HELLENIC REPUBLIC
National and Kapodistrian University of Athens
EST. 1837

3rd Student Workshop on Industrial Minerals & Energy Resources

Milos Island | 29th September – 4th October

Field Trip Report

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Sponsors

We would like to thank the main sponsors of the 3rd Student Workshop, NKUA, Αιγέας, Hellafarm, that without their funding the implementation for this meeting would not be possible.

Special thanks are also expressed to the companies:

Their economic and/or technical contribution was also substantial.

Introduction

Since 2017, the staff of the Geology and Geo-environment Department of the NKUA, Section of Economic Geology and Geochemistry, implements a project related with the further training of students who are interested in industrial minerals and rocks. Specially to improve their efficiency to present their research work to the audience in the form of presentation. Another reason for this action is to get a closer contact of the University people with technical and scientific staff of mining companies.

The title of the project is: 3rd Students Workshop on Industrial Minerals and Energy Resources, the 1st and 2nd being implemented in 2017 and 2018. It was requested by students for their further information on industrial minerals and energy recourses. The best area to implement such a schedule is the Milos-Kimolos island complex and it is proved by the results we have already obtained from the past two years.

The duration of the project was six days and included visiting of mining areas, outcrops with exposures of significant industrial minerals and rocks of scientific interest, areas with volcanic emanations, and finally sites of geoarchaeological interest.

The full details of the fieldtrip are given in the following paragraphs.

Day 1: September 29th

At the first day of our workshop, after an introductory speech from Mr. Manouso Kantsos about Milos Conference Center – George Eliopoulos and some historical facts, we had two presentation and discussion sessions at Milos Conference Center. The participants presented their own projects on the topic of Industrial Minerals and Energy Resources. The chairmen of each session consisted of the participant students and the scientific committee. The sessions were followed by a light dinner offered by Imerys S.A.

Fig. 1 (left), 2 (right): Presentation and discussion sessions 1&2

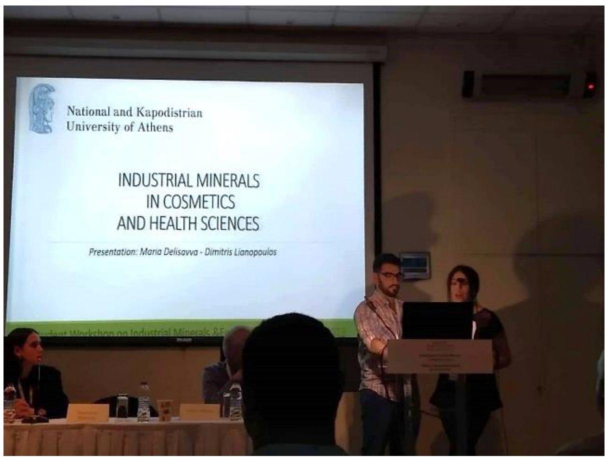

Fig. 3 (left), 4 (right): Presentation and discussion sessions 1&2

Fig. 5 (left), 6 (right): Presentation and discussion sessions 1&2

Day 2: September 30th

At the morning of our second day we visited Prassa Quarry of Kimolos Island, where we studied about white kimolian bentonite (consisting mainly of Ca-montmorillonite), white pozzolan, and zeolite tuffs. By agreement of Maria Roussou, Mr George Tselepis, a geologist working at Bentomine S.A., escorted us giving us geological and mineralogical/petrological information about the ore and the quarry district. We also discussed about logistics, mining engineering and minerals processing.

Fig. 7: The processing unit of bentonite at Prassa quarry

Fig. 8: Prassa quarry (Bentomine S.A.). A lake mainly of rain water inside the quarry.

Fig. 9: Our group at Prassa quarry. Two qualities of bentonite can be seen, a white one (which is the better quality) and a greyish one.

We were guided to the platforms where bentonite (with approximately 25% moisture) is Na-activated (using soda) and then let it to be air-dried. Mr Tselepis showed us the processing unit of drying (naturally at platforms or technically at large furnaces where higher temperatures occur) and of crushing bentonite. The technically dried bentonite is usually destined for other than the conventional uses, e.g. for research & development projects. Bentonite is dried so that its moisture is decreased at 10-15%, in order to be shipped and later processed. Due to its high-water absorption capacity, swelling and sealing capacity after it is saturated in water, bentonite is used as a sealant mainly at oil and water well drilling, at pet litter. It is also used as a binding material at foundry, at iron and steel making, at construction projects, at paper industry, at porcelain as an additive to kaolin and many other uses such as cosmetics, due to its high colloidal properties, plasticity, viscosity and thixotropy.

Pozzolan is used at cement industry. Here it is lying under a cap of andesitic tuff which gradually transforms into a sandstone tuff the closer to the pozzolan it gets.

Zeolite tuffs are consisting mainly of mordenite, which indicates high temperature formation (unlike clinoptilolite which is formed at lower temperatures), higher than the zeolite tuffs of Milos island.

As for the genesis of the ores, at first thermal alteration resulted to the conversion of volcanic glass to mordenite, therefore the formation of zeolite tuffs, and subsequent water reaction and hydrothermal alteration that resulted to the formation of bentonite beds which partially contain mordenite and a few clinoptilolite and opal-CT.

Fig. 10: The white bentonite of Kimolos. The greenish part is rich in zeolite (mordenite)

Fig. 11 (left), 12 (right): Our group at the quarry.

Fig. 13: Bentonite Na-activation platforms.

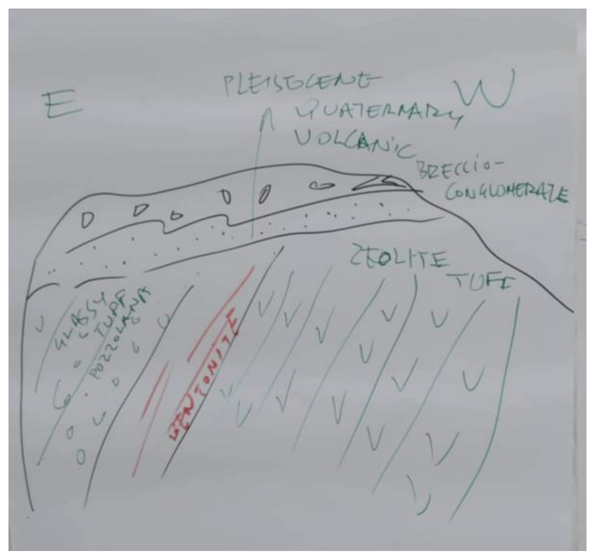

Fig 14: Schematic cross section of Prassa quarry.

At the evening of the day we had our third and fourth presentation and discussion sessions, which were followed by a light dinner offered by Imerys S.A.

Fig. 15 (left), 16 (right): Presentation and discussion sessions 3&4


Fig. 17 (left), 18 (right): Presentation and discussion sessions 3&4

Day 3: October 1st

At the third day we visited the White Silica Quarry (LAVA S.A., integrated in HERACLES Group of Companies) at Kastriani, with the guidance of Mr Michael Vamvounis, a mechanic working for LAVA S.A. Here we also studied about kaolinite, Sulphur and alunite. The white silica is of diagenetic origin, a result of hydrothermal alteration from solutions/gases rich in sulfur. It consists mainly of SiO_2 as quartz at the greatest percentage and as cristobalite at a smaller percentage and alunite. The quarry is an open pit that does not involve explosives during the extraction of the material. The raw material production is of 80.000 tn/year average which is supplied to many companies, inland or abroad, including TITAN S.A.

The stratigraphy of the area with a lahar cap lying unconformable above the silica tuff, and an intermediate oxidized zone (iron-rich), as well as the sulfur that is found in faults, in fractures or in the pores of the silica tuff, reveal an intense volcanic, pyroclastic and tectonic activity. The genesis model starts with the sedimentary deposition of the tuff, a process that is depicted in the layering and the fine grain size of the unaltered tuff (*fig. 13*). After the tectonic activity, hydrogen sulfate-rich solutions flow into the basin, they are oxidized and therefore they alter the tuff by destroying the glass, while quartz (and cristobalite) remains.

Kaolinite is also found within the tuff, at a percentage of 10%. Due to the way it is formed, involving acid solutions rich in iron, the kaolinite is of bad quality and not profitable for mining.

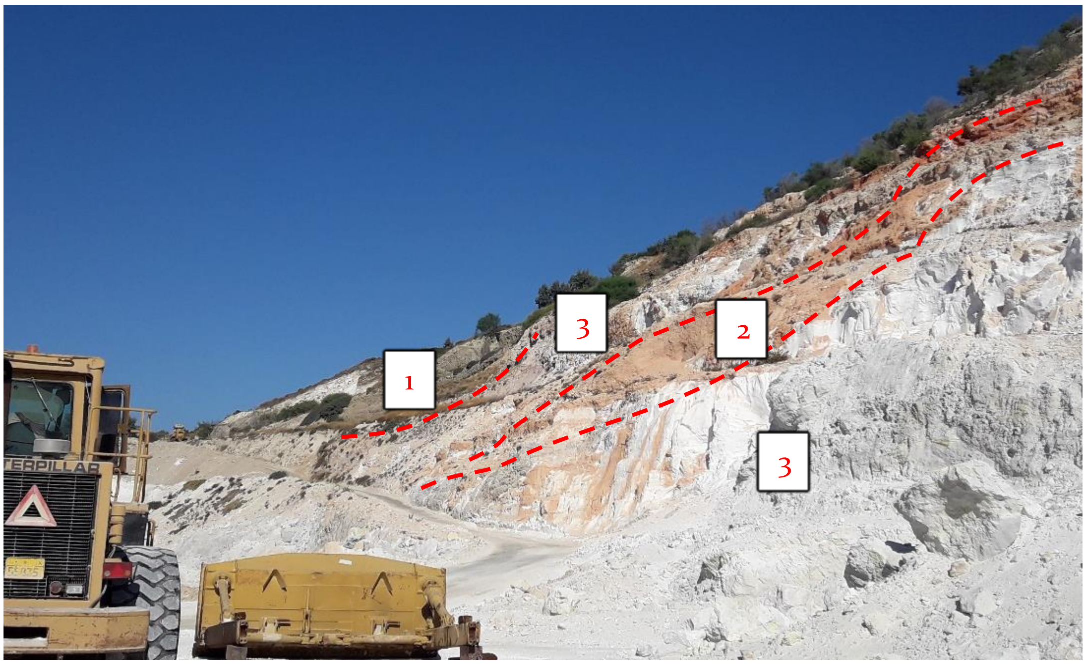

Fig. 19: (1.) Lahar (grey), (2.) iron oxidized zones (orange), (3.) white: silica sand deposit.

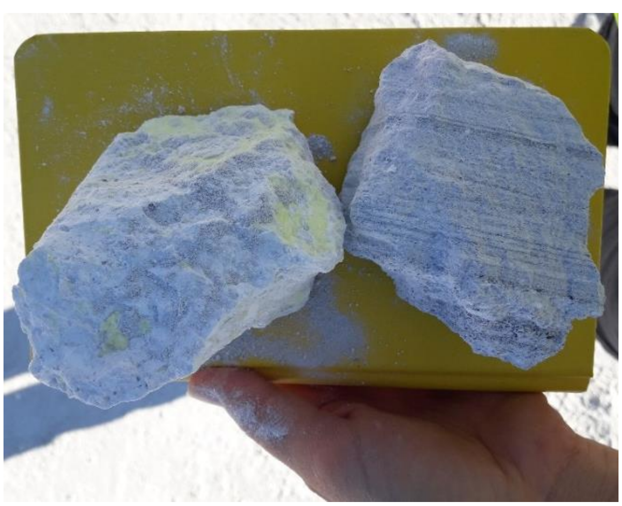

Fig. 20: Sulfur fissure fillings in white silica sand (top), layered silica tuff (bottom)

Fig. 21: Sandy tuff (right)

Fig. 22: Processing unit of white silica

Fig. 23: White silica with sulfur and pyrite

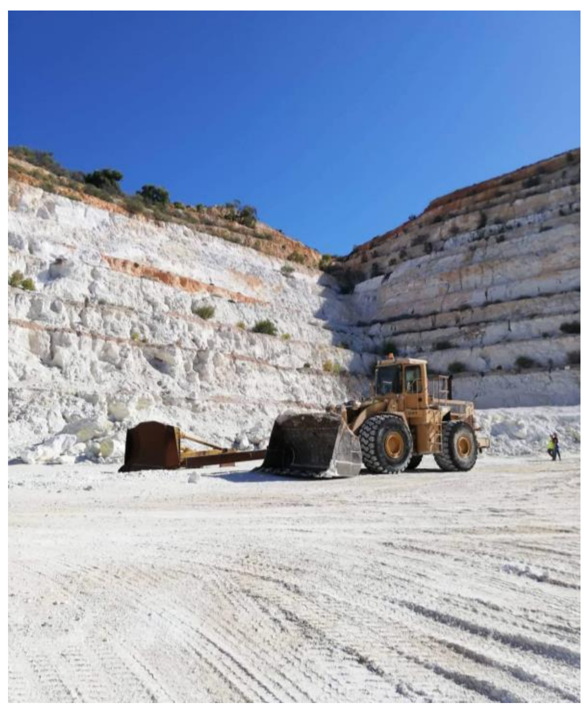

Fig. 24: Bulldozersat at the quarry

Fig. 25: Our group with Mr. Vamvounis, mining engineer.

We had a stop at Zefyria, where a mature geothermal field exists with a capacity of 120 – 250 mW. We observed a borehole 200 meters deep drilled to obtain geothermal energy. The project failed because no one had taken into account the high salinity of the water as no filters for the salt where used. As a result, the 20 cm diameter pipes clogged from the accumulating salts in only two weeks.

After Zefyria geothermal fields, we visited Xylokeratia Quarry (TITAN SA) where we studied about cement pozzolanas and diatomites.

Fig. 26: Our group at Xylokeratia mine. The bigger part of the mine (right) has been restored.

Fig. 27: Our group with Mr. Vamvounis who guided us at Xylokeratia mine.

Four different materials are found in the quarry (as seen below, at *fig. 23*), all used at cement industry as pozzolanic material, in order to reduce the firing temperature and therefore reduce the production cost:

1. Uppermost, white beds of diatomites and other silica-rich (SiO_2>70%) materials along with tuff.
2. Tuffaceous marlstone.
3. Lapilli tuff with volcanic blocks and/or bombs.
4. Pumice tuff (consisting mainly of glass).

After Xylokeratia, we collected samples from the Zeolite tuffs of Panagia Kipos, which are lying under an andesite cap. The tuffs that are closer to the andesitic lavas form thick white layers and are fine-grained. They consist mainly of cryptocrystalline mordenite (at an average percentage of 80%) and glass ± clay minerals. Only few crystals of mordenite can be detected at the microscope, in cavities and pores. They are a result of low thermal zeolitic metamorphism, when glass was destroyed and mordenite ± clinoptilolite was formed.

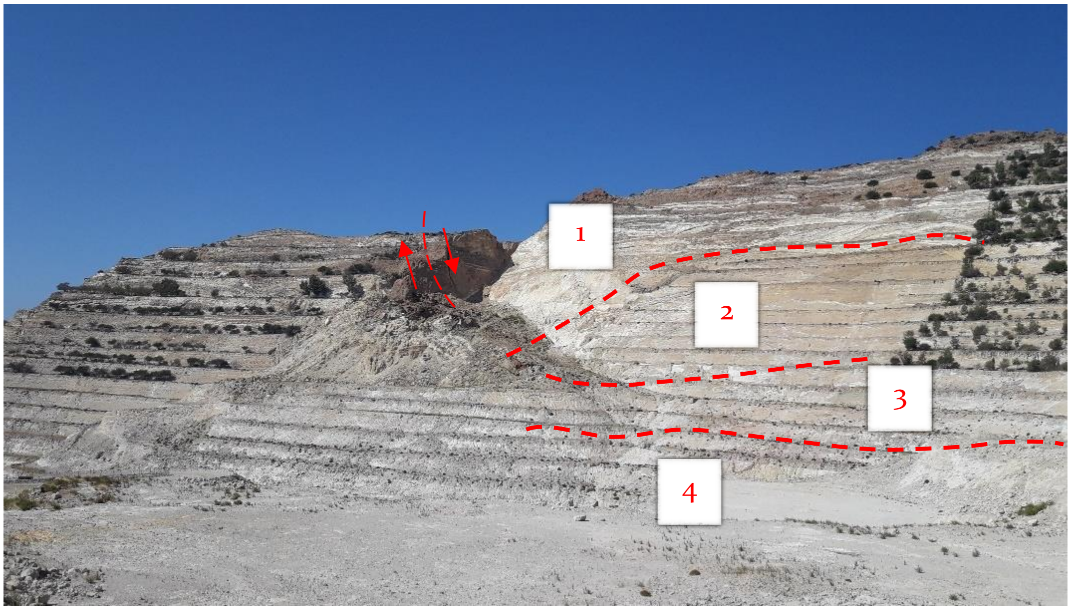

Fig. 28: Xylokeratia quarry. The different pozzolanic materials are numbered as they are explained in the above paragraph. A landslide can be seen at the center of the quarry, a result of ground instability due to clay minerals occurrence that contributed to the creation of a normal fault.

The last stop was the red beds at the road from Kipos to Provatas, a sedimentary formation enriched in iron, manganese and other trace elements. Two stages of enrichment took place, one syn-sedimentary at Miocene, where the main source of iron is believed to be the crystalline basement – as the enrichment in chromium and vanadium imply. The basement consists of greenschist metamorphic phase rocks (phyllites, meta-basalts and quartzites) with some occurrences of glaucophane schists. A later post-sedimentary stage of enrichment is related to hydrothermal activity, as the increased content in manganese, barium, arsenic, zinc, molybdenum, lead, copper and antimony indicate. It occurs in veins cutting the rocks with direction NW to SE, therefore the source is believed to be Profitis Ilias mountain and/or cape Vani. A student of our group (Asimakopoulou Stamatina) is doing a research on the origin and genesis model of this formation for her diploma.

At the evening we had a dinner-catering offered by the Dean Assembly of the Earth Sciences, NKUA at Milos Conference Center – George Eliopoulos.

Day 4: October 2nd

The first stop we made was Trachilas Perlite quarry where Mr. Panagiotis Tsakalakis of IMERYS S.A. gave us information about the mineralogy/petrology of the mine, the genesis of the perlite ore, the processing and the uses of perlite as well as information about mining engineering and logistics.

Fig. 29: Our group with Mr. Tsakalakis, mining engineer, discussing about the geology of the mine.

Perlite consists mainly of amorphous glass with water trapped inside its mass (crystalline water) and of cryptocrystalline SiO_2 at a percentage of 4-5% average. It may also contain trace elements, such as barium and/or rare earth elements. It is closely related to felsic volcanic centers as it is formed by rapidly cooled lava. Two such volcanic centers in Milos created perlite ores, Trachilas and Fyriplaka volcanic center. More specifically, here at Trachilas, two qualities of perlite occur: the good-quality perlite is found at low altitude (the bottom layers of the ore) and is a result of the first eruption (the first lava flow). The second lava flow was semi-perlitized lava with impurities, characterized as poor-quality perlitic lava.

Due to the water trapping within its mass gives perlite the ability to expand at high temperatures (~ 800-950^oC), perlite is used for insulation, from cryogenic applications to insulating concrete or refractory bricks, while fine-grained perlite is used at building materials and construction - such as ceiling tiles-, at horticulture and at filtration.

In order for perlite expansion to be characterized as “good”, LOI (loss in ignition) must be at an average of ~ 2.9%, where optimum expansion is achieved at the appropriate conditions, with an upper limit of 3.1%. Different percentages of LOI result to different percentages of fine versus coarse grains of expanded perlite (at the same heating conditions). If LOI is higher than the upper limit the percentage of shatters at expanded perlite increases significantly. The less the crystalline phases there are, the better the expansion of the perlite is. Also, the ratio K_2O/Na_2O must be under 1.5.

Fig. 30: Our group collecting perlite samples at Trachilas quarry.

We discussed about mining engineering information; each terrace of the mine is 5m high and 4-3m wide with 70° slope dip. The average slope dip of the mine is 32.8°. The stripping ratio is 0.25 which is translated to 1 ton of waste for each 4 tons of perlite extracted. As for the restoration of the mine, no additive material was needed to make the soil fertile, as the non-profitable perlite was rich in clay minerals.

Fig. 31 (left) & 32 (right): Our group at Trachilas quarry

Fig. 33: At Trachilas quarry.

Next, we visited Bentonite Processing Plant (IMERYS S.A.) at Voudia and after a safety measures introduction from Mr. Anastasios Fragkos, we watched the crushing and drying of bentonite, its Na-activation with soda (sodium hydrogen carbonate) and the warehouses where bentonite is stored.

After a discussion with Mr. Vasilis Demenagas, an Imerys mechanic who escorted us all the time, we understood more about the processing of bentonite, its multiple uses, about shipping and logistics.

When a layer of bentonite is blended with soda, it is let to dry at large platforms for about 2 weeks, while the ion exchange between Ca – Na (activation reaction) takes process. Then a second layer of bentonite blended with soda is added etc. The platforms consist of 13 layers maximum. The percentage of the soda that is added differs in each material, as each bentonite quality is characterized of different ion capacity. It is noted that this percentage varies from 1.5% to 4.5%, 3-3.5% average.

The moisture of bentonite must be at 20-23% in order to be activated, which is achieved by natural drying. A lower moisture (13-16%) can also be obtained by technical drying of the bentonite at furnaces (dryers), where the material remains for few seconds.

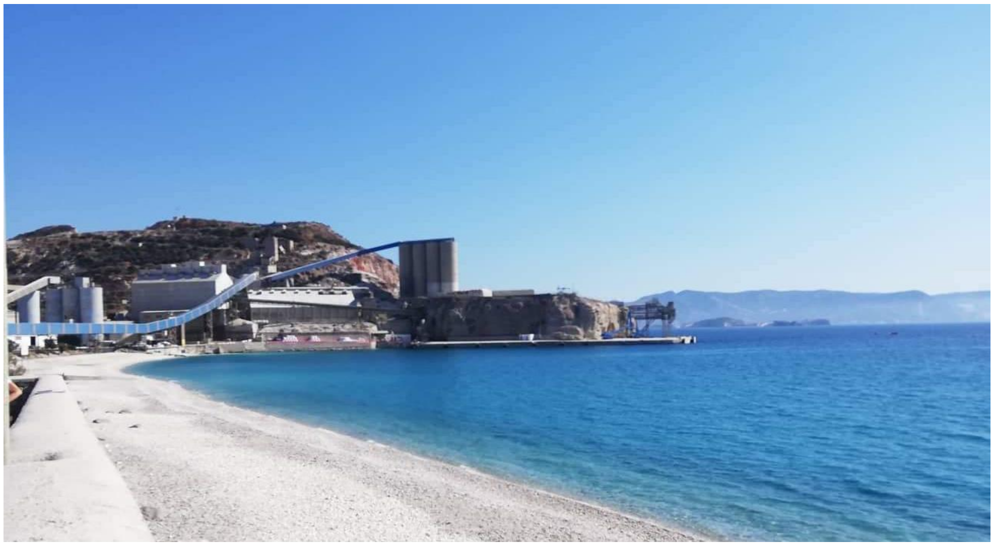

Fig. 34: Bentonite processing plant, IMERYS S.A., Voudia.

The production of the mining year reaches up to 2.000 tons per day and all the extracted material needs to be activated to cover the winter period, when mining stops. There are over 40 different types of bentonite produced, depending on the customer's demands.

Fig. 35: Bentonite processing plant, IMERYS S.A., Voudia. The platforms of bentonite activation can be seen.

Continuing our fieldtrip, after the processing plant we paid a visit at Bentonite quarry of Aggeria (IMERYS SA), one of the largest bentonite mines worldwide, with reserves over 5 million tons, length 2.7 km and area about 5.5 million m^2. We discussed about the proposed model of the genesis of the ore and we learned a lot mineralogical/petrological information, as well as mining engineering information with Michael Papasotiriou (a mining engineer of IMERYS S.A.) and Stefanos Zaimis (a geologist working for IMERYS S.A.).

Three qualities of bentonite are extracted: a grey (dark colored) that is used mainly for iron-ore pelletizing, a greenish and a yellowish one. The mining is not selective; the material is blended for optimization. The waste materials are (a.) overlying sediments, (b.) phreatomagmatic intrusions (intermediate layers) and (c.) bentonite with impurities (mainly marcasite), that is not profitable.

There are three stripping ratios, the annual, the five-year stripping ratio and the life of mine stripping ratio which is > 1.2.

The proposed genesis model of the ore is an open hydrological system (lake) where volcanic material (tuff) was hydrothermally altered. An andesitic lava cap, created thermal flow towards the underlying tuffaceous material and created a steam heated kaolinite – alunite ± opal zone above the water (lake) level and an advanced argillic alteration zone (rich in smectites) below the water level. The alteration fluids are possible to have flown through fractures and faults, as all the formations are tectonized.

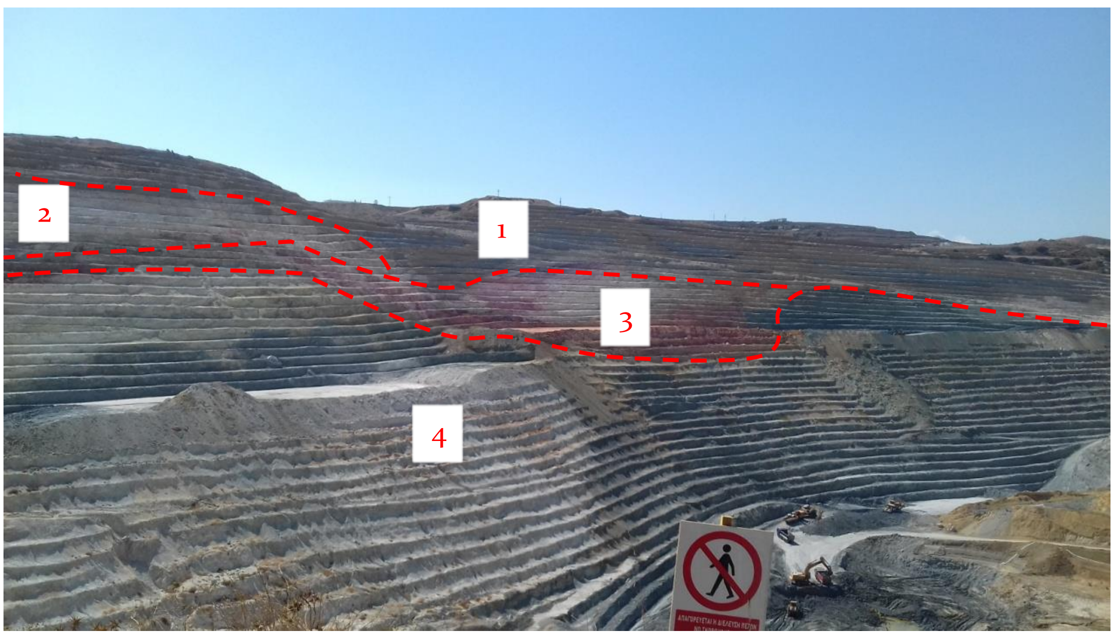

Fig. 36: Aggeria quarry: (1.) Pumice tuff, (2.) Kaolinized tuff (pozzolanic material), (3.) sedimentary channel fill, (4.) Bentonite.

Fig. 37: Our group discussing about the geology of the mine.

Last for the day was the Pumice Diatomite of Phylakopi (at Papafragkas) and the diatomites of Sarakiniko. The source of the pumices is believed to be a seafloor volcano between Milos and Aegina, as geochemical data has revealed. Also, depending on the eruption stage pumice tuff is connected to it has different geochemical characteristics (REE and trace elements).

Fig. 38: Sarakiniko junction: The interbedded deposits of diatomite, tuff and marly tuffite with terebratula, corals, chlamys, pecten, spicules, etc.

At the evening we had a dinner-catering offered by the Dean Assembly of the Earth Sciences, NKUA at Milos Conference Center – George Eliopoulos.

Day 5: October 3rd

On our fifth day we visited the hydrothermal alterations and volcanic emanations of Adamas, beach Kanava (Aliki thermal springs) and Kalamos. At Adamas we observed a drill hole filled with cement is strongly altered by CO_2, H_2S and other volcanic emissions. Here, we sampled the volcanic gases which reflect the chemistry and of the magma, as they originate from the magma chamber. The thermal flow here is approximately 97°C at the depth of just 60 cm. The high percentage of CO2 is originated mainly from carbonate alteration. Carbon monoxide occurs at a smaller percentage. The sampling method involves capturing of the gas and mixing with a soda solution. As a result, acidic gas reacts with the alkaline soda solution, therefore the gas is easier to be collected.

Fig. 39: Cemented and strongly eroded drill – hole.

Fig. 40: Volcanic Gas sampling and sampling of alteration minerals at Adamas.

Fig. 41: Volcanic gas sampling of Aliki thermal spring.

Fig. 42: Kalamos fumaroles at Fyriplaka volcano crater. Rhyolite is altered to kaolinite and opal.

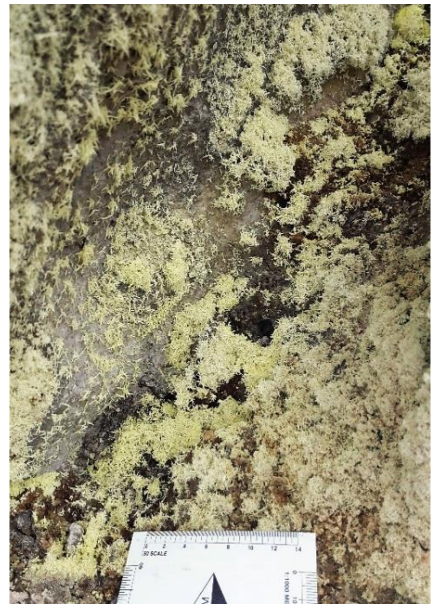

Fig. 43: Sulfur and organic minerals (green) were abundant.

Fig. 44: Kalamos fumaroles at Fyriplaka volcano crater. Rhyolite is altered to kaolinite and opal.

Last but not least, we visited the hot soils and hydrothermal alterations at Paleochori beach, where there is also an occurrence of the crystalline basement.

After the fieldtrip we had a lunch on the coastal area of Paleochori offered by Milos Municipality (*Fig. 45&46*).

Fig. 45 (left), 46 (right): Lunch at Paleochori beach offered by Milos Municipality.

Day 6: October 4th

At our final day we visited an obsidian occurrence at Adamas where we discussed about its origin, genesis model, mineralogical/petrological information and trading at ancient times to the Aegean Region.

Secondly, we paid a visit at Milos Mining Museum, where amongst many exhibits we studied about the famous obsidian collection.

Fig. 47: At Milos Mining Museum.

Our final stop was the Ancient theatre and the Christian catacombs of Milos Island. Here, we also visited the ancient walls of Klima.

There, building blocks and unfinished boulders, composed of hard andesitic lava and massive tuffs, as well as stairs and sculptures' columns made by Naxian marble were studied. As the recent excavation/restoration works revealed, the Theater has been constructed by excavation of soft pumiceous tuff, which is the same in origin with the one that occurs in the nearby area of Catacombs.

Catacombs themselves, as well as other digging traces and small caves have been developed in a pozzolanic tuff with pumiceous nature, similar to the one originated from Pozzuoli, Napoli, a tuff which used for the production of the famous Roman cement.

Fig. 48: Hard andesite and massive tuff used as building stones in the ancient walls of Klima, Milos.

Fig. 49: The ancient theater of Milos where Naxian marble was used for the benches and decorative columns/bases of sculptures

Objective – Upcoming project

Our next objective is to create a project based on combining mineralogical/petrological and geological information we gained at the field with a mineralogical and chemical analysis (from X-Ray Diffractometer and Scanning Electron Microscopy - Energy Dispersive Spectroscopy) of the samples we collected from the field trip. This will help us have a better understanding on the geology and mineralogy/petrology of Milos Island.

References

All the pictures are owned from the participants. No bibliography was used, only notes from the information we collected during the fieldtrip.

Acknowledgments

We want to give special thanks to all the people who guided us at the mines and gave us vulnerable information about geology, mineralogy/petrology, mineral processing, mining engineering, logistics and more.

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