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# Metallic Mineral Resources of Greece

Review Article

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Abstract: Today Greece produces and exports raw bauxite and alumina, concentrates of galena and sphalerite and ferronickel. The indicated reserves of bauxite, located in the Mt Helikon-Mt Parnassus-Mt Giona-Mt Iti zone, are estimated at approximately 100 mt and those of aluminum 2.5 mt. The probable and indicated reserves of lead and zinc from Chalkidiki are approximately 3.125 mt. The total production of concentrates of galena and sphalerite is approximately 220,000 tpa. The proven reserves of nickel are approximately 1.392 mt and the production of ferronickel is approximately 18,500 tpa. Production of copper, silver and gold is pending in 2015. The probable and indicated reserves of copper from Skouries Chalkidiki are approximately 1.943 mt. In the Prefecture Units of Chalkidiki and Evros the probable and indicated reserves of gold are approximately 19.37 million ounces and those of silver 131.6 million ounces. Chromium, manganese and molybdenum present good prospects of exploitation. Calculated at current prices, the total gross value of the probable and indicated reserves of the metallic minerals of Greece is €79.4 billion.

**Keywords:** Reserves • gross value • metal concentrations • production

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#### Introduction

In 2010 the European Union (EU) adopted the initiative of sustainable production from domestic raw materials, sustainable consumption and recycling. In the content of this initiative, 14 minerals were classified as critical and of strategic importance for European industry. Most of them are found in Greece, but further investigations are needed to determine the proven reserves. In February 2012 the Greek State established a new mining law which is in accordance with the European raw materials initiative (Verheugen initiative), in order to reduce the projects

and activities which require environmental permits, to reduce the licensing time in the EU average (currently it is up to 5 times) and to remove the premeditation of environmental impacts. The mining licensing in Greece follows regulations set by the EU directives. The development of mining and metallurgical industry in Greece presents a strong comparative advantage over other EU countries and this should benefit the national economy [1–3].

The projects of the mining companies in Greece vary depending on their size, the product range, the ambitions of owners, etc. During recent years the profile of the industry began to change rapidly through mergers, acquisitions and funding according to the listing in the stock markets. However most of the mining companies need to establish or expand their strategic alliances with international businesses in the know-how and through marketing. There is no doubt that the mining industry in Greece has signifi-



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cant strength. But it must identify and explore the trends and opportunities of the international business environment if it wants to remain competitive and further improve its position and prospects.

Greece, in relation to many other countries of similar size, is very advantageous for its mineral wealth. A great variety, mostly industrial and metallic minerals, and energy mineral raw materials such as lignite, exist in its territory. The probable and proven reserves of most of the mineral resources of Greece are unknown, as detailed investigations (e.g. drillings, mineralogical and chemical analyses, etc.) are lacking. In addition, recent feasibility studies for most of the Greek resources are inexistent. However, following the rules set by PERC here we present the indicated reserves and the gross value of the mineral resources of Greece amounted to about €1.5 trillion [1, 5], of which €1.36 belong to energy mineral resources (i.e. coals, natural gas and oil).

The scope of this article is to present comprehensive data of the most important metallic mineral resources of Greece currently exploited, and those presenting good investment perspectives. We believe that substantial contribution to the debt reduction of Greece will occur by granting rights to exploit its metallic mineral wealth.

# 2. Methodology

The Pan European Reserves and Resources Reporting Committee (PERC) Code by its 2008 edition set out minimum standards, recommendations and guidelines for public reporting of exploration results, mineral resources and mineral reserves in Europe. The code which is applicable to all solid mineral raw materials has been adopted among others by the European Federation of Geologists. The main principles governing the operation and application of this Code are transparency, materiality, competence and impartiality [4].

Increasing the geological certaintyin mineral resources can be classified as hypothetical, indicated or measured, while the mineral reserves as probable or proven. According to the PERC code from 2008, specific and strict requirements apply for moving from one category of deposits to another. Mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors (known as modifying factors) are considered. Moreover the credibility and the equipment of the body performing the research and the sustainability study of the probable investment are taking into account [4].

In Table 1 we show the probable and indicated reserves of the metallic mineral resources of Greece currently exploited, and those resources presenting good prospects

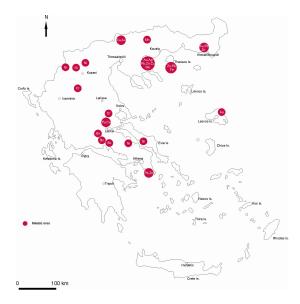


Figure 1. Metallic mineral resources of Greece.

Ag=Silver, Au=Gold, Bx=Bauxite (Aluminum), Cu=Copper, Cr=Chromium, Fe=Iron oxides, Mn=Manganese, Ni=Nickel, Pb=Lead, Pq=Pqrite, Zn=Zinc

for exploitation, along with their gross value. Data is from the PERC Code, annual public reports posted on the web sites of the companies involved in Greece, press releases and specific scientific reports. Figure 1 shows the areas of the most important metallic mineral resources of Greece.

# 3. Results

#### 3.1. Aluminum (AI)

The karstic bauxite deposits of Greece are among the world's most important sources of non-metallurgical bauxite. These deposits are interbedded with the form of lenses, veins, pockets or irregular masses in limestone formations. Exploitable deposits of bauxites exist in the regions of Mt Parnassus, Mt Giona and Mt Helikon (central Greece). Economically insignificant occurrences of bauxites are found at Mt Kallidromo, Mt Iti, Mt Othrys, Evia, Skopelos, Elefsina. In general the bauxite deposits are brown-red in color, because of the contained iron oxides. But there are also white colored bauxites, which are richer in aluminum and poor in iron. The mineralogical composition of bauxites of the Parnassus-Giona Zone is: 10-30% boehmite, 20-50% diaspore, 20-25% haematite, 1-5% calcite, 1-2% quartz, 1-5% kaolinite and 0.5-2% anatase [6, 7]. The total production of bauxite of all three companies operating in placecountry-regionGreece in 2011 was 2.3 mt.

Table 1. Reserves (probable+indicated) and gross value of the metallic mineral resources of Greece.

Mineral Resource	Indicated reserves(th. t) <sup>3</sup>	Price [65] (€/t)	Value (m. €)
Aluminum (Al)	2,500	1,616	4,040
Lead+Zinc (Pb+Zn)	3,125	1,659	5,184
Nickel (Ni)	1,392	14,343	19,965
<sup>1</sup> Copper (Cu)	1,943	6,398	12,431
<sup>1</sup> Gold (Au)	19.37 <sup>4</sup>	1,371/ounce	26,556
<sup>1</sup> Silver (Ag)	131.60 <sup>4</sup>	26.25/ounce	3,454
<sup>2</sup> Chromium (Cr)	1,200	2,127	2,552
<sup>2</sup> Manganese (Mn)	2,250	2,320	5,220
			Total 79 402

<sup>&</sup>lt;sup>1</sup> pending exploitation in 2015,

A sole company is the largest consumer of Greek bauxite, processing more than 1.5 m tpa. In 2011 this Co produced 165,000 t of aluminum, much of which was exported [8].

The most important known bauxite deposits are located in the Mt Helikon-Mt Parnassus-Mt Giona-Mt Iti zone, and are estimated at approximately 100 mt [9].

The indicated reserves of aluminum in Greece are approximately 2.5 mt and their gross value €4.04 b.

# 3.2. Base metal sulphides (Pb+Zn)

Base metal sulphide ores (usually with chalcopyrite, and traces of Ag, Au, Sb, As, Cd, Ga, Ge and Se) occur in Lavrio Attica, in Chalkidiki (Olympias and Stratoni) and in Evros (Kirki and Esimi), and were exploited in the past. The Lavrio carbonate-hosted Pb-Aq-Zn deposit was subjected to supergene oxidation giving rise to gossans. The supergene dissolution and re-precipitation of Fe and Zn in the host carbonates increased metal grades and separated these metals from Pb, forming economically significant ores. The Chalkidiki Pb-Zn(Au,Aq) sulphide ore deposits are developed in carbonate rocks and are structurally controlled. The Olympias deposit is generally strata bound or fracture controlled and in places stratiform. Its main mineral constituents are pyrite, galena, sphalerite and arsenopyrite with quartz, calcite and rhodochrosite as ganque minerals [10-12]. In Skra Kilkis the probable reserves of base and precious metals include: 4.7 mt of sulphides with 7.7% Zn+Pb, containing 172,000 t Zn, 113,000 t Pb and 80 t Aq. The indicated reserves of these sulphides are 12 mt with the above mentioned metal concentrations. In addition, in the same mining area molybdenum has been located the indicated reserves of which have a gross value of €0.2 billion [13].

Occurrences of base metal sulphides – although economically insignificant – occur in Evia, Almopia, Serres, Palea Kavala, Xanthi, Rhodope, in the islands of North and East Aegean and in most of the Cyclades [7, 14–17].

The end of the 19th century found the Kassandra mines in NE Chalkidiki exploiting primarily ores of manganese and then base metal sulphides. In the period 1974-1975, small amounts of chalcopyrite were also extracted. Milestones in the history of the mines were the construction of enrichment plants at Stratoni and Olympias in 1952 and 1969, respectively. The activity of the mines included the extraction of base metal sulphide ores from the deposits of Stratoni, Mavres Petres, Madem Lakko and Olympias. In Stratoni the exploitation began in 1940 and in Olympias in 1945. The extracted ores were processed locally in the enrichment plants, where after crushing and grinding flotation was applied to produce concentrates of galena, sphalerite and Au-bearing pyrite [18]. The first two concentrates are exported, while the third one remains stowed in the courtyards of treatment units. In 2011 the total production of concentrates of galena and sphalerite was 222,000 t [8].

In 1992 the mines came under a special clearance. Uncertainty about the operation and future of the mines prevailed. Their operation by the end of 2004 was based on revenues from stocked product sales and funding from the National Bank with the state guarantee. Then was the acquisition of the initial Co by another one. By the end of 2011 a Canadian Co and a European one own 78% and 22%, respectively, of the share capital of this Co. Mine lifes, deposit types, reserves and metal concentrations are presented in Table 2 after data released by the Canadian Co in October 2012 [19].

<sup>&</sup>lt;sup>2</sup> good prospect of exploitation,

<sup>&</sup>lt;sup>3</sup> thousand tons,

<sup>&</sup>lt;sup>4</sup> million ounces,

<sup>€1=\$1.293 (</sup>Oct. 9, 2012), 1 troy ounce=31.1 g.

Today, the mines of Chalkidiki are the only ones which exploit base metal sulphide ores in Greece.

#### 3.3. Chromium (Cr)

More than 200 occurrences of chromite ores of all four textural types (podiform, disseminated, nodular, massive) are known in Greece. The ores are found within dunitic bodies of the Mt Pindos, Mt Vourinos, Mt Othrys, etc. ophiolitic complexes. The Vourinos complex constitutes a tectonically disrupted ophiolite sequence and belongs to the supra-subduction zone type of ophiolites. Petrologic data confirm the existence of multiple magma chambers. The harzburgites represent mantle residue remaining after a high degree of partial melting. The most important chromite ores of metallurgical type are in Kozani (Vourinos, Xerolivado, Rodiani), Veria, Edessa and Chalkidiki (Gerakini, Ormylia). The most important chromite ores of refractory type are in Eretria Larissa and Domokos Fthiotida [7, 20–26]. Both types are economically significant. Abundant PGE-minerals hosted in the chromitites of Veria ophiolite complex are reported [27]. In addition platinumgroup elements contained in the chromites of many Greek ophiolite complexes are reported [28].

The largest deposits of chromite are those of Mt Vourinos Kozani, which were under exploitation until 1991. The metallurgical Co at Almyros Magnisia produced ferrochromium during the period 1983–1991. The reasons for closure of the chromite mines and the ferrochrome metallurgical plant in 1991 were the crisis in the price of chromium, the inability to produce fine grained ore material for the production of  $\text{Cr}_2\text{O}_3$  concentrate through flotation, and the high number of personnel. Today the reopening of the chromite mines is favored because of the high demand for chromium, its significant proven reserves and the existence of the metallurgical plant

The indicated reserves of chromium from Vourinos Kozani are approximately 1.2 mt [26] and their gross value  $\pounds 2.552$  b.

# 3.4. Copper (Cu)

The copper deposits of Greece are divided into the following ore deposit types [29]:

Porpfyry-type: These are the most abundant type, and are associated with granitic to dioritic magma intrusions of Tertiary age. They are low grade in Cu, but there are large reserves. Usually they contain small amounts of Au and Mo. The most importanteconomically significant ore is the

deposit of Skouries Chalkidiki with indicated reserves of copper ores 138 mt. In 2011 a Canadian Co granted the right to exploit this ore. Mine life, deposit type, reserves and metal concentrations are presented in Table 2 after data released by the Co in October 2012 [19]. Of the same type are the deposits of Kilkis (Gerakario-Vathi and Pontokerassia). The probable reserves of the first area are 28 mt with 0.4% Cu and 0.9 q/t Au. Their gross metal value is €1.88 b. The indicated reserves of the same area are 180 mt with approximately the same metal concentrations and gross metal value €11.75 b. The indicated reserves of Pontokerassia are 50 mt with 300,000 t copper and 50 t gold and gross metal value €4.12 b. [13]. In July 2012 a Greek Co granted the right to complete the exploration in the whole mining area. The deposits of Fissoka Chalkidiki and of Maronia Rhodope are of porphyry type. [7, 30–35].

Epithermal high-sulfidation Cu-Au: of such type are the deposits of Pefka Evros and Sapes Rhodope.

Volcanic-hosted massive sulfides (VHMS): genetically they are connected with submarine exhalations of basic magmas. Numerous abandoned mines of Cyprus-type mineralization exist in Greece. The copper deposits of Ermioni Argolida belong to this type.

Skarn-type: the deposit of Kimmeria Xanthi belongs to this class. Several other minor sub-economic skarn-type mineralizations are associated with contact aureoles of Tertiary granitoids in Greece.

The production of copper and gold concentrates from Skouries Chalkidiki by the Canadian Co is pending in 2015. The probable and indicated reserves of copper from Skouries Chalkidiki are approximately 1.943 mt (Table 2) and their gross value €12.431 b.

#### 3.5. Gold (Au)

On an annual basis in Greece about 14 tons of imported gold are used, mainly in the manufacturing of jewelry. Almost all gold is imported from Switzerland. Today the sector of jewelry in Greece employs directly and indirectly about 40,000 people. The bank reserves of Greece after 2000 amounted to 122 tons, at the request of the European Central Bank [7].

Intense mining activity is dated since the 4<sup>th</sup> century BC in Greece. The Kassandra mines in NE Chalkidiki, together with those of Mt Pangeo were the main sources of gold during the period of Philip II and Alexander the Great, as the old mining galleries and ore smeltings reveal. The smeltings of this period identified in the regions of Olympias and Stratoniki, amount to 350,000 tons [36]. The mineral jarosite is considered as an indicator of concentrations of Ag and Au with an economic interest. It has

Table 2. Presentation of mining sites in Chalkidiki (Olympias, Stratoni, Skouries) and Evros (Perama Hill).

Mine life	Deposit type	Reserves(th.t)	Au(g/t)	Ag(g/t)	Pb(%)	Zn(%)	Cu(%)	Au(moz)	Ag(moz)	Pb(th.t)	Zn(th.t)	Cu(th.t)
$^{1}$ Olympias <sub>u</sub> (25 y)	RBMS	13,572	8.70	132.1	4.44	5.87		3.79	57.70	599	796	
$^2$ Olympias $_t$	RBMS	2,408	3.40	14.0				0.27	1.10			
$^3$ Olympias $_u$	RBMS	12,435	10.0	154.0	5.10	7.10		3.99	60.80	630	839	
<sup>4</sup> Stratoni <sub>u</sub> (10 y)	RBMS	1,760		176.7	6.25	8.58			10.00	110	151	
<sup>5</sup> Skouries <sub>u</sub> (27 y)	CAP	138,362	0.81				0.53	3.59				738
$^6$ Skouries $_u$	CAP	246,350	0.67				0.49	5.35				1,205
<sup>7</sup> Perama Hill <sub>u</sub> (8 y)	DED	9,697	3.13	4.20				1.00	0.70			
<sup>8</sup> Perama Hill <sub>u</sub>	DED	12,439	3.46	3.75				1.38	1.30			
							Total	19.37	131.60	1,339	1,786	1,943

<sup>&</sup>lt;sup>1</sup>Underground reserves (proven+probable), <sup>2</sup>Tailing reserves, <sup>3</sup>Underground reserves (measured+indicated),

RBMS=Replacement Base Metal Sulphide, CAP=Cu-Au Porphyry, DED=Disseminated Epithermal Au-Ag Deposit, moz=million ounces, th.t=thousand tons.

been detected in oxidized ores of base metal sulphides in Chalkidiki, Palea Kavala and Thassos. The jarosite-enriched ores contain up to 4.6 g/t Ag and 8.5 g/t Au [37]. Native gold from Greece contains up to 44% Ag. The gold in placer deposits has lower levels of Ag (10% on average), due to the physical removal of Ag during the transport of sediments into the rivers [38]. The elements platinum, palladium, gold, tellurium and arsenic have been identified in porphyry copper occurrences in Kilkis and in Chalkidiki [39].

Greece, due to the geotectonic position and its geological structure, presents a large number of occurrences and ores of Au, which are often accompanied by Ag, Pb, Zn, and Cu. The gold deposits in Greece are divided, according to the mineralogical composition and the manner of their formation, into five distinct deposit types: a. polymetallic base metal-bearing sulphide ores (e.g. skarn, carbonate-replacement and "mesothermal" quartz veins), b. porphyry ores of Cu-Au, c. epithermal Au (both high-and intermediate-sulfidation types), d. supergene mineralization of Mn-Au and e. placer Au [40].

The gold in the first type is found along with quartz and within the minerals of base metal sulphides (Pb, Zn, Fe, Cu, As, etc.). The underground of NE Chalkidiki hosts significant ores of base metals (Zn, Pb, Cu, Mn) and precious metals (Au, Ag) [36].

Occurrences of Au and Ag mineralization of hydrothermal origin (epithermal or mesothermal type) into quartz veins have been found in Kavala (Mt Pangeo, Mt Symvolo, Palea Kavala), Drama, Serres (Mt Menikio, Metalla, Angistro), Stanos Chalkidiki, Almopia, Peloponnesus and

in the islands of Limnos, Lesvos, Samos, Sifnos, Milos and Evia. The Kallianos Evia ore contains on average 4.6 g/t Au and 292 g/t Ag [7, 41–44].

Deposits of placer gold exist in many regions of Macedonia and Thrace (northern Greece). The deposits of Gallikos River were the only Au-bearing deposits of Greece exploited in modern times. During the period of 1953-1960 1355 kg of gold were collected [45]. Occurrences of placer gold exist in Langadas and Strymon River [7]. Placer gold and minerals of the platinum group (alloys of Os-Ir-Ru, Os-Ir-Rh, Os-Ir-Pt, and Pt-Fe) were also found in Servia Kozani and along the riverbeds of Aliakmonas and Axios and their tributaries [40]. Ilmenite, rare earths and placer gold have been detected in the seafront sands of Nea Peramos-Loutra Eleftheron Kavala [46]. Gold has been located in the submarine fan sandstones of the Ionian Zone [47].

The most important and economically significant ores of gold are located in Chalkidiki (Olympias, Skouries), in Perama Hill Evros, in Sapes Rhodope and in Kilkis (Antigonia, Gerakario, Vathi, Pontokerassia) [12, 13, 33, 34, 48–50].

In October 2004 a new Greek Co acquired the initial Kassandra mines Co and the mining and processing of galena and sphalerite continued. In January 2006, this Co submitted a comprehensive operational plan for the exploitation of the mines in Olympias, Stratoni and Skouries. This was an investment with development operations of existing and new mining facilities and interventions of environment recovery, which had been disturbed by previous mining activity of long duration.

<sup>1,2,3</sup> Processing: flotation (AsPy, Pb-Ag, Zn concs.) and flash smelting, Recoveries: ±90% of Pb/Zn/Ag/Au concs.,

<sup>&</sup>lt;sup>4</sup>Underground reserves (proven+probable), Processing: flotation (Pb-Ag, Zn concs.), Recoveries: 92% Pb+Zn, 85% Ag+Pb concs.,

<sup>&</sup>lt;sup>5</sup>Underground reserves (proven+probable), <sup>6</sup>Underground reserves (measured+indicated),

<sup>&</sup>lt;sup>5,6</sup>Processing: flotation (Cu-Au conc.) and gravity circuit (Au doré), Recoveries: 91% Cu, 84% Au,

<sup>&</sup>lt;sup>7</sup>Underground reserves (proven+probable), <sup>8</sup>Underground reserves (measured+indicated),

<sup>&</sup>lt;sup>7,8</sup>Processing: carbon in leach (CIL), Recoveries: 90% Au, 60% Ag,

Since the end of 2011, a Canadian mining Co (which operates gold mines in Turkey, China and Brazil) were granted the right to exploit the Chalkidiki mines. This Co and a European one own 78% and 22% respectively, of the share capital of the previous Greek Co [8]. Mine lifes, deposit tupes, reserves and metal concentrations are presented in Table 2 after data released by the Co in October 2012 [19]. Another Greek mining Co, which is owned by the same Canadian Co (100%), is engaged in the development of the gold mine of Perama Hill Evros (Thrace). Eighty percent of the gold is hosted by sandstones (oxidized upper part of the deposit) and the rest is associated with base metal sulphides and tellurides hosted within andesitic breccias and conglomerates [50]. The upper oxidized part of Perama Hill deposit is free of As, Pb or other heavy metals. Mine life, deposit type, reserves and metal concentrations are presented in Table 2 after data released by the Co in October 2012 [19].

A second Greek mining Co were granted the right to exploit the gold ore of Sapes Rhodope (Thrace). Since the end of 2011 an Australian mining Co owns the total share capital (100%) of this Co [8]. So far more than 35 km of drillings have been performed for detecting and technoeconomic evaluation of the ore at the areas of Agios Dimitrios and Ochia. The largest part of mining will be underground, while the recovery of gold will be done by flotation and gravity circuit (Au doré). Based on proven reserves, the company will produce a total of 510,000 ounces of Au, 250,000 ounces of Ag and 3,000 tons of Cu [8].

The approval of Environmental Impact Assessment Studies by the Greek M.E.E.C.C. (Ministry of Environment, Energy and Climate Change) gave the green light to the Canadian Co for implementation of approved business plans in Chalkidiki (in July 2011) and Perama Hill Evros (in June 2012), respectively. The approval of the corresponding study of the Australian Co for Sapes Rhodope project is pending.

The first gold production in Greece is expected in 2015 [19].

The probable and indicated reserves of gold from Chalkidiki and Evros are approximately 19.37 million ounces (602.4 t) (Table 2) and their gross value €26.556 b.

#### 3.6. Manganese (Mn)

The western Rhodope massif in NE Greece contains a significant number of "battery grade" Mn-oxide deposits. These are best developed in the areas of Drama (Nevrokopi, Granitis, Perithorio, etc.) and Chalkidiki (Varvara, Stratoniki, etc.). The mineralization was formed by weathering of hydrothermal veins that are genetically related to Oligocene magmatism. The economically significant contains the significant contains the contains that are genetically related to Oligocene magmatism.

nificant ore of Granitis Drama has a maximum thickness of 40 m, 70-90 m length and content in Mn 22-29% [51]. Occurrences of manganese deposits also exist in Thassos, Serres, Petroto Kozani, Mt Othrys, Mt Pindos, Zarko Trikala, Seskoulo Magnisia, Eretria Evia, Argolida, etc. [7, 52-55].

Sub-marine manganese deposits in the form of nodules have been reported in Greece [56–58]. Manganese nodules, spheroid or columnar in shape, up to 7 cm, have been found in pelagic limestones in Panormos Fokida. These nodules are characterized by high ratio of Mn/Fe and low concentrations of trace elements (e.g. Ni, Co, Pb, Zn, etc.) [56].

Greece's sole natural manganese mining Co exploited the ore in Granitis Drama until the mid 90's. The material produced was in two grades, Scalma 74 (min.  $72\% \, \text{MnO}_2$ ) and Scalma 72 (min.  $70\% \, \text{MnO}_2$ ). Both grades were chiefly supplied for dry electrical cells. In addition to natural production, a Japanese Co produces 12,000 tpa of electrolytic manganese dioxide from its plant in Thessaloniki for use in batteries [59]. The exploitation of manganese ores in Greece was interrupted in the mid 90's, although it is the only country in the EU that has natural reserves of this metal.

The indicated reserves of manganese are approximately 2.25 mt [60] and their gross value €5.22 b.

#### 3.7. Nickel (Ni)

More than 110 occurrences of Fe-Ni-bearing deposits, which come from lateritic weathering of ophiolites and contain extra Cr and Co, have been identified in Greece (Kozani, Pella, Mt Parnitha, Skyros, Mytilini, etc.) [7, 21, 61].

Detailed petrographic and mineralogical investigation of lateritic weathering crusts on ultramafic rocks in SW Balkans indicated typical growth of the zones: bedrock, saprolite, clay zone, massive goethite and ferruginous pisolite. The associated Fe-Ni-bearing ores are composed of ferruginous spheroidal particles, silcrete, saprolite and mineral fragments and are considered clastic sediments. There are extensive laterite Fe-Ni-bearing ores; those at Artaki Evia, Agios Ioannis Viotia, Lokrida Fthiotida and Kastoria (Mesopotamia and Ieropigi) are all economically significant [62, 63].

A sole Co, one of the largest metallurgical industries of Greece and one of the largest of this kind in placeEurope, remains the sole producer of Ni in the EU from domestic ores. It operates in five prefecture units in the country. From the mines of Evia, Viotia and Kastoria in 2011 a total of 2.2 mt of ore was extracted and ferronickel production was 18,500 t [8]. The total production

of the company, which is about 2% of world production, was exported in the form of ferronickel alloy in stainless steel European industries. The metallurgical plant is located in Larymna Fthiotida. Meanwhile, in 2011 at the company's lignite mine in Servia Kozani, 350,000 t of lignite-peat were produced mainly for own consumption in the metallurgical plant (a significant portion went to PPC for electricity generation). The gradual increase in the price of nickel, due to increased demand for stainless steel products, boosted the company, which has increased its production in 2011 by 33% compared with 2010 [8]. Today, the shareholder structure of the Co is: 36% Greek State, 35% National Bank of Greece and 29% PPC. With the schedule of the medium-term financial framework for exit of Greece from the crisis, in 2013 the Greek State will allocate for sale all of the shares it holds.

The proven reserves of nickel are approximately 1.392 mt [64] and their gross value €19.965 b.

# 3.8. Silver (Ag)

While the silver minerals are represented by a relatively large range and frequency in various types of mineralization, native silver was found only in Agrileza Lavrio, Asimotrypes Pangeo and Panormos Tinos. The Ag-bearing galena of Lavrio was in antiquity the source of the economic boom of the Athenian State. Silver has been also detected in Chalkidiki (Olympias, Stratoni), Evros (Perama Hill, Kirki), Thassos, Skra Kilkis, etc. [7, 10, 11, 13, 19]. In Skra Kilkis the probable reserves of base and precious metals include: 4.7 mt of sulphides with 7.7% Zn+Pb, containing 172,000 t Zn, 113,000 t Pb and 80 t Ag. The indicated reserves of these sulphides are 12 mt with the same metal concentrations [13].

In 2011 a Canadian Co granted the right to exploit the silver ores of Chalkidiki with gold and other base metals. Mine lifes, deposit types, reserves and metal concentrations are presented in Table 2 after data released by this Co in October 2012. The first silver production in Greece is pending in 2015 [19].

The probable and indicated reserves of silver from Chalkidiki and Evros are approximately 131.6 million ounces (4,093 t) (Table 2) and their gross value €3.454 b.

# 4. Conclusions

In Greece investments in the sectors of agriculture, commerce, maritime, renewable energy sources (RES) and in the exploitation of mineral raw materials which hitherto remain unexploited (e.g. oil, gas, gold, copper, etc.) are encouraged.

- The indicated reserves of bauxite, located in the Mt Helikon-Mt Parnassus-Mt Giona-Mt Iti zone, are estimated at approximately 100 mt and those of aluminum 2.5 mt.
- The probable and indicated reserves of lead and zinc from Chalkidiki are approximately 3.125 mt. The total production of concentrates of galena and sphalerite is approximately 220,000 tpa.
- 3. The proven reserves of nickel are approximately 1.392 mt and the production of ferronickel is approximately 18,500 tpa.
- Production of copper, silver and gold is pending in 2015. The probable and indicated reserves of copper from Skouries Chalkidiki are approximately 1.943 mt.
- In the Prefecture Units of Chalkidiki and Evros the probable and indicated reserves of gold are approximately 19.37 million ounces and those of silver 131.6 million ounces.
- 6. Good prospect of exploitation present chromium, manganese and molybdenum.

Calculated at current prices the total gross value of the probable and indicated reserves of the metallic minerals of Greece is  $\[ \in \]$ 79.4 billion.

Although the country's economy outlook for the next few years is not expected to improve, we believe that substantial contribution to the debt reduction of Greece will occur by granting rights to exploit its metallic mineral wealth. Greece is expected to remain a major supplier of bauxite and ferronickel. The pending exploitation of copper, silver and gold from 2015 will strength the country's mining industry and hence Greece's economy.

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