quartz, feldspars and muscovite ± Li, Be, Nb, Ta and Sn minerals [6, 32, 33, 36]. They are Li aplite-pegmatites veins and can be included in the LCT family [7, 37, 38]. The rare element pegmatitic field is in a granitic area, essentially Variscan syn-to late-D3 phase granites. The most enriched Li veins, where the C-57 mine is located, occur in the Gonçalo region, where the Guarda granite outcrops, as well as in small outcroppings in the schist-greywacke complex (Fig. 3).

The intrusion of these pegmatitic bodies induced phenomena of metasomatism in the granitic zone, with the replacement of biotite by zinnwaldite in the contact zones, and the transformation of muscovite in a rich Li mica (lepidolite) in lower central zones of the vein. Apart of that, there are some other interesting aspects of this mining field: the tabular and sub-horizontal form; the relative narrow thickness; the metasomatic effects in the country rocks with the migration of B, Li, Rb, Nb, Ta and Sn from the pegmatitic magma to the country rock; the distribution of the richest zones in lepidolite in the footwall of the veins; the local occurrence of gold [6].

In addition to quartz, feldspars and muscovite, other mineral phases of Li, Be, Nb, Ta, and Sn occur, allowing to define three types of veins in the Seixo Amarelo Gonçalo zone [6, 32, 33]: (i) Lithium veins; (ii) Stanniferous veins; and, (iii) Mixed sills:

i) Lepidolite-rich lithiniferous veins occurring at the highest structural levels of the mining field. The average values of Li at the lithiniferous sills are 5845 ± 592 ppm, i.e., 1.24% $Li_2O$ [6] [33]; These lithium veins show more enrichment of Li, Sr, Nb and Rb than other veins.

ii) Stanniferous veins that appear at lower structural levels, southeast of the NE-SO fault of Vela-Gonçalo (Fig. 3).

iii) Mixed sills with aspect like the stanniferous veins, appearing in an intermediate position.

According to Ref. [6], the more significant enrichments from stanniferous to lithiniferous veins are: Li (3.8x); F (3.4x); Rb (2.0x); Nb (1.4x) and Ta (1.05x).

The special distribution of these aplite-pegmatite veins in the Seixo Amarelo-Gonçalo zone is strongly controlled by the tardi-hercynian fracturation [6], and by the erosion of the faulted sectors of the Estrela Mountain horst [46].

## 4. The IC&DT Project and the C-57 Mine of Aplite Pegmatitic Field of Gonçalo

The C-57 mine is located within a rare element aplite pegmatite field that outcrops in the Central Eastern region of Portugal. Lithiniferous veins are embedded in the facies of the Guarda porphyroid, essentially biotitic granite [47], as well as in the surrounding metasedimentary rocks (Fig. 3). The veins are usually sub-horizontal or with slight slope of less than 15° and thicknesses < 3.5 m [6]. The veins exhibit an aplite pegmatite structure consistent with the other sills in the mining field, with a main composition of quartz, feldspars and muscovite ± Li, Be, Nb, Ta and Sn minerals [6, 32, 33]. The special distribution of these aplite-pegmatite veins in the C-57 mine area, shows a strong structural control of the pegmatitic field by late-hercynian faults (Fig. 3). In fact, towards the south-east of the NE-SW Vela-Gonçalo fault, only stanniferous veins outcrops. Westwards from the NNE-SSW Ribeiro do Seixo fault, only lithium veins appear and between these two faults we have a zone with Sn and Li veins. North-westwards from the NNE-SSW fault, at lower topographic levels, stanniferous veins outcrop again.

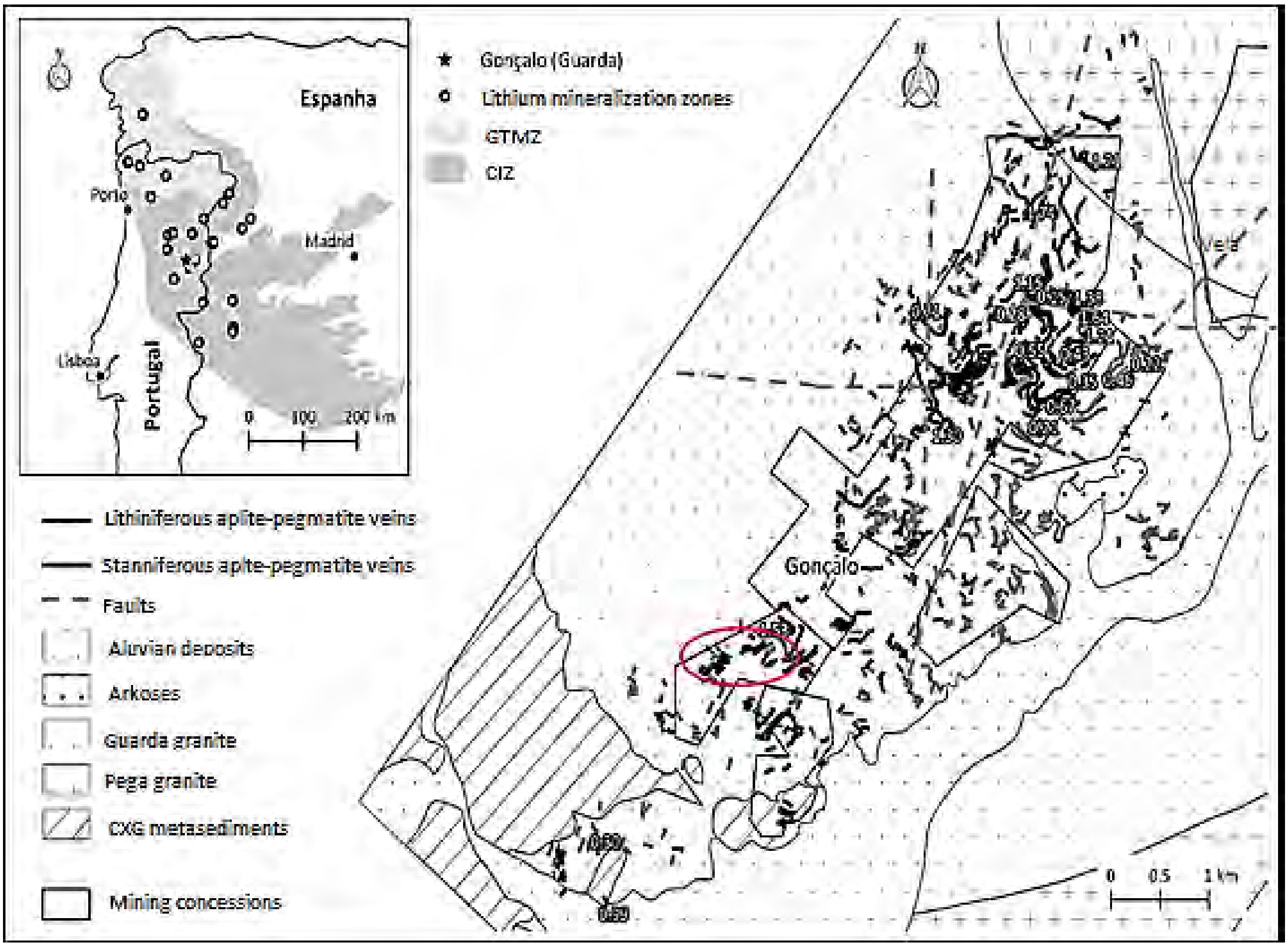


**Fig. 3 Main lithiniferous occurrences of the Iberian Peninsula and geology of the pegmatitic field of Gonçalo (Guarda); % $LiO_2$. C-57 Mine field. Adapted from [6, 7, 32, 40].**

As we go up in the mountain, we find the mixed veins and, finally, the lithium veins appear at the highest levels. This block is depressed. To the west of the N-S fault, even in the lower topographic levels, only lithium veins appear.

The C-57 mine is working for decades, being there main production a lithiniferous feldspar used by the ceramic companies in the central Portugal region. This product allows a significant reduction of the energy consumption during the fabric process of the ceramic industry. As a small mine company, C-57 mine works most of the time, with outsourcing services for its mining process. It is also intention to complete its activity to a cultural/scientific and touristic branch

In the mining area we can still observe the mining work of several years of exploration, where we can detect some examples of the distinct phases of mining that can be synthesized considering the table presented in Fig. 4 [48].

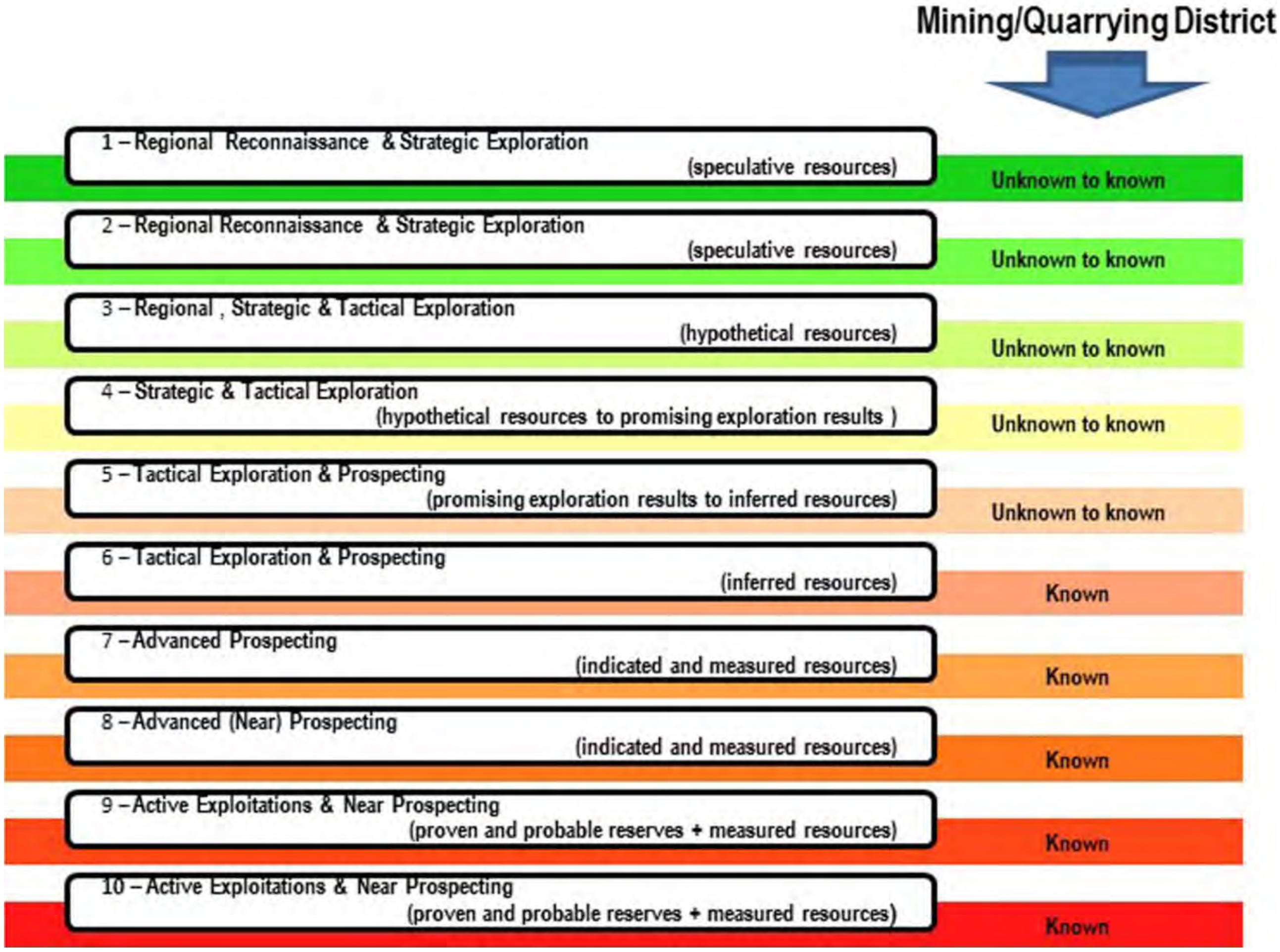


**Fig. 4 Schematic illustration of the *MRoPIr* value distribution in the [1,10] range and conceivable correspondence with the classes of resources previewed by the "McKelvey diagram" through the "geological confidence" axis, according to [48].**

*4.1 The Project*

The IC&DT project Lítio has a grant of the Portuguese government for a period of 18 months of working, being the budget co-financed by the H2020 EU project and the Portuguese state. It is a project in copromotion among a mining company (Pegmatítica, Lda.), three Higher Schools (Instituto Politécnico da Guarda, Instituto Politécnico de Castelo Branco e Instituto Politécnico de Tomar) and a professional association (Associação Portuguesa de Geólogos).

The objective of the project is valuing the natural endogenous resources and territorial innovation in the mining district of Gonçalo (municipality of Guarda, Portugal). The priority domain is the valuation of natural endogenous resources associated with the territorial innovation, being the principal areas of this project the preservation and sustainability of this resource (lithium), by the development of product, processes and services as well as the development of innovative proposals for qualification of tourism in the region, aimed the promotion of the mining heritage in the Gaia valley where the mine is developed. In fact, this ancient mining place has been, since the time of the Romans until the middle of our days, a vast mining field with a negative environmental impact in local communities. The turndown of this paradigm will be another objective of this project.

The proposed activities are developed in the areas of topography and land survey, geology and geotechnical investigation, environmental impact studies, and geotourism. In recent years, tourism is one of the most important sectors of the national and international economy, and the reasons of this success are very different. The World Tourism Organization (UNWTO) [49] predicts that global revenues from international tourism can achieve the value of 2 billion USD in 2020, which will require an average annual growth of 6 to 7% for the period 1995/2020, much higher than the estimated for the rest of the economy (3.3%), providing thus a prominent place. However, this growth is closely linked to increasing diversification and competition among destinations. The contribution of tourism to the economic development of countries depends on the quality of the revenue that tourism offers. Thus, we must know how to position the tourist destinations, in a sustainable way, national and international markets, which are increasingly demanding and complex. It is common to say that the development of tourism must be based on sustainable tourism practices which act by themselves

Being the tourism a social and economic phenomenon, characterized by various segments of demand, can be an element of development of the municipalities and regions that require other sources of revenue or even revitalize the local economy.

Considering the previously mentioned, and existing in the region, notably in the Guarda municipality a lithium mine, which provides an important source of income for the region, can at the same time becoming a "sanctuary" for the passionate about the study of the lithium phenomenon in the world. Thus, in addition to the importance that the mine C-57 has, in terms of feldspar with lithium production, may also have in terms of tourism business. For this, it is necessary to integrate a considerable number of sites of geological interest which, by their peculiarities or rarity, present value/relevance scientific, educational, cultural, economic and aesthetic, and may be considered as places to visit. These sites must have other reasons of interest and value, such as: ecological, cultural, and historical theme park and other infrastructures, which should be linked in a network, for tracks, thematic scripts and routes. Thus, it is essential that the structures associated with the mines of the region, share knowledge, cultures, experiences and experiences, so that all together we can assert as a destination for success.

As a former mining area with deep scars on the territory and in the local community, the involvement of the population through knowledge of the natural heritage of geological nature is very important. The elaboration of thematic pathways relating to mining heritages, delimitation of an “open-air museum”, as well as the implementation of visits of schools of all types of education and other institutions, aims at the promotion of this resource in the structuring of differentiated tourism products, such as: the geotourism and the tourism of experiences. Therefore, the aim is to disclose, to the local community their own territory, maximizing it, as a specific product which emerge in this region and is little spoken on a national scale, and in the touristic population

## 5. Conclusion

The pegmatitic field of Gonçalo, Guarda, presents a strategic source for lithium in Portugal. For decades, the extraction of these lithiniferous veins is carried out by different Portuguese companies, with several active mining concessions in the region. This activity provoked the interest of several companies listed in international Stock Exchange, reproduced in the abnormal requests of P&P for lithium submitted in 2016. The next step, and perhaps the most important, either in the region of Gonçalo, as at the Iberian level, is the definition of resources and mineral reserves. One of the advantages of the Gonçalo region, regarding other pegmatite bodies fields, is the fact that they already have guaranteed mining contracts as we can see in Fig. 3. If we consider the lithiniferous ore estimate presented by Farinha Ramos [32, 33, 40] of 1.4 M of tons, and assuming the average content of the lithiniferous veins, we are in the presence of a lithiniferous potential of approximately 43,000 metric tons of LCE.

The IC&DT project Lítio is a copromotion between a mining company (Pegmatítica, Lda., owner of the C-57 mine), three Higher Schools (Instituto Politécnico da Guarda, Instituto Politécnico de Castelo Branco e Instituto Politécnico de Tomar) and a professional association (Associação Portuguesa de Geólogos). The priority domain is the valorization of natural endogenous resources associated with territorial innovation in the mining district of Gonçalo, being the main areas of this project the preservation and sustainability of this resource (lithium), by the development of product, processes and services as well as the development of innovative proposals for qualification of tourism in the region, aiming the promotion of the mining area.

The proposed activities are developed in the areas of topography and land survey, geology and geotechnical investigation, environmental impact studies, and geotourism. As a former mining area with deep scars in the territory and in the local community, the involvement of the population through knowledge of the geological natural heritage is very important. The elaboration of thematic pathways relating to mining heritages, the delimitation of an "open-air museum", as well as the implementation of visits of schools of all types of education and other institutions, aim the promotion of this resource in the structuring of differentiated tourism products, such as: the geotourism and the tourism of experiences.

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