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Sustainability perspectives in Greece as reflected by mineral deposits exploitation

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Abstract

The mining activity and further exploitation of mineral wealth remain the main development priorities of Greece. The exploitation of rich deposits of mineral raw materials is a timeless essential reference for the mining and metallurgical activities in Greece. The Greek minerals are early target of productive investment and interest, with strong commercial presence in the global market offering employment opportunities for large numbers of workers. Today employs about 23,000 workers and there are still more than 100,000 employment positions. The specification of strategic options for the future of mining in Greece should be of high priority, as well as the definition of a «roadmap» for the optimal use and sustainable exploitation of specific mineral raw materials.

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1. Introduction

The timeless development of mineral resources has contributed decisively to the social and cultural evolution of man. Even today, in the period of post-industrial era, the exploitation of mineral resources serves, to a large extent, daily and general needs of society, and contributes to further development and progress. The increasing demand for them is a constant value for the future. Despite this fact, both Greece and the EU lack specific mining policy and strategy. A consequence of this is that areas with large ore deposits interest for Europe, are binding to other land uses, without taking into account the increasing needs of the European mining industry (www.inspire.net and www.gmes.info). It is obvious that this situation will trigger the coming decades adverse developments in Europe, which will be found unprotected against the intense and often unfair global competition and dependent on the production and distribution of mineral raw materials (e.g.

penetration of China into the global market).

Demand for so-called non-energy raw materials, with reference to metallic, industrial, quarrying and mineral aggregates tends constantly growing. Today every EU citizen consumes 16 tons of minerals. On the other hand, 70% of the necessary raw materials for the European industry is imported from third countries, while 70% of European industry generally relies on mineral raw materials. Europe produces only 3% of world production of metallic minerals, while consuming 30%. In 2009 Europe imported mineral resources for 393.6 billion €, while exports amounted respectively to 136.0 billion € (<http://ec.europa.eu/enterprise>). The dependence of EU in non-energy raw materials ranges from 48% in ores of copper, 64% zinc and bauxite, 78% nickel and up to 100% in cobalt ores, platinum metals, titanium and vanadium. For the next 10 years it is estimated that demand will continue to rise.

The mineral resources are today a top priority of the development agenda of EU. This trend is now visible at all levels of administrative and political decisions. It is commonly accepted by almost all EU institutions, that Europe now needs to support economic and social development in own sources of minerals. On the basis of these developments is the consensus and acceptance by the majority of European citizens for sustainable relationship of the mining industry with environment and social progress.

This article refers mainly to non-energy minerals which, according to a report by the European Directorate and Industry (<http://ec.europa.eu>), include metal products, industrial and construction minerals (construction materials, decorative and building stones, aggregates), and the «general» waste/byproducts of certain materials as secondary sources of economic deposits.

2. Development opportunities in the mining and processing of mineral raw materials in Greece: socio-economic impacts

The Greek minerals are of the very early a goal and an important productive investment interest, with strong commercial presence in the global market and employment opportunities for a large number of workers. Today employs about 23,000 workers and there are still more than 100,000 employment positions. Greece holds an important position in European and world market on mining and production of specific non-energy mineral raw materials.

The results of research conducted mainly by Institute of Geology and Mineral Exploration (IGME) are expected to add significant and in many cases measurable economic and social value in relation to the current productive capacity of non-energy raw materials in Greece. However, these results will significantly increase our understanding of the dynamic reserves and prospects of exploitation of Greek non-energy raw materials. Figure 1 presents the active mining centers of metallic and industrial minerals in Greece.

The value of proven ore deposits of zinc, lead, copper, gold and silver in Greece, based on current metal prices, is around 25 billion €, while dynamic reserves hosted on existing mining areas and on new areas of interest are able to multiply the above economic size. These reserves are located mainly in deposits of NE Chalkidiki (Olympias, Stratoni, Skouries) and Thrace (Perama, Sappes). Indicative plans for the productive exploitation of them are in progress by international companies holding mineral deposits. The aforementioned mining value can totally be 32 billion € under the new ore resources of about 15-20% additional reserves that are expected to arise by an ongoing new research project contacted by IGME, including the dynamic presence of rare or other "critical" metals (www.igme.gr). It is estimated that the enhancement of at least two investment opportunities in productive exploitation of ore reserves of base and precious metals will create more than 500 new jobs in direct employment. Thus, the developmental dynamics is inextricably linked with

the direct productive exploitation of the rich deposits in Chalkidiki and Thrace. The implementation of major



Figure 1: The active mining centres of metallic and industrial minerals in Greece (map by IGME).

investment projects in these areas becomes an important tool for ore deposits evaluation and prospects for economic exploitation of new ore deposits of base and precious metals in the country, including public-owned Pontokerasia mine and metalliferous occurrences in Agistro area.

Based on reserves and metal content in gold, silver, copper, lead and zinc, Northern Greece is, in terms of economic geology, one of the richest regions of Europe and can be a constant source of ore deposits for sustainable development of the country. The Greek mineral wealth in addition, could be able to contribute decisively towards more intensive and efficient exploitation of intra-European sources of non-energy mineral raw materials.

The production of materials with high added value (nano-composites) from bentonitic clays with or without

the addition of zeolites create favorable economic conditions for innovative investment projects in new technological applications of environmental protection with an annual growth rate of 15-20% (www.sme.gr).

The economical approach of ornamental stones in areas with relatively mild mining activity will likely provide incentives for new investments, contributing by this way to sustainable development through employment and exports of marbles and granites. Promoting projects of organized management and processing of byproducts in areas of intensive exploitation of marble, creates new prospects for new business activities for exploitation of mining waste products of non-energy mineral raw materials and thus production of value-added products. Arvanitidis and Papavasileiou, 2011, have discussed that the prospect of exploitation the mining and «generally» waste of public-owned mine of Kirke, by bioleaching, could increase the production of basic metals in Greece, contributing to the recovery of non-energy mineral raw materials, which in Europe is 5.9 billion tons.

The mineral raw materials such as bauxites, nickeliferous ores, pozzolanic earths, bentonite, perlites, gypsum, pumice, aggregates minerals and marbles are found in top productive activity positions, during the last two decades, together with lignite. The Greek mining industry is highly extroverted and steady, with about 77% of sales directed to exports. There is no doubt that Greek mining activity is an important economic sector of Greece with highly promising growth prospects. It constitutes a structural element necessary for competitiveness and development of many other sectors of Greek economy, supplying raw materials for the needs of Greek industry and everyday life. Its contribution to regional employment and growth is remarkable, since the mining industry is operating in peripheral or mountainous areas with limited possibilities for other business activities. Table1 lists almost all minerals produced in Greece (Tzeferis, 2010). It is obvious by this Table that there is a remarkable decline of produced mineral quantities between the years 2008 and 2009 due mainly to global economic crisis.

Table 2 refers to sales of minerals, ores, marble and processed metallurgical products for 2008, which amounted to about 1.1 billion €, of which 72% represent exports. For the first time, after a long period of positive growth, the Greek mining industry showed significant decline in 2009 and a decrease in demand and prices for raw materials. There was still falling production and sales value ranging from 20-30% compared to the corresponding figures in 2008 (Table 2).

The non-energy metallic minerals are found in the highest levels of resource utilization and exploitation, due to higher economic growth and sizes available in respect of the reserve potential and value of metal content (Table 3). This Table shows that the recorded measured mineral reserves of Greece are amounting to approximately 5.7 million tons, with a total economic value 38.2 billion €, based on current metal prices. Furthermore, it should be noted that according to recent European report on the subject 14 non-energy mineral raw materials - Antimony, Beryllium, Cobalt, Gallium, Germanium, Indium, Magnesium, Niobium, Platinum metals, Rare Earths, Tantalum, Tin, Fluorite, Graphite - are considered of critical and strategic importance for European industry. Some of these minerals are found in our country and could be subject to economic geology investigations and interest, given their added development value.

The quarry minerals, decorative and building rocks, with marble as the basic product and uses in construction and building industry, are traditional raw materials for the Greek mining industry, with a strong global production and export orientation.

Concerning energy mineral raw materials, the deposit in Paranesti area is well known, while relevant reserves occur in regions of Serres. At the same time, the proven exploitable lignite reserves in Western Macedonia and in regions of Megaloupolis, Ellassona and Drama amounted to 3.2 billion tons.

Table 1: Production of Mineral Raw Materials in Greece for 2008 and 2009 (simplified after Tzeferis, 2010).

Mining Industry in Greece		
<i>Production of Quarry / Mining / Metallurgical Products</i>		
Production	Quantity in metric tons	
	2008	2009
Bauxite	2.147.000	1.935.000
Primary cast aluminium	162.339	134.737
Alumina Al ₂ O ₃ (anhydrous)	771.769	718.797
Alumina Al ₂ O ₃ (hydrous)	807.500	795.500
Sulphide ores	264.299	225.054
Lead Sulphide PbS (concentrate)	23.314	17.027
Zinc Sulphite ZnS (concentrate)	46.532	34.255
Iron nickel ore (laterite)	2.261.637	1.400.000
Ferronickel Alloy (FeNi)	87.664	42.423
Nickel in Ferronickel Alloy	16.640	8.269
Slag (coarse by-product)	85.345	62.022
Slag (crushed by-product -5 mm)	90.180	52.696
Magnesite	455.069	250.234
Caustic Magnesia	70.545	55.545
Refractory Masses	35.617	31.634
Bentonite (primary material)	1.500.000	844.804
Attapulgitic clay	28.584	81.382
Huntite / Hydromagnesite	19.600	10.652
Pozzolan	1.059.000	830.000
Pozzolan for special uses	NA	21.532
Kaoline	4.360	0
Perlite (primary material)	1.000.000	862.935
Perlite (after treatment)	600.000	398.451
Pumice	828.000	381.000
Silicon Dioxide	64.521	37.905
Gypsum and anhydrite	1.000.000	730.000
Olivinite (primary)	37.150	48.050
Amphibolite	57.500	25.902
Calcium Carbonate (amorphous and Crystalline)	126.357	580.000
Feldspars	62.000	28.617
Quartz and quartzite	16.201	10.909
Coal Dioxide (liquid)	12.200	8.000
Talc	NA	NA
Lignite	64.521.000	61.800.000
Crude Oil (barrels)	477.679	628.278
Natural Gas (Nm ³)	14.058.056	11.123.714
Salt (not mineral, evaporation product)	220.000)	189.000
Chalky material	85.000.000	65.000.000
Marbles (m ³)	347.526	155.516
Marble by-products (gravel)	1.218.056	761.933

Table 2: Drop in production and sales value ranging from 20-30% for 2009 as compared with the corresponding figures of 2008

Mining Industry in Greece		
Production of ore / minerals / rocks / aggregates / marbles		
Non-energy raw materials excluding the presence of lignite	Production in metric tons	
	2008	2009
Metallic Minerals	5.155.005	3.810.288
Industrial Minerals and Rocks	6.952.448	5.217.716
Lignite	64.521.000	61.800.000
Aggregates	85.000.000	65.000.000
Marbles (in m3)	799.031	510.007

Table 3: Reserve potential of the main metals in Greece (with the addition of Mn, Mo and W, but without Al, the total value will approximately be 40,2 billion €).

Metals included	Ni	Cr	Pb+Zn	Cu	Au	Ag	Sb	Total
Reserve in tons (10 ³)	935	170	3.083	1.488	0,42	2,8	2,4	5.680,62
Metals Value in € (10 ⁶)	4.016	727	6.048	10.826	14.424	2.104	10,8	38.155,8

The metallogenetic environment of Northern Greece is particularly favorable for the formation of exploitable deposits of non-energy metallic mineral raw materials. The mining value of proven reserves of nickel, zinc, lead, copper and silver in Macedonia and Thrace, based on strong metal production, investments in progress and current metal prices amounts to about 27.6 billion € (Table 4). A very small portion of that value is currently utilized productively. The dynamic reserves hosted in existing mining, but also in new areas of metallogenetic interest, are able to multiply the above mentioned economic size.

In the foreground of prospecting is to locate and identify 40 and 20 tons of gold in areas of economic interest Kilkis and Serres, respectively. Also, projects related to production of specific nano-composite materials with applications in environmental technology and ore deposits evaluation of "critical" minerals found in Greece, should be included.

Table 4: Economic value of metals for deposits in Northern Greece with investment and production capacity. * ounce price in €.

Metals included	Ni	Pb+Zn	Au*	Cu	Ag*	Total (€ X 10 ⁶)
Price / ton in €	26.985	2.300	1.065	6.770	26	
Kastoria mine	2.819					2.819
Stratoni		853	320		361	1.534
Olympias		2.818	3.834		1.398	8.050
Skouries			5.357	7.060		12.417
Sappes			852	27	12	891
Perama			1.810		80	1890
Total (€ X 10 ⁶)	2.819	3.671	12.173	7.087	1.851	27.601

2.1 Industrial Minerals

The industrial minerals of Greece contribute significantly to economic geology potential of non-energy mineral resources of the country. IGME has over time made extensive surveys and studies on economic and

technical implementation approach, development of innovative technologies and new industrial uses for specific minerals such as perlite, bentonite, feldspars, quartz, olivine, white carbonates, pozzolanic earth, zeolites, wollastonite, gypsum, kaolin, vermiculite, attapulgitite, huntite and talc.

According to Arvanitidis, 1998, these minerals contribute to production and environmental technology developments for industrial minerals of Northern Greece. Researchers continue to reveal new reserves data and potential use in high-value products and generally new perspectives for sustainable exploitation and management.

2.2 Aggregates Minerals

Currently, in Greece are operating 222 aggregates minerals quarries, relating mainly to mining of carbonate rocks. The total production covers largely the construction needs of the country, with annual production of approximately 100 million tons.

2.3 Secondary sources of ore deposits

Omission would ignore the waste from the mining and quarrying activity, which in reality are «*anthropogenic deposits*». In particular, regarding the decorative rocks, mining marble blocks for the period 1980-2006 was in Greece approximately 13 million m³. With an average recovery rate for this period, approximately 15% (optimistic estimate), the total quantity of mined rock is estimated at 90 million m³. Even if a rate of about 10% utilized in other uses, except marble blocks, a material amount of over 170 million tons already deposited as waste during the same period, while continuing to be produced annually and deposited large amounts of such aggregates waste.

There is clear application field of solid waste for at least two major and emerging markets: a) the production of powders for use as filler and b) the production of dry mortars. From market survey was found that the capacity of Greek white carbonates production units doubled in a period of eight years and is now at the level of 0,8 Mt per year. Respectively doubled the Greek production also (exported 60%), which is now at the level of 0,35 Mt annually. Use is already made of marble waste in 30%, while continually requests are made from marble quarries for evaluation of their products. It has to be underlined that these products have great added value given that their prices are between 45-200 €/t. In the mean time it is possible to use and implement, as appropriate, waste from the mining of marble for production of aggregates for concrete. Newly identified areas in the country are of interest for new business development activities related to the above mentioned main applications (products with high added value, prepared powder, aggregates minerals).

In the Region of Central Macedonia, of specific interest are waste from the mining of decorative rocks in the vicinity of Vermio area (Koumaria, Kastania etc. with total reserves of about 2×10^3 m³). Typical samples of the region were studied in laboratory and semi industrial scale. From this study it was found that there exist materials with carbonaceous composition ($\text{CaCO}_3 > 98\%$) and very high whiteness ($Y = 95-98\%$), characteristics that make them suitable for the production of high added value products. The tests which were also conducted on the use of these materials as crushed aggregates for ordinate concretes (parent rock strength, endurance Los Angeles) gave values of mechanical properties within limits of international standards (parent rock strength $> 65\text{MPa}$, LA30, FI35).

Regarding the «mining» waste, characteristic examples are:

a) Olivine waste rock from the operation of magnesite at Vavdos inactive state-owned quarry and at Gerakini active quarry, Northern Chalkidiki.

- b) 3 million t flotation ponds, in enrichment and condensate production of sphalerite and galena, hosted at the Olympias dam and containing approximately 3g/t gold.
- c) 2-3 million t metalliferous waste rock and pyrite remains after mining found in the intermediate areas between Stratoniki and Stratoniki, Northern Chalkidiki.
- d) metalliferous mining waste rock at state-owned Kirke mine.
- e) manganese-rich waste accumulated during the production process of manganese in the region Piavitsa-Varvara.

3. Roadmap for Sustainable Development

The sustainable development of Greek mineral wealth is of great importance for national progress and employment. Towards this perspective specific options and targeted actions are required.

The productive exploitation of Greek mineral raw materials is very important for the Greek economy. The predicted increase of future demand requires identification and exploitation of more ore reserves in the country. This development is particularly important for the growth potential and prospects of many local communities. This course requires effective and dynamic actions on crucial issues of exploitation of mineral raw materials in Greece, in relation to the conditions created by current international and European developments. Specifically:

- Globalization of mining competition, e.g. industrial minerals, mainly from the countries of low production and environmental costs (e.g. countries BRIC).
- Pressures, with characteristics of regional competition from the Balkan countries, e.g. Turkey (with a favorable environment for the mining industry) and other new candidate member states.
- Increasing environmental costs and conflicts of interest for land use.
- Implementation of research technology development programs which require costly and high cognitive level. A key challenge is the implementation of «smart» and environmentally friendly technologies, aiming to high productivity and also high added value.
- Significant areas of metallogenetically economic interest are constrained by other land uses. It is necessary to complete geographic and spatial mapping to eliminate potential conflicts of interest.
- There is obviously lack of awareness among citizens about the role of mineral raw materials.
- Lack of comprehensive synergy between various levels of government, particularly among those involving local communities and landowners.
- The strong export orientated sector of natural decorative stones, is one of the few sectors of the Greek economy, which is able to compete related sectors in international markets. The pressure on this industry from international competition and the imperative need for a common European policy, constitute the conditions for harmonization of how to determine the physicochemical properties of Greek ornamental stones, with the rules applied in EU (e.g. standards, processes, procedures).
- Aggregates minerals are in top demand among non-energy mineral raw materials consumed by European countries to meet their development needs. This demand of the construction industry tends growing at a rate greater than 4.2% per year in terms of the manufacturing industry of the new EU member states. At the same time, policies and management practices of the aggregates in these countries are not to the same extent compatible with the environment, and generally with sustainable exploitation and use of natural resources.

4. Objectives to plan and anticipate

- Promotion and implementation of a reliable evaluation system of Greek non-energy mineral raw materials.
- Assessment of current situation of the Greek mining industry in relation to European and international developments.

- Mapping of all proven and possible geological reserves in relevant economic geological and prognostic maps.
- Contributing to remove «potential» conflicts and to avoid future conflicts over land use issues.
- Ensuring and strengthening of social progress and improvement of the quality of life.
- Preservation of public health, workplace safety and environmental protection.
- Implementation of a fully transparent system for mining information, serving the local community, industry and landowners.
- Public debate in the context of sustainable development.
- Open communication to report potential risks.

5. Conclusions

The Mining Activity in Greece should be seen generally as a tool for sustainable development and economic growth, for this sector of business development. The determination of strategic options for the future of mining in Greece as it is now is imperative, as well as the definition of a "roadmap" for the optimal use and sustainable exploitation of certain minerals, featuring national and/or regional comparative advantage for Greece, in order to maintain in long-term the comparative advantages of the country.

The mineral raw materials such as bauxites, nickeliferous ores, pozzolanic earths, bentonite, perlites, gypsum, pumice, aggregates minerals and marbles are found in top productive activity positions, during the last two decades, together with lignite. The Greek mining industry is highly extroverted and steady, with about 77% of sales directed to exports. There is no doubt that the Greek mining activity is an important economic sector of Greece with highly promising growth perspectives.

On the other hand, delay or even more non-utilization of recovering of viable productive resources, such as mineral raw materials (metallic, energy, non-energy, aggregates and industrial minerals) reduces and almost eliminates the ability of the country to fundamentally change, exploiting its comparative advantages, the current developmental data.

References

- Arvanitidis, N., 1998. Northern Greece's industrial minerals: production and environmental technology developments, *Journal of Geochemical Exploration* 62, p. 217-227.
- Arvanitidis N. and Papavasileiou K., 2011. In Greek Mineral Wealth, *Institute of Geology and Mineral Exploration*.
- Tzeferis K., 2010. Production of Mineral Raw Materials in Greece for 2008 and 2009, *Mineral Wealth* 156, p. 51-52. <http://ec.europa.eu/enterprise>. Raw Material Initiative–COM 2008/699.
- http://ec.europa.eu/enterprise/policies/raw-materials/public-consultation/index_en.htm. DG Enterprise and Industry
- www.gmes.info. Global Monitoring for Environment and Security.
- www.igme.gr. Institute of Geology and Mineral Exploration
- www.inspire.net. Infrastructure for Spatial Development in Europe.
- www.sme.gr. Association of Mining Companies.