NATIONAL AND KAPODISTRIAN UNIVERSITY OF ATHENS
FACULTY OF GEOLOGY AND GEOENVIRONMENT

SEG/SEGF Student Chapter Stewart R. Wallace Funding

National and Kapodistrian University of Athens Faculty of Geology and Geoenvironment

Field Trip Report

"*Shallow submarine hydrothermal mineral deposits and mineralized geobiology systems in emergent volcanoes— the example of the Milos natural palaeogeothermal laboratory*"

October 9-October 13, 2023

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Sponsors:

Field Participants

This field trip was attended by 16 participants (Table. 1), including the team leaders Professor Stephanos Kilias, 1 PhD student, 2 MSc students and 12 BSc students

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Table 1: Field trip participants of National and Kapodistrian University of Athens, SEG Student Chapter.

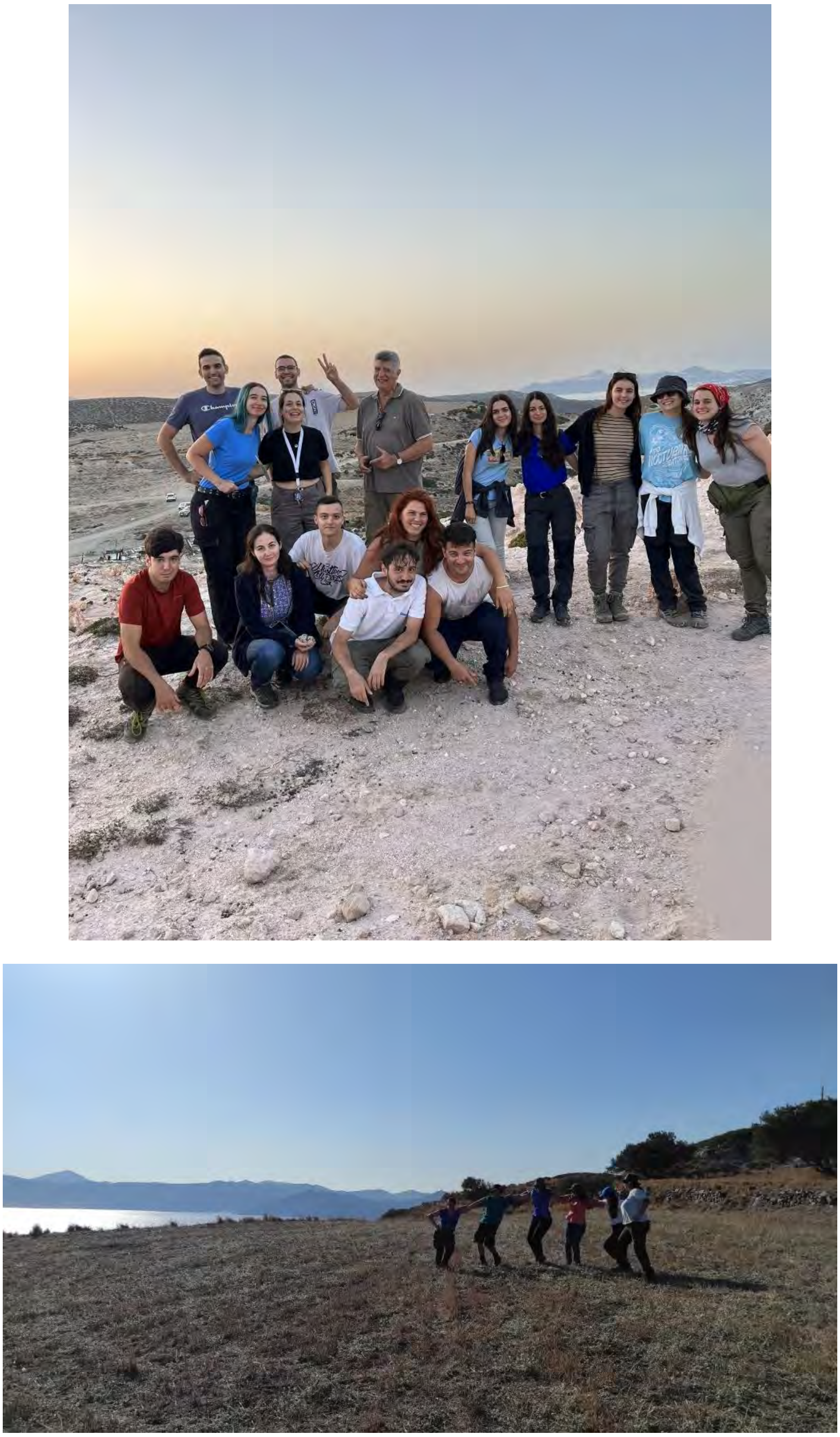

Figure 1: The team of the NKUA SEG Student Chapter that participated in the Milos field trip.

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Acknowledgments

The National and Kapodistrian University of Athens, SEG Student Chapter organized the field trip to Milos Island, October 9th - 13th 2023, entitled "***Shallow submarine hydrothermal mineral deposits and mineralized geobiology systems in emergent volcanoes— the example of the Milos natural palaeogeothermal laboratory***", as a part of the Student Chapter's activities, and was funded by the Stewart R. Wallace Funding scheme. As field participants, over the course of the field trip we had the chance to observe some of the most unique geological formations in the world and gain a great amount of knowledge over a wide variety of geological fields of volcanology, hydrothermal alterations mapping, structural geology and ore deposits. All the participants are very grateful for the financial support provided by the Society of Economic Geologists.

We also would like to thank ΔΕΗ Ανανεώσιμες company for funding the biggest part of this field trip and also, Mr. Zalakoudis Demetrios for his financial support.

Introduction

Milos island is a recently emergent (<2 Ma) volcano in the active Pliocene–modern Hellenic Volcanic Arc (Fig. 1), Greece, where arc-volcanism and seafloor hydrothermal activity are occurring in thinned continental crust [1]. Milos hosts one of the largest active mineralized shallow-submarine to coastal geothermal systems described to date, that has been operating for ~2 My [2, 3, 4]. Milos forms a distinctive and renowned on-land natural laboratory for studying volcanic-hydrothermal and geothermal processes in a submarine setting and is identified as a new metallogenic environment—namely shallow submarine epithermal-style mineralization associated with emergent volcanoes [5, 6, 7]. In this rapidly evolving environment, heated seawater mixes with magmatic and meteoric waters, to produce young and extremely well preserved palaeogeothermal systems that give rise to hybrid VMS and epithermal mineralization (Au, Ag, Cu±Te) [5, 6, 7, 8], and industrial mineral deposits (i.e. bentonite, perlite, pozzolanes) [9, 10, 11], as the driving volcanism changes from submarine to subaerial and the system becomes open to meteoric water. Furthermore, Milos provides a unique window into the interplay between volcanic-hydrothermal, metallogenic and biological processes; it hosts the first identified ~2.0 Ma unmetamorphosed, fossiliferous sedimentary iron formation (IF) comparable to Precambrian banded iron formations (BIFs) [12, 13, 14]; IF is spatially associated with sedimentary manganese oxide deposits of economic potential [15] where biological processes may have played a major role in concentrating Mn [16, 17, 18]. A number of large open pit bentonite and perlite mines are operational in Milos by S&B Industrial Minerals S.A./Imerys; the bentonite open pit is one of the biggest across the world (http://www.ee-quarry.eu/large-companies/s-b-industrial-minerals-s-a.html).

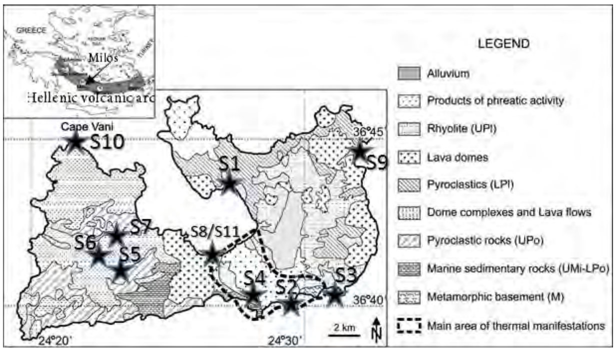

Figure 2: *Main geologic features of Milos Island that is located approximately 200 km S of Athens, and location of proposed field destinations. Inset shows Milos and volcanic centers along the Hellenic volcanic arc. UPI—Upper Pleistocene; LPl—Lower Pleistocene; UPo—Upper Pliocene; LPo—Lower Pliocene; UMi—Upper Miocene; M—Mesozoic (Milos map adapted from 19). Destination sites are marked with SX (X: number).*

First day

The first day of our trip we arrived at the port of Adamas, around 11:00 a.m. were we received our rental cars for our transportation on the Island of Milos and then we reached our accommodation destination, were we checked in. After a quick break in the hotel we began our geological excursion.

The very complex geological evolution through time, makes it one the best-case studies to observe the difference between continental and submarine volcanism. One of the main goals of this field trip is for students to understand that difference using only field observations.

Side of the road near Nychia ancient obsidian mines

The location of Nychia is very well known for its ancient obsidian mines, that were active even from the Paleolithic age. The outcrops around the Nychia location are mostly compromised by pyroclastic material, followed by sedimentary formation. The obsidian ore bodies are usually found inside pyroclastic flows interbedded with marine sediments. A brecciated pyroclastic horizon, containing obsidian fragments can be identified through out the entire location of Nychia, indicating a big eruption took place after the obsidian deposition. This horizon is beneath a bioturbaded sedimentary formation and beneath fine-grained sediments, showing that this eruption took place underwater.

Figure 3: Pyroclastic outcrop with obsidian. Sharp paleosurface - discontinuity shown by red line. Obsidian is found all over the synthetic material (A, B) showing that acidic lava flows pre-existed the eruption. The paleosurface shows two distinct episodes of pyroclastic rock formation where surfacing and pause of sedimentation follows a volcanic eruption. Sedimentation started again to form the upper layer with material possibly provided by a second explosion. The surface is also affected by differential weathering as the upper layer is coarser and more compacted than the underlying layer (A).

As an overview, the environment of the above formation featured underwater volcanism. Interaction of lava flows with seawater rapidly cooled the acidic lava forming obsidian. Volcanic eruption provided large quantities of pyroclastic material which was later sedimented by diagenesis forming tuff formation with lithic texture and fine-grained matrix. It was later brought to the surface by tectonic uplift.

Figure 4: Bioturbated layer: From a stratigraphic perspective, we noticed that this layer lies on top of the pyroclastic obsidian rich formation which indicates its deposition occurred after the explosion stage. It has formed in shallow seawater and possibly a tidal - flat environment as indicated by the cross bedding sedimentary structures. Its matrix is composed of fine material (silt) and all over the outcrop the formation features fossilized bio activity such as tubes created by organisms and later filled with sediment (B, C).

Moving towards the Adamas area we took another trail and we saw obsidian ore found in banded outcrops where obsidian alternates with white-yellowish bands of loose material with mostly marine sediments and minor kaolinite. The bands show that we are dealing with a formation created under seawater and kaolinite indicates the presence of advanced argillic alteration of the nearby volcanic rocks.

Figure 5: In situ obsidian bodies interlayered by fine-grained marine sediments

Bombarda location and hydrothermal alterations

Bombarda is located very close to the Nychia obsidian ore bodies and is a restricted area characterized by a sequence of hydrothermal alterations. The volcanic rocks of Bombarda appeared to be generally silicified, followed by an argillic alteration rich in kaolinite and native sulfur. Also, there can be observed a phreatomagmatic hydrothermal explosion due to the reaction of magma with groundwater resulting in the creation of the diatreme breccia at low pH levels and high temperature. The matrix of this diatreme is composed of argillic minerals and pyroclastic debris. While the clasts are compromised by, hydrothermally altered rocks including silicified rocks, argillic altered rocks, vuggy silica and lastly obsidian. This might be the first ever reported case of obsidian clast in an epithermal related diatreme.

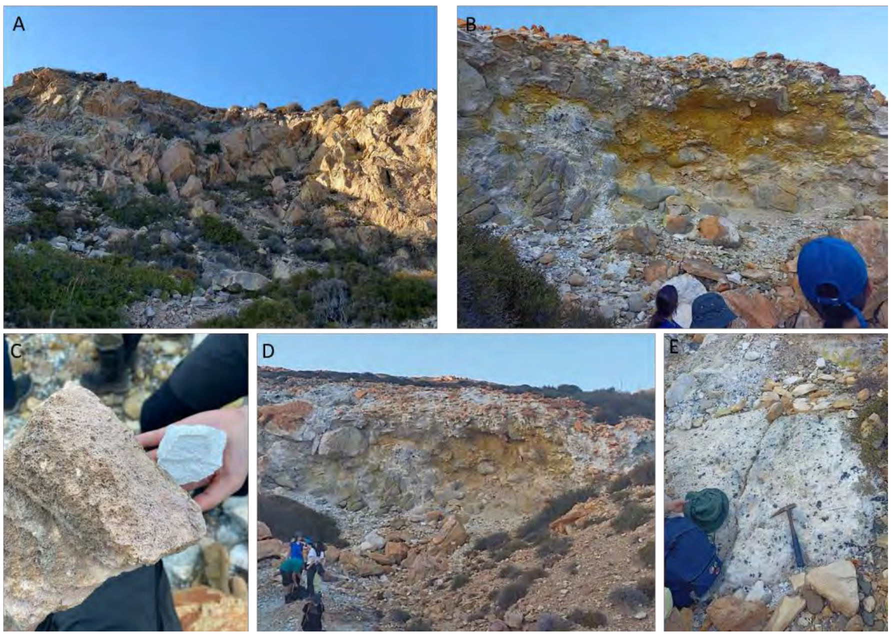

Figure 6: Phreatomagmatic breccia and hydrothermally altered rocks. (A) Silicified volcanic rocks exhibiting conchoidal fracture. (B, D) Phreatomagmatic breccia created by the reaction of hot magmatic material with cold water. (C) Photograph of vuggy silica with kaolinite. (E) Hydrothermal breccia with obsidian clasts.

Second Day

The second day of the field trip we visited the Kondaros-Profitis Ilias low sulfidation system. At the Kondaros area we found the once active silica sinter terrace while at the Profitis Ilias we visited a world class Au-Ag vein type deposit. At the end of the day we visited the active fumaroles of the Kalamos volcano [5].

Side of the road near Hivadolimni area

In the first location of the second day, we observed the Lava Flows (Flow-banding) in the area near Hivadolimni Beach. The road from Mavra Gremna to Hivadolimni towards Agia Marina, cuts through a lava dome of rhyolite with very distinguished porphyritic texture and flow banding [18]. According to Plimer this rhyolitic flow compromises from perlite, meaning that this dome formed underwater.

Figure 7: Rhyolitic lava dome. (A, B) Rhyolitic lava flow banding. (C) Mafic xenolith inside the acidic lava. (D, E) Porphyritic texture with large phenocrysts. (F) Magnified photograph of (E) showcasing a biotite mega-cryst.

Kondaros Silica Sinters

At Kondaros area lies a typical "petrified" silica sinter system. This land was once a very active hydrothermally area, with geysers, steaming grounds-rocks, hot springs and boiling mud pools. This had as a result the exhumation of acidic fluids, rich in silica, that formed the todays silica beds. Desiccation cracks, mud pools and "fossilized" bubbles can still be found at the Kondaros area. The existence of desiccation cracks indicates that this silica sinter system was once on land. Steam-heated advance argillic alteration can also be identified, as it is typical for this kind of environment [5, 18].

Figure 8: Silica sinters at Kondaros area. (A) Hydrothermal silica beds that formed from fluids related to hot springs. (B) Steam heated advanced argillic alteration with kaolinite. Notice the layering of the kaolinite horizon. (C) Desiccation cracks of the white opaline silica. (D) Fossilized bubble of steaming hot fluids, with concentric texture.

Profitis Ilias Au-Ag vein deposit

The Profitis Ilias—Chondro Vouno epithermal Ag–Au deposit, constitutes a 20 km epithermal system with a combined resource of 0.8 Moz gold and 12.4 Moz silver [6]. Mineralization is hosted by altered rhyolitic pumiceous tuffs-ignimbrites and consists of crustiform/colloform-banded quartz-chalcedony veins related to quartz, adularia, sericite wall-rock alteration (Fig. 3B, C). Mineralized steep vein system extend to depths of at least 300 m below the current surface (~600 m above sea level). Baryte veins are also present at the Profitis Ilias peak and are usually related with sulfide mineralization. This gold-rich deposit is closely associated with the Kondaros epithermal paleosurface. Due to the very intense tectonic activity of Milos, related to normal faults, the Kondaros paleosurface is found below the Profitis Ilias deposit. The veins size ranges from cm to 1.5 m in width and from a few cm to tens of meters in length (Figure 9) [5, 18].

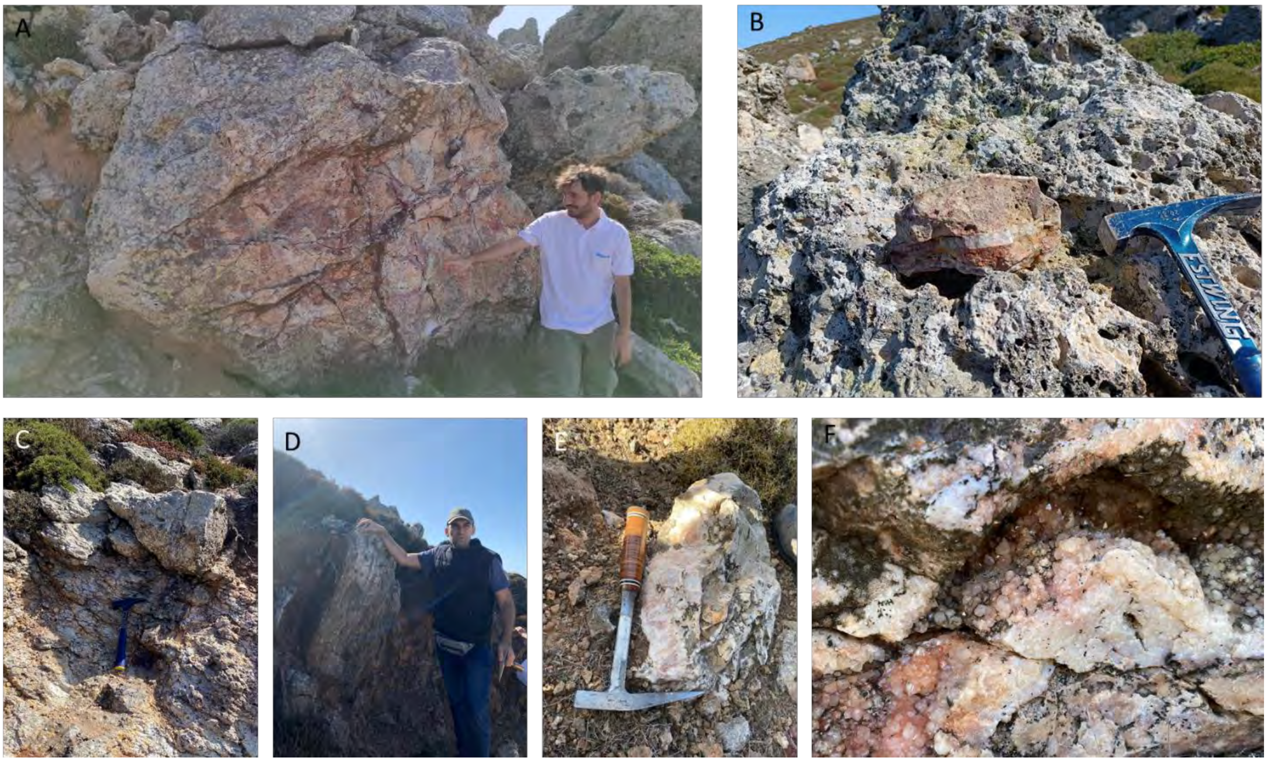

Figure 9: The Profitis Ilias gold mineralization vein type deposit. (A). Quartz stockwork, with at least 5 distinguished generations of quartz veins. (B) The ignimbrites host rock of the Profitis Ilias deposit. (C) Baryte veins with sulfide mineralization (darker areas). (D) Quartz vein with approximate 1 m length and 0.5 m width. (E) Comb quartz texture. (F) Open space-cavity fill quartz.

Fyriplaka-Kalamos volcano

Fyriplaka is located at the South of Island of Milos and it represents an old terrestrial volcanic center. The volcano walls compromise mostly from eruptive pyroclastic material such as lapilli tuff with fragments of the metamorphic basement. Evidence for the terrestrial activity of the volcano is the remnants of organic matter (old parts of tree trunks) that are found inside the pyroclastic horizons. Kalamos is one of the many sights in Milos where its very easy to observe the active volcanic-hydrothermal and geothermal field of Milos. With active fumaroles depositing native sulfur occur in biotite-quartz-phyric rhyolite.

Figure 10: The Fyriplaka-Kalamos volcanic system. (A) Pyroclastic eruption of the Fyriplaka old colonic center. (B) Magnified photograph of (A). Notice the brown clasts (in red circle) of organic matter (old tree parts) indicating the terrestrial environment of the eruption. (C), (D) The active fumaroles of the Kalamos volcano, notice the white smoke in the background. (E) Kalamos rhyolitic lava flows in the background. (F) Acicular native sulfur and white sulfosalts deposition near active fumaroles in the Kalamos area.

Third Day

On the third day we visited Cape Vani Fe-Mn-Ba deposit. Cape Vani operated as Mn mine during two periods: 1886-1909 and 1916-1928. In the first period 220, 000 tons of manganese ore have been produced [19]. Reserves amount to 2.1 million tons at 14.4 % Mn [20]. Beneficiation studies that were conducted for barite-bearing rocks have resulted in high-grade barite concentrate [21]. Ore-grade beds have mean composition: 14.6% Mn, 12.8% BaSO , 62% SiO , and 7.5% Fe O [15]. Manganese ore occurs in siliciclastic sequence of the the Pliocene-Pleistocene Cape Vani sedimentary basin (CVSB) that is nested by submarine dacitic/andesitic lava domes and consists chiefly of todorokite [19], hollandite and manjiroite that cement volcaniclastic sandstone/sandy tuff. Ore formation took place in a volcanic-tectonically uplifted, sunlit and oxidizing paleoenvironment of interacting shallow-marine/tidal-flat sedimentation, microbial ecosystem, and hydrothermal vent- sourced metals (Mn) and bioessential elements [17, 19]. Following the scheme of Hein et al. (2008) [22] for seafloor active arc-related Mn deposits, those in Milos exhibit a range of deposit styles (Fig. 6): (a) Mn-crusts: Mn-oxide encrustations of sandy substrates; (b) Mn sandstone/sandy tuff: These deposits are stratabound Mn oxides that cement sandstone/sandy tuff, breccias and conglomerate; (c) Stratiform/bedded Mn: Mn oxides which occur as stratiform and stratabound dense layers, discrete beds, lenses and sheets mm to cm thick; (d) Mn cobble deposits: irregularly shaped and structurally chaotic melanges of Mn oxide hosted in sandstone/sandy tuff; (e) Stringer Mn deposits: Mn oxides which form parts of crustiform and colloform banding, vug-filling, and cockade textures in epithermal-style veins which crosscut the sandstone/sandy tuff host sediments and the underlying dacite/andesite. Ore-grade Mn structures typify MISS [19, 22] formed due to interaction of littoral sedimentation, white smokers and active photosynthetic and/or chemotrophic microbial activity.

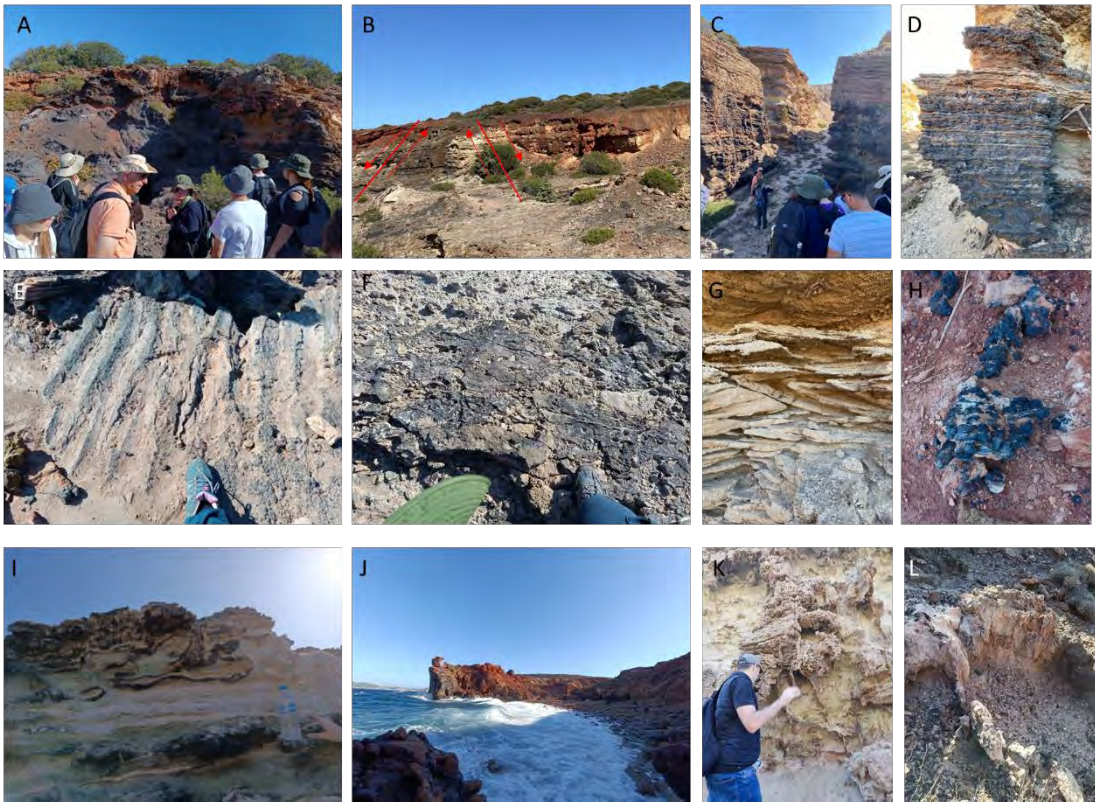

Figure 11: Cape Vani Manganese deposit. (A) Old manganese mine. Sandstone is the host of the manganese ore. (B) Tectonic setting of the Cape Vani. Horst and Graben structures control the geological evolution of the Vani area, making possible the coexistence of manganese and iron ore, even though they require different redox conditions. (C) Manganese mineralization hosted between sandstone layers. (D) Banded manganese ore. (E) Ripple marks. (F) Microbially induced sediment structures. Notice how the form as a crust on top of the sandstone. (G) Sandstone exhibiting cross bedding. (H) Typical manganese nodules found on Cape Vani coastal area. (I) Visible slabbing of the microbial induced manganese mineralization. (J) Photograph of the current beach of Vani. (K) White smokers. Notice the visible conduits indicative of focused flow of hydrothermal fluids. (L) Baryte veins associated with the manganese deposition.

Cenozoic Banded Iron Formation

Submarine hydrothermal iron formation (IF) occurs within the Cape Vani siliciclastics sequence in association with the Mn ore. The IF displays banded rhythmicity of alternating Fe(hematite)- and Si-rich bands analogous to Precambrian banded iron formations (BIF) and earlier reports showed association with anoxygenic phototrophic biofilms and abundant microbial fossil assemblages [12, 13]. New field-wide sedimentary and biogeochemical analysis [14] reveal at least two temporal and spatially separated IFs in Cape Vani showing distinct sedimentary and depositional features. The data suggest an intricate interaction between tectonic processes, changing redox, biological activity and abiotic Si precipitation as requirements for the formation of the BIF-type deposits.

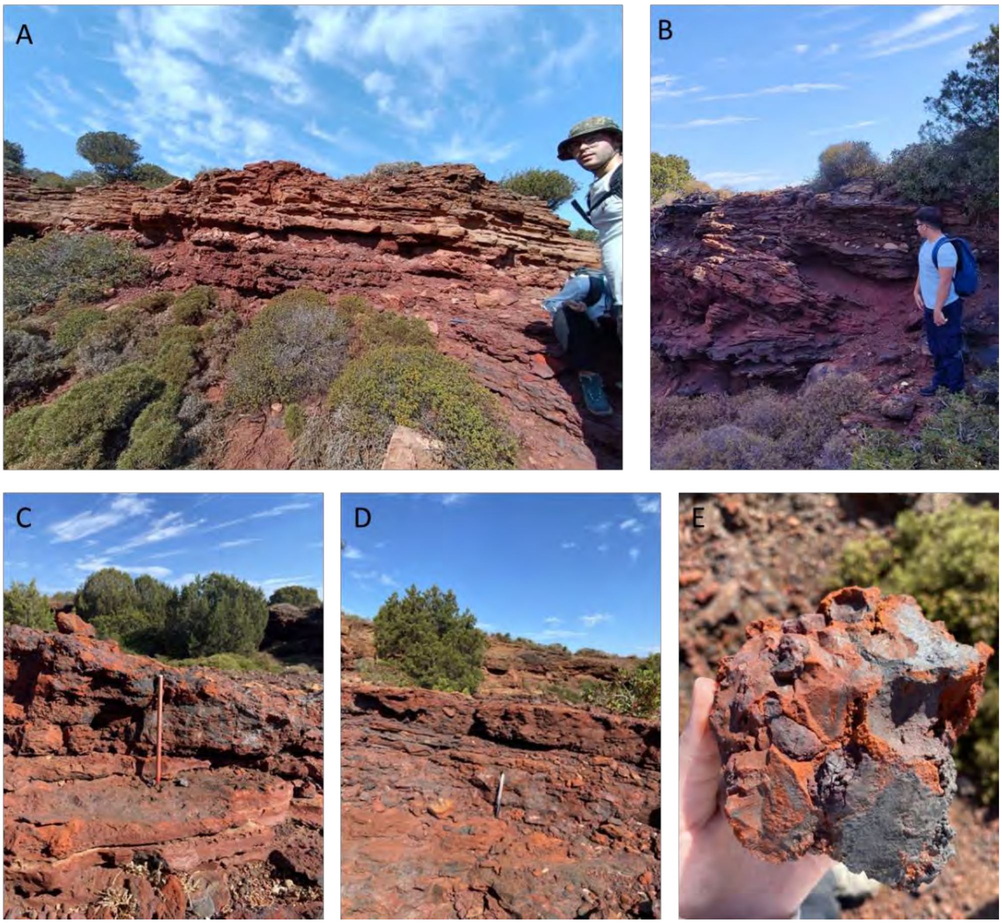

Figure 12: Cape Vani Iron deposit. (A, B) Silicified sandstone rich in Iron, it is considered the paleo-beach of the cape Vani. Notice the cross-bedding structures in (B). (C, D) Banded Iron Formation, the dark-black horizons are rich in Fe oxides while the red horizons are rich in silica. (E) Hand specimen of the iron formation.

Smoker land

Cape Vani is one of the most important geological destinations of Milos Island because of its geological diversity. Except of the iron and manganese deposits we visited Smoker Land, a small area at the premises of Cape Vani where we found a fossilized hydrothermal vent field that exhibits Organ Pipe structures. These, hydrothermal type chimneys are related with bioturbated sediments and also with manganese mineralization. It's worth mentioning that this particular samples have never been described or analyzed. Also, baryte veinlets usually cross cut the organ pipe structures and are related with manganese mineralization.

Figure 13: Fossilized hydrothermal vent field related with biological activity. (A) Fossilized vent field. (B, C, F) Close up of organ pipe strucutres. (D) Large conduits that worked as paths of hydrothermal fluid, are overlaid by bioturbated sediments. (E) Fossilized mud pool at the paleo-seafloor level. (G) Bioturbation structures. (H) Bioturbation structures related with manganese precipitation. (I) Baryte crystals that usually cross-cut the organ pipes.

Lava flows with hyaloclastites and baryte veins

At the last stop of the day we found hyaloclastite lava flows near the edges of the cape Vani area along with a baryte vein type mineralization.

Figure14: (A) Hydrothermal alteration of volcanic rocks with bendonite. (B) Magnified photograph of (A). Notice the green color of the alteration indicative of the presence of bendonite. (C) Lava flows. (D, E) Baryte veins with variable length and width. Notice the stockwork-like system in (E). (F, G) Typical hyaloclastite lava textures.

Fourth Day

On the fourth day of our trip we visited the areas of Sarakiniko shore, Papafragkas Cape, the Kalogeros Cryptodome and the old Sulfur mines.

Sarakiniko shore

Located just five kilometers away from the town of Plaka, which is also the island's capital, Sarakiniko Beach is the most renowned shore on Milos Island. Sarakiniko area is said to have been named after the Saracen pirates who used the caves as a shelter. Geologically, the Sarakiniko area is composed of marine sediments alternating with tuffs, the volume of which indicates intense volcanic activity in the past (1.9-0.1 Ma). In the area of Sarakiniko, there are mushroom-like structures made up of volcaniclastic material, probably pumice, which came from the explosive activity of another volcano and was deposited on top of the marine sediments. The volume and dimensions of the material indicate that the volcano was probably at a close distance. The abrupt contact between cold marine sediments and hot volcaniclastic material, has created a low-temperature metamorphic zone at the contact, the minerals of which are unknown. The presence of numerous fossils suggests that the area was submerged below sea level at that time, likely within the euphotic zone (depths<200m b.s.l). The action of neotectonics may have raised it to its current position.

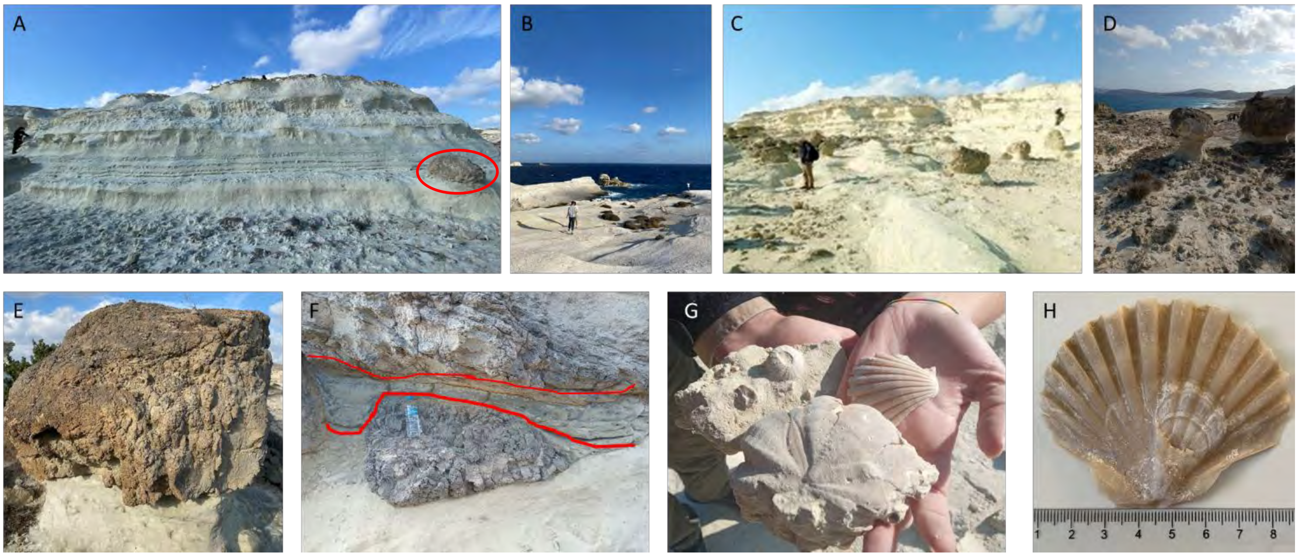

Figure 15: (A) : Marine sediments in alternation with tuffs. The volume of this volcaniclastic material indicates intense volcanic activity. Notice the large rhyolitic pumice blocks on top of the volcaniclastics. (B) View of Sarakiniko beach. (C) Multiple mushroom structures created by divergent erosion. (D, E) Singular mushroom structures. (F) Reaction front between the hot rhyolitic pumice with the cold sediments resulted in the formation of a transitional silicified layer. (G, H) Typical fossils found in the Sarakiniko sediments. The presence of numerous fossils, mostly pecten (on the top left), common sea urchin (on the top right) and uncommon sea urchin (on the bottom), indicates that the area was below sea level at that time, probably in the euphotic zone.

Papafragkas Cape

In this area, the tectonic status of the island is reflected in macroscale. The wider area of the Aegean is characterized by a state of extension, resulting in the activation of fracture and rupture mechanisms and the creation of a system with different generations of faults that form tectonic horst and graben structures. These are high-angle normal faults that deform the upper part of the crust and delimit symmetrical tectonic basins. A negative granulometric grading is also observed, with the largest boulders and cobbles on the top, the possible explanation of which is fault action that has inverted the area. The cobbles' range of size varies, revealing the explosive volcanic activity of the island. We are uncertain whether what we are observing in Papafragas cave is the result of one, two or more explosions. Confirmation of any theory requires further field work.

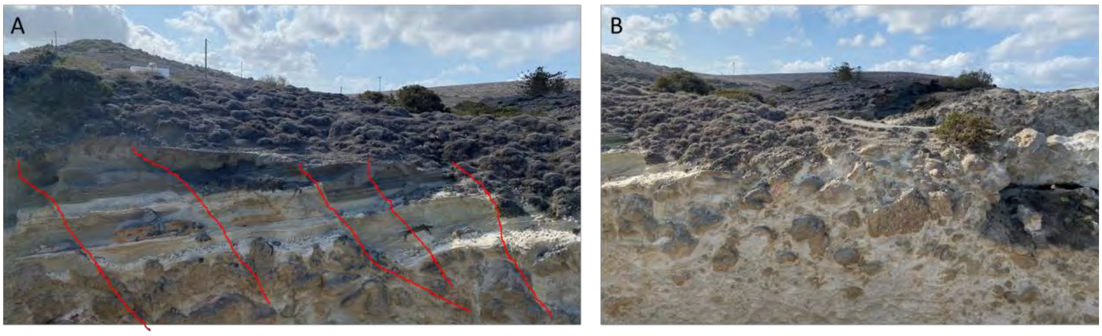

Figure 16: Papafragkas volcanoclastic formation and regional tectonics. (A) Typical normal domino listric faults found in the Papafragkas area. (B) Negative granulometric grading indicating the presence of a fault which may had inverted the area. The size range of boulders and cobbles shows explosive volcanic activity.

Kalogeros Cryptodome

On the northeastern part of Milos, is exposed the Upper Pliocene Kalogeros Cryptodome, which intruded a shallow submarine volcanic successsion about 2.5-3 million years ago. In plain view, the cryptodome is oval, ranging in diameter from 800 m (east-west) to 1300 m (north-south) and in cross section it is broadly semi-circular with very steep sides and an exposed height of 120 m [23. The formation of columnar joints, occur with the gradual cooling of the magma from the outer to the inner parts of a magmatic intrusion at small depths (cryptodome) [23]. Having in mind that the area consists of dacite-andesitic rocks, and after observing the presence of this specific structure, we comprehend the initial temperature of magma which was between 840-890 degrees Celsius.

Figure 17: Kalogeros dacitic Cryptodome displaying columnar joints.

While walking along the coastline, we observed that the crypt was coming in contact with the alternations of cold marine sediments and volcaniclastic materials. Biotite was also found in the marine sediments, a fact that indicates the gradual transition from one formation to another.

Figure 18: (A) The Kalogeros lava flows overlaid by marine sediments. (B) Interchanges between pyroclastic layers (dark grey) and altered marine sediments (white).

Old Sulfur Mines, Paliorema

In ancient times sulfur was mined in Milos although the exact locations are unclear. Sulfur mining has been an age-old activity in the Cyclades, dating as far back as antiquity. The current sulfur mines (called 'Theioryhia' in Greek) in the area of Paliorema are located on the east coast of the island and where first founded in 1862. During the 1930s, the sulfur mines were under the direction of Victor Melas, who owned the oldest sulfur mining company in Greece. That is when the current complex was built and machinery was installed for the mining of sulfur using the newest "Svoronos method" which made processing easier. At the time, the sulfur mines were producing 15,000 tons of sulfur per year. Mining operations ceased in 1958, following bankruptcy of the company involved as a result of a several-fold drop in sulfur prices and the processing of petroleum for sulfur retrieval as a far cheaper way. That is when the mines were completely abandoned. The 1930s complex still stands today and the machinery within the buildings has been left there as it was. The sulfur was mainly extracted from underground deposits. The wider area of the Aegean is characterized by phenomena of magmatism, volcanism and tensile regime. The tensile forces create low-angle extensional detachments that uplift the rocks of the Aegean microplate to the surface, a structure called a metamorphic core complex. The Aegean microplate is made up of continental crust, while the complex of the metamorphic core consists of blueschist. This complex is the main source of heat for the magmatic hydrothermal solutions and the detachment is a passage for their ascent. Rocks that were found near the sulfur mine indicate that this is an epithermal deposit. The host rock is a hydrothermally altered lava. The sulfur deposition is associated with advanced argillic alteration. The presence of vuggy silica and the appearance of cavities in the host rock reveals the action of acidic hydrothermal solutions, which dissolved pre-existing minerals.

Figure 19: The old sulfur mines. (A) Advanced argillic alteration in bedded structures associated with sulfur deposition. Notice the Abandoned accommodation block for the workers and company offices. (B) The blueschist metamorphic basement of the Aegean microplate.

Fifth day

The last day of our 5-day trip we visited the old mines of Silver and Baryte Ores Mining CO. S. A located at Triades-Galana Pb-Zn-Ag-Au mineralization. The mineralization as suggested by

Plimer [18] and Stewart and McPhie [24] represents sub-seafloor/seafloor stockwork zones, which formed in a shallow submarine setting. The Triades-Galana system is classified as intermediate to high-sulfidation epithermal type [25] mineralization located along NE-trending faults, NW Milos Island, Greece. Mining activities at Triades, which began in the late 19th century, primarily targeted lead and zinc, and later focused on silver, with estimated silver reserves of 10 million tons of ore at a concentration of 500 ppm of silver. It is hosted in 2.5–1.4 Ma pyroclastic rocks and is genetically related to andesitic/dacitic lava domes. Mineralization occurs as breccias, quartz-barite-galena veins and stockworks within sericite-adularia or kaolinitic altered rocks. The mineralization is enriched in Mo, W and base- and precious metals (e.g. Pb, Zn, Ag). We also had a unique opportunity to witness the importance of mass wasting events during the formation of a deposit and their preservation. Mass wasting and landform modifying events have a profound impact on hydrothermal processes in terrestrial environments. Mass wasting events in submarine settings also modify hydrothermal systems and their associated mineralization. The lack of sulfide ore bodies at the Triades system indicates that mass wasting events such as landslides may have destroyed any preexisting sulfide mineralization [26].

Figure 20: The Triades silver and baryte old mines. (A, B, C) Mass wasting baryte lenses without sulfide deposition. (D) Sulfide deposition in baryte lenses, mostly copper related sulfides with minor galena. (E) Mass wasting baryte bodies related with advanced argillic alteration.

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