RAW MATERIALS UNIVERSITY DAY
Future, needs and opportunities

Ornamental stones and aggregates in Greece

Dr. K. Laskaridis, Dr. M. Patronis, Mrs. F. Chalkiopoulou, Mrs. K. Hatzilazaridou (MSc)

Institute of Geology and Mineral Exploration (I.G.M.E.) of National Center of Sustainable Development (E.K.B.A.A.)
Department of Natural Mineral Resources

1, Sp. Loui, Acharnae 136 77, GREECE
Tel: + 30 213 133 7316, Fax: + 30 213 133 7463
e-mail: laskaridis@igme.gr

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GREEK MARBLE THROUGH THE AGES:
An Overview of Geology and today’s Stone sector

THE AGREGATES SECTOR IN GREECE
• The geological history of Greece has been influenced by conditions of intense orogenesis, magmatism and metamorphosis that led to the creation of extended areas of deposits of ornamental stones.
The following ornamental stones are widely used in Greece:

- **Metamorphic stones:** Calcitic marble, dolomitic marble, cipollins and ophicalcites.
- **Sedimentary stones:** Limestones, travertines, brace, onyxes and alabaster’s.
- **Magmatic rocks:** (Granites), granodiorites and gneiss.
In ancient Greece the use of marble had been very wide.

Marble and stone were the materials that deeply touched the human sensitivity and drove man to the world of aesthetics and symmetry.
The ancient Greeks were the first among many ancient civilisations to notice the unique properties of this remarkable stone that:

- lasted so long
- remained so beautiful and
- shaped to their needs so easily
The peak of the Greek classical period is represented by such outstanding structures as:

- the Athens Acropolis with Parthenon and Erechthion,
- the Aphrodite of Milos,
- the Hermes of Praxitelis etc.
The Parthenon today

The Parthenon is the temple of the Greek goddess Athena, built in the 5th century BC on the Athenian Acropolis.
The Caryatids from the South Porch of the Erechtheum

Source: http://www.theacropolismuseum.gr
During the 6th and mainly the 5th century B.C. intensive quarrying is reported in the following exploitation centres:
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GREEK MARBLE PRODUCING AREAS (DEPOSITS) IN ANTIQUITY

Thassos
Skyros
Eubea
Tinos
Naxos, Paros

Hassabali
Larissa

Penteli and Ag. Marina of Attica area

Krokees Peloponnese

Naxos, Paros
• The history of the Modern Greek marble industry started in the 1960's when building activities and standards of living rose remarkably.

• The number of marble quarries has been continuously increasing since the 1960's.
GREEK MARBLE PRODUCING AREAS (DEPOSITS) TODAY

Today, the major marble producing areas in Greece are:

1. Drama, Kavala-Thassos regions (Eastern Macedonia)
2. Kozani, Veria regions (Western Macedonia)
3. Ioannina region (Ipiros)
4. Volos region (Thessalia)
5. Dionyssos (Attika region)
6. Levadia-Hellikonas, Evia and Skyros (Sterea Hellas)
7. Argolis region (Peloponnese)
8. Other regions such as the Aegean islands: Naxos, Tinos, Paros, Crete, and
Drama, Kavala-Thassos regions

Evia and Skyros
Dionyssos
(Attika region)

Naxos, Tinos, Paros

Crete

Kozani, Veria regions

Ioannina region

Volos region

Levadia-Hellikonas

Argolis regions

GREEK MARBLE PRODUCING AREAS (DEPOSITS) TODAY
Number of quarries per region
(Data National Statistics Bureau, 2005)

Eastern Macedonia: 80 (39%)
Central Macedonia: 20
Western Macedonia: 27
Ipiros: 4
Thessalia: 25
Sterea Hellas: 12
Peloponnese: 14
Cyclades islands: 19
Crete: 12

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Number of quarries per region
(Estimated Data, 2014)

Eastern Macedonia: 80 (43%)
Central Macedonia: 17
Western Macedonia: 20
Ipiros: 25
Thessalia: 5
Sterea Hellas: 13
Peloponnese & western Greece: 10
Cyclades islands: 7
Crete: 4
Drama, Kavala - Thassos: 5
Geographical distribution of Greek marble block production
(Data by the Ministry of Environment Energy & Climate Change 2011, in % of total production)
EXTRACTION

Marble quarrying in antiquity

• By findings and studies about and around the remaining ancient quarries, it seems that ancient quarrying procedures did not differ much from those applied by quarrymen till a few years ago, before the extensive use of the modern quarrying machinery.

• The ancient quarries were classified into open and underground, as that in Paros where the “Lychnitis lithos” was produced.
EXTRACTION

Marble quarrying today - 1
Greek marble deposits usually occur in layers of small, medium or big thickness with horizontal or nearly horizontal inclination.

Criteria for the selection of the quarrying method are:
- the relation between waste and exploitable blocks. It is directly related to the thickness of the overlaying waste, the thickness of the marble layers, the layer inclination, its direction and trend
- the in depth extension of the deposit
- the tectonic shape of the deposit
- the topography of the deposit
• The thickness of the overlaying wastes, in the currently exploited Greek marble deposits, is usually small. Consequently, **opencast quarries** are the most common in Greece.

• Nevertheless, underground quarrying activities have restarted almost 15 years ago in order to minimise environmental impact.
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Opencast marble quarry in Thassos

Underground quarrying in Dionyssos, Attica

Bench cut in blocks with diamond wire saw

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Greek marble producers have performed major investments relating to mechanical and technical quarrying equipment.

Now-a-day, 95% of traditional quarrying techniques (such as explosives) have been substituted by modern methods, like diamond wire.
EXTRACTION

Marble quarrying today - 3

The advantages of the diamond wire technique are:

✔ improved productivity
✔ increase of the percentage of the deposit that can be exploited
✔ reduction of necessary squaring activities
✔ better overview of the deposit
✔ quality control of the extracted blocks
✔ better working conditions for personnel
✔ improved security - no use of explosives
✔ reduced cost in comparison to other traditional techniques and
✔ Production of less wastes material
The marble blocks cut from the mountain (after vertical and horizontal drilling, horizontal and vertical cut, bench overturning, bench cut, block handling and transport) are transformed through successive work cycles.

The basic processing cycles are the following:

- Cycle for slabs
- Cycle for tiles, from slabs
- Cycle for mass production of modular tiles
Cycle *for slabs*

- This cycle is intended to produce large slabs, starting from a regular or commercial-sized block and can be summarised as follows:
  - block squaring (if needed)
  - block cutting into slabs (with Gang Saw)
  - cross cutting and trimming (cut to size)
  - polishing
  - auxiliary operations handling
Cycle for slabs
The definition and demarcation of marble bearing areas is realized with contemporary research methods and techniques such as:

- **Geological mapping**
- **Commercial marble types mapping**
- **Fractures mapping**
- **Satellite remote sensing techniques**
- **Geophysical prospecting** *(surface Ground penetrating radar, Borehole radar and Acoustic method)*
Geological and Commercial marble types map
Fractures map
3D fracture model, consists of processing the GPR data
This map shown the status of exploitation of the quarry, updated with tectonic mapping data, borehole logs and geophysical results.

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QUALITATIVE CHARACTERISTICS

(PROPERTIES)

• The chemical and mineral content of a marble specimen distinguishes its colour, aesthetic and physical properties. Certain characteristics are scrutinised to determine whether or not this marble is suitable for building or artistic applications.

• These include:
  1) Colour and overall aesthetic appearance
  2) Veining its distribution and colour
  3) Presence and amount of fossil content and stains
  4) Physical, mechanical and technical properties

A marble's look is the result of the sum and interaction of its three basic components:

  colour, pattern and grain size

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Technical analysis of marble is an important means of examination.

The technical characterisation of marble can be performed either in laboratory or in situ.

*Laboratory characterisation* is based on tests performed on samples taken for this purpose either in the quarry or from semi-finished or finished products and is based on the use of a wide range of tests.

These tests are divided into four categories namely: *petrographic, chemical, physical and mechanical characterisation.*
As a general rule:

- **Petrographic characterisation** is needed to assign a correct petrographic name to the stone.
- **Chemical characterisation** is needed when it is not possible to assign a petrographic name on the basis of petrographic analysis as in the case of studying the decay and conservation of stone elements in monuments.
- **Physical and mechanical characterization** focuses on the proper evaluation of a stone for the various end-uses.
Physical, mechanical and technical properties

• The Institute of Geology and Mineral Exploration of Greece (I.G.M.E.), established a modern and fully equipped laboratory, called “LITHOS”.

• The laboratory is accredited according to ELOT EN ISO/IEC 17025 and performs quality control tests for the ornamental stones, according to EN standard procedures.

• Also LITHOS Laboratory can provide:
  ✓ information,
  ✓ advice and
  ✓ support
to anyone interested in the Greek marble sector.
The Greek marble quarry production overview is following:

• In year 1966, the quarry production of marble blocks was only 141,000 tonnes.
• In 2002 and 2003, the annual production was ca. 2,100,000 tonnes, or 3% of the world ornamental stone production.
• In 2011, the annual production was ca. 500,000 tonnes.
STONE SECTOR IN GREECE - CURRENT STATUS - 2 - QUARRY PRODUCTION

Production in m$^3$


Graph showing quarry production from 1966 to 2011.
The evolution of Greek marble exports

Quantity of unprocessed and processed exported marble in tones
EXPORTS – IMPORTS VALUE

Source: (ELSTAT) - National Statistical Service of Greece

Import and Export of Ornamental Stones in million €

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Residues

- In the quarries, only a small percentage of the excavated rock, less than 15%, is exploited for marble products, while the rest 85% remains at the quarry area as residues.
- Based on the official Greek marble blocks’ production data, it is estimated that more than 200 million tonnes of waste material, have been stockpiled in national level during the period 1980-2011.

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Stages and efficiency of the existing stone production chain

Quarrying
1000tn Marble

Waste 780 tn

220 tn blocks
15 blocks (1.5x1.4x2.8 m)

Block Sawing
(strips/slabs) 145 tn, 10 blocks

75 tn unsuitable
5 fractured blocks

Waste 26 tn
15 tn, 1 block
unexpectedly broken
due to fractures

Building Application
1 building (70 tn, 1900 m² floor)

3% destroyed due to poor maintenance

Calibration, Polishing, Sizing
~100 tn, ~2700 m² (~15 mm thickness)

15 tn Broken Slabs/Tiles
5 tn slabs Rejected Slabs/tiles
Waste 10 tn
The Greek Marble Quarrying Residues

- In the frame of I.G.M.E. research projects, the potential of the Greek quarrying activity residues was evaluated for two major applications:
  - Production of fillers, and
  - Production of aggregates for common concretes.
Fillers’ Market Aspects

• Globally, CaCO₃ (Ground Calcium Carbonate – GCC, or precipitated CaCO₃ - PCC) has become a dominant mineral filler in the production of wood free paper, paints and plastics.
• Marble is mainly used to feed the GCC production plants in Europe*
• *Roskill 2005
The Importance of Aggregates for the Everyday Life

• Aggregates are essential to economic growth!
• It has been shown that the consumption of aggregates is growing as an economy grows!
• Construction industry is the major consumer of the 65% of the aggregates produced annually in Europe!
• For instance,
  ➢ 18,000 tonnes / km for a national scale road
  ➢ 250 tonnes for a Greek house of 185m² surface
  ➢ 114,000 tonnes / km for the METRO
  ➢ Around 3,000 tonnes of aggregates are required for every new typical school
  ➢ up to 300,000 tonnes for a new sports stadium
Origin of Aggregates in Europe, % per source

- **Crushed Rock from Quarries**: 49%
- **Sand & Gravel from Pits**: 41%
- **Recycled from Construction & Demolition Materials**: 6%
- **Marine Aggregates (Sea or Lake Dredged)**: 2%
- **Manufactured Aggregates (Crushed Slag, Fly-Ash)**: 2%
Overview of the Greek Aggregates sector

Europe
• The industry of primary aggregates is very important for Europe. The overall production (2013) was 2,5 billion tonnes.
• This production was accomplished by 25,000 quarries and 15,000 companies which employ about 250,000 employees.
• The average annual consumption in Europe is 5,2 tonnes per capita.

Greece
• 94% of the aggregates produced derive from primary resources, comprising mainly crushed rock aggregates due to the existence of good quality limestone deposits.
• The average annual consumption is 2,2 tonnes per capita, while in other Southeast European countries it is 4,2 tonnes per capita.
• The annual production is estimated at 25 million tonnes, at least 70% lower than the production of 2008 (98 million tonnes).
Location of aggregates quarries in Greece (2011)

Source: Ministry of Environment, Energy and Climate Change, Department of Mineral Resources Policies

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Production of Aggregates in Greece during the Period 2009-2012

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Aggregates’ Production \((10^6 \, \text{t})\) in Greece per Region (2007-2008)

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Aggregates’ production ($10^6$ t) in Greece per Region: Comparison between the figures of 2007 and 2011

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The drastic decrease in annual production, is a direct impact of the financial crisis which is evident in Greece the last 5 years.

The recession concerns also other EU countries. The four main “bail-out” countries were all badly hit by the economic crisis.
Overview of the Greek aggregates sector - 2

The production activity involves infrastructure works on-site and off-site (e.g. access / transport roads), development of quarry faces, extraction of rock, treatment of the extracted material with crushing and sieving, storage and finally transportation of the final products to market.

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Overview of the Greek aggregates sector - 3

- Quarries are located in areas with suitable geological resources in pre-defined Quarrying Areas (L.1428/84 as amended with L.2115/93), with certain exceptions.
- Only 50-55% of the current total aggregate production in Greece derives from quarries established in Quarrying Areas. The rest is either due to the legislative exceptions, or/and illegal quarrying activities.
- The sector is characterized by the following main features:
  1. Small enterprises with a large geographic dispersion;
  2. Intense competition mainly on sales price level;
  3. The market is local since road transport becomes uneconomic at >40-50 Km;
  4. There are problems affecting its operation related with difficulties in granting permits as well as issues of illegal quarrying and illegal trading of quarry products without a CE marking.

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Overview of the Greek aggregates sector - 4

Demand and consumption

- Following the decrease in the number of issued construction licenses (-77% during the period 2005-2012) and the construction index (-69%), the aggregates’ demand decreased into 25 million tones in 2013 (-72%).
- There is a continuous decrease of private, public consumption and investments since 2008.
- The scheduled restart of the public works is estimated that will consume small quantities from the quarries that operate within Quarrying Areas, since they are mainly served by close borrow-pits (one of the exceptions).
- However: The decrease in the construction activity index (-5,2%) referring to the first semester of 2013 was considerably smaller compared to that of 2012 for the relevant period (-26,9%)

(Source: Foundation for Economic & Industrial Research, Issue No 73, October 2013)

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Aggregates’ planning issues

1. Besides the problems affecting the aggregates sector in Greece important issues that have been raised at EU level concern the implementation of sustainable planning principles for aggregates production.

2. Such principles involve Sustainable Aggregates Resource Management and the Sustainable Supply Mix practices which are closely related to the Resource Efficiency* concept.

3. Most of the SEE countries are well behind in implementing sustainable planning principles for aggregates production. For this reason two special projects were funded by the EU Commission. IGME has strong participation in both projects.

*“A practice in which the primary consideration of material use begins with the concept of ‘reduce-reuse-recycle-repair’ stated in descending order of priority’
EU Commission approved two projects, co-funded by ERDF funds: SARMa (Sustainable Aggregates Resource Management) and SNAP-SEE (Sustainable Aggregates Planning in South East Europe). In both projects IGME is a key partner.
Aims of SNAP-SEE project and deliverables

The SNAP-SEE:

• Focuses on developing and disseminating tools for aggregates management planning in South East Europe (SEE) that are based on the principles of the Sustainable Aggregates Resource Management (SARM) & the Sustainable Supply Mix (SSM).

• Will develop a Toolbox for Aggregates Planning to support national/regional, primary and secondary aggregates planning in SEE countries.

www.snapseeoproject.eu

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International Conference on Sustainable Aggregates Planning in South East Europe - contributions to the EU minerals policy framework

1st announcement
22-24 October 2014
Bled, Slovenia

The purpose of the conference is to share the results of SNAP-SEE and place those results in the context of the European Innovation Partnership on Raw Materials’ call for an improved minerals policy framework.

www.snapsee.eu
"Optimizing the Minerals Policy Framework at EU and National Levels by 2020"

Objectives of the commitment:

The objective of this commitment is to contribute to ensuring a stable and competitive supply of raw materials from EU sources to promote good governance and facilitate public acceptance.

Sub-objectives are to enhance EU efforts to harmonize national mineral policies and plans, as well as permitting and reporting on primary and secondary minerals, based on best practice, so as to ease the access to primary and secondary resources, improve transnational permitting procedures, contribute to the definition of transnational standards for exchange of data and knowledge, and offer a more transparent and participative exchange of ideas with stakeholders.

Coordinator: University of Leoben.

44 participating partners.

3 partners from Greece (IGME, University of Crete, GEK TERNA).
Call for commitment
EUMINET
"European Minerals Information Network"

Objectives of the commitment:

The objective: This commitment is a contribution by National Geological Surveys, represented by EuroGeoSurveys, to the EU Raw Materials Knowledge Base. Building on the ongoing EGDI-Scope and Minerals4EU projects, its general objectives are, by 2020, to stimulate investment in the exploration and exploitation of EU mineral resources assets, as well as to provide data, knowledge and tools for their sustainable management.

Sub-objectives: Its specific objectives are:
• Development of interoperable/harmonised data models and digital information services;
• Development of a multilingual EU data infrastructure, compliant with the INSPIRE Directive, providing access to national/regional data assets;
• Providing annual publications of an EU minerals yearbook and minerals foresight;
• Set up a coordinating body to develop and manage the needed common data models and interoperability arrangements.

Coordinator: EuroGeoSurveys

24 participating partners (Non EU Member States 2).
1 partner from Greece (IGME).
Thank you very much for your attention!