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THE EMERY OF NAXOS: A MULTIDISCIPLINARY STUDY OF THE EFFECTS OF MINING AT A LOCAL AND NATIONAL CONTEXT

Argyrios Periferakis
"Carol Davila" University of Medicine and Pharmacy Bucharest, Romania
argyrisperiferakis@gmail.com

ABSTRACT:

The aim of this paper is to present the fluctuations of emery mining, from Ancient times to the present day, in the island of Naxos, Greece. Many Aegean islands were characterised in Antiquity by intense mining and quarrying activities, and many such activities continue even today. Emery is along with marble, the distinctive industrial mineral of the Cyclades, even now that production has largely ceased. This is an analysis of how emery came to be in Naxos, and how its existence and its exploitation by the local population shaped the society, the economy and the folklore of the local mining communities. In addition, since such mineral wealth is a matter not only of local but of national importance as well, the significance of emery export in Greek national economy will be discussed, along with how the changing international industrial and financial reality affected mining and thus the life of the locals. While presently profitable emery mining is rather unlikely, it is still possible for the insular community and economy to benefit from the establishment of a thematic geopark, based on the existing mines and the old mining infrastructure.

Keywords: emery, mining, Naxos, society, economy, folklore.

I. INTRODUCTION:

Modern civilisation has been, since the advent of tools and weapons, dependent upon natural resources and raw materials, be it for weapons, or tool production, or for more complex machines later on. Apart from wood and bones, which were the first raw materials, so to speak, of early human communities, as the technological sophistication improved, different kinds of raw materials became available. But it was not only a question of demand but also a question of availability, which constrained or enhanced the potential of civilisations. Invariably, most raw materials, from obsidian and pumice to iron and tin, are created through geological procedures.

The first geological material to be exploited was probably obsidian, where detailed analyses for the significance of its use at a cultural and a technological level exist (e.g. [1][2][3]) for the Mediterranean region. Likewise, such analyses exist for other geospatial contexts (e.g. [4][5][6][7][8]). Obsidian may be the earliest lithic material used specifically for its properties, chert being the other probability, and it is interesting to note its ubiquiteness in archaeological sites of different periods, all over the world. This alone, speaks volumes about the need for certain geological resources, in different populations and periods.

After obsidian, other geological materials came to the forefront, as technology progressed and new needs and opportunities arose. It is evident that the availability and use of geological materials constitutes a major factor of shaping a society, in many ways. A special case is that of the exploitation of emery in Naxos island, in the Aegean. This study aims to assess, throught the evidence provided by historical sources, the impact of emery exploitation in the context of this specific insular society, via a multidisciplinary approach.

Many of the Cyclades islands have been bestowed with significant geological resources. Most notably the emery of Naxos [9][10] and the

marbles of Paros [11][12] are of national and international reputation and significance. The pumice and obsidian of Melos island have also been instrumental in shaping the island's history and economy. Other notable ancient quarrying endeavours include the marbles [13] and ophicalcites [14] of Tinos, and the limestone quarries at Samos [15]. Recently, evidence for Ancient mining activities were also found in the island of Kea [16], while in Lemnos island, terra lemnia - lemnian earth - was exploited for its medicinal properties [17], as was the well-known samian earth from Samos island [18]. In addition, alum, known in Greek as «styptyria lithos», was exploited in the village of Stypsi, Lesvos, where curiously, the porphyry-epithermal systems [19][20][21][22][23] are not known to have been exploited. The nearby ores at Megala Therma [24] were exploited only after the 19th century. Then, as now, mineral wealth, when exploited, has a formative effect on the socioeconomical framework of a local or even national population.

As far as human habitation is concerned, archaeological evidence have been found for pre-Neolithic settlements in the Aegean islands [25], and there are even some researchers [26][27] who claim that Early Palaeolithic activity in some islands can in fact be documented. At any rate human habitation at Naxos can be documented at least since the Lower Palaeolithic, as demonstrated by the existence of chert quarries of that era at Stélida [28]. While many islands had prominent deposits, it is remarkable that Naxos should have both emery and marble as exploitable industrial minerals. Only Melos would be more prosperous in terms of geological resources. In the island of Naxos emery is a very important industrial mineral, which has been mined for since Antiquity, and has shaped the socioeconomic development of the island throughout most of its history.

Industrial minerals are defined as rocks, minerals and natural occurring substances of economic significance. In this wide group, metallic ores, mineral fuels and gemstones are not included. Although this is a somewhat ambiguous definition, e.g. bauxite and emery contain metallic minerals, it is generally agreed upon that such natural occurring substances which are raw materials of major nonmetallic substances are included [29]. Today, industrial minerals, whether cheap and abundant like gravel, or rare and expensive like industrial diamonds, are instrumental both in the matrix and in the economic and technological network of modern societies. While technological advances, mostly in the field of abrasives, may ultimately mean that some natural materials are supplanted by artificial ones, it must be borne in mind that most such replacements would not have existed if not for the decade-long use and study of their natural «precursors».

Abrasives, in some form or another, have been used since Prehistory, and archaeological findings of ca. 20000 years ago support this assertion. Spears and tools were shaped and polished, using sand or hard rock surfaces. Evidence from emery use exist in the Near East already from the Bronze Age [30], while it must have been used since earlier times also. This primitive abrasive use continued for centuries, and was supplement by the manufacturing of more sophisticated abrasive equipment in the Middle Ages, when the first types of sandpapers were produced [31]. While the Industrial Revolution resulted in a phenomenal increase in abrasive demand and use, advances in chemistry resulted in the creation of synthetic emery, which is much cheaper than natural one, and has largely supplanted it.

II. METHOD

In assessing the impact of emery availability, for the people of Naxos island, a multidisciplinary approach will be undertaken, involving historical, ethnographical and sociological approaches.

The historical context of Naxos, from Ancient Greece to the present day, will be examined in order to determine how Naxos affected and was influenced by historical events. Then, the correlation between major and minor changes brought about by the changing historical circumstances, with the fluctuations in mining activity will be presented.

Thus, the impact of mining in all aspects of the local society, as outlined above, will be assessed in a qualitative way, following the precedent set by analogous studies, (e.g. [32][33][34][35][36][37][38][39]), linking geological materials and civilisations. Finally, the links between the community and the local geoheritage will be established, along with proposals for its development into a viable attraction, thus correlating the local community with its geological past.

III. NAXOS GEOLOGY, EMERY OCCURRENCES AND USE:

Naxos (Fig. 1) is the largest island of the Cyclades and belongs, tectonically, to the Attic-Cycladic massif [40][41], which has been affected by at least two major metamorphic events [42]. The Attic-Cycladic extensional complex, located in the central Aegean comprises several tectonostratigraphic units which can be classified in two major structural groups. The upper group comprises non-metamorphosed Permian to Mesozoic sediments, ophiolites, and greenschist-facies to medium-pressure/high-temperature metamorphic rocks, with some granitoid intrusives in places. The lower group of the consists mainly of a Permo-Triassic volcanosedimentary and bauxite-bearing marble dominated passive-continental margin sequence of the Cycladic Blueschist Unit and its Variscan para-and orthogneiss basement [43; and references therein][44].

The first major event was a HP-LT metamorphism of Eocene age (~ 50 mya), which corresponds to a compressional phase, involving continental margin material subduction, and nappe generation [45][46].

Fig. 1: Simplified schematic geological map of Naxos island Cyclades Greece (after [47][42][48]). 1) marble with intercalations of micaceous schists; 2) granodiorite; 3) amphibolites and schists with marble intercalations; 4) sedimentary rocks 5) migmatite complex with marble intercalations. The black masses represent the major mineable emery deposits (modified after [47]).

This compressional regime was succeeded by an extensional one, which resulted in the formation of the Aegean back-arc basin [49], characterised by uplift of lower crustal rocks, and a thinned crust [50]. The metamorphism associated with this extensional phase, is divided in two events, a greenschist facies of Upper Oligocene age (~ 25 mya) and a more localised HP-LT one, of Middle Miocene age

(~ 16 mya), which produced thermal domes [51].

The island of Naxos can be thought of as a Cordilleran-type metamorphic core complex, formed during crustal extension, during which upper crustal rocks were superimposed upon deeper crustal units, moving along detachment faults and shear zones of a shallow gradient. This theory was proposed by [52][53] and later corroborated by [42].

The earliest geological and petrological research of Naxos was undertaken by [54] and [55]. Based on these studies, as well as that of [48], the island comprises the metamorphic rocks of the metamorphic core complex, and a large granitic body to the West.

The structure of the metamorphic complex comprises large-scale isoclinal folds, whose axes are of a N-S direction. These structures are subsequently folded along an E-W direction, resulting in a dome and a regional foliation warping over the migmatite complex [56][42]. The Naxos metamorphic core complex consists of a gneiss dome with a migmatite core, flanked by a low-angle normal fault to the East and a steep strike-slip fault zone to the West [57].

As far as emery is concerned, it must be noted that metabauxites rich in corundum are rare rocks, only found in the Aegean, Turkey (Fig. 2) and some locations of the former USSR. The last two groups of metabauxites were deposited at an earlier stage, compared to those in Naxos. All of them however are intercalated with marbles and as such are considered as metamorphosed kartsbauxites [47]. Metabauxites are not unique to Naxos as they can be found throughout the Attic-Cycladic massif, in the islands of Heraklia, Sikinos, Ios, Paros, Samos, and Ikaria [58]. The metabauxites of Naxos, which are quite common throughout the island, occur in a lenticular form, intercalated with marbles. They bear evidence of two distinct metamorphic events, the earlier one being an Eocenic HP-LT event, followed by a Late Oligocene-Miocene MP-LT event, corresponding to the metamorphic phases mentioned above for the Attic-Cycladic complex. Mineralogical investigation indicates that the fist event belongs to the glaucophanitic facies and the second to the greenshist-amphibolitic facies grade.

Fig. 2: Metabauxite occurrences in the islands of the Aegean and in Asia Minor. The corundites are represented by black triangles and the diasporites by orange ones (after [47]).

It is interesting to note that although most of the bauxites of Naxos where transformed into emeries via medium to high grade metamorphism, there are some bauxites at the SE of the island, which remained diaspore-bearing, and therefore are classified as diasporites, having undergone only low grade metamorphism. Geochemically, diasporites are the second type of metabauxites, the first being corundites, whose commercial name is emery. They are rich in diaspore and corundum respectively. Since corundites are formed through the metamorphic dehydration of diasporites, it follows that they are of a lower metamorphic grade [59].

From a geochemical standpoint, there is a close correlation between aluminium oxide and titanium oxide contents, which is indicative of a parallel enrichment during the bauxitisation process, as indicated by [60] and [61]. The bauxites of Naxos belong to the Mesozoic-

Cenozoic Mediterranean bauxite belt [61]. According to [47], prior to the metamorphic events, the deposits consisted of oxidised bauxites, comprising Al-hydroxides, hematite, kaolinite and anatase. However, depending upon differences in the metamorphic and geochemical processes, the metabauxites, according to [47] can be divided into three categories, with the so-termed «commerical type» having less than 30 % silica minerals.

Since early investigations [62] it was supposed that the numerous lenticular metabauxite horizons, could be traced back to a relatively small number of initial horizons, which have been repeatedly folded and thrusted. While [56] assert that there was originally one stratigraphic bauxite horizon, the presence of at least two or even three horizons is by far more likely [47]. Regarding mining endeavours, the interest lies in the horizon in the NE part of the island, where the emery lenses are more numerous and extensive.

The term «emery» is used to describe a black granular rock, consisting mostly of corundum and one or several Fe-bearing minerals, namely magnetite, hematite or hercynite. Usually, there are trace impurities such as mullite. Geologically, emery is most properly named metabauxite. Metabauxites occur when already deposited bauxites undergo HP-LT metamorphism.

The precise chemical and mineralogical composition of the emery determines its physical features, and that which is of the most interest in the abrasives market is hardness. Lower quality emeries have a hardness value close to 7, while higher quality ones approach 9 on the Mohs hardness scale.

The Greek term for emery is «smyris», and is derived from the port of Smyrna, which was the focal point for emery distribution in ancient times [63]. On the other hand, the term «emery» is derived from the Emeri peninsula, where the emery mines of Naxos are located. The principal mineral of emery, corundum, is believed to have been named from the corruption of the Indian word «kauruntaka» which was used to describe the same mineral [64].

At a worldwide level, the only emery deposits of economic significance are found in the USA, Greece and Turkey. In the USA however, the majority of emery production has ceased since the 1980s, and the only commercially active emery mines can be found in Oregon, in the Western Cascade Range.

Naxian emery was exported in three qualities, with decreasing corundum percentages corresponding to cheaper prices [65]. The highest grade quality is richer in corundum than all other emery types and as such is considered to be qualitatively the best natural emery in the world [65].

Before the advent of synthetic artificial abrasives, emery was used in most industrial applications. However it has since be replaced by artificial corundum, silicon carbides and artificial diamonds. The few uses of emery in the modern industry include stone sawing and surfacing, as well as metal polishing and rough grinding of plate glass. It is also used in bonded abrasives, most notably grinding wheels. Another use is that as a coated abrasive, i.e. emery grains cemented in a paper of cloth matrix. Other applications include its uses as a nonskid dusting agent in floors, stairs and pavements, and its use in pressure blasting [64].

The reasons why emery is not largely used today are quite a few, the most important in a profit-oriented reality being that artificial abrasives are much cheaper to produce. Most often they can be produced by domestic industry, thus obviating the need for imports from the few emery producing countries. The further automation of the manufacturing process requires specially constructed abrasives, while the increase of grinding speeds favours the use of fused alumina-zircon abrasives. Finally, artificial

abrasives now perform far better than natural ones, and due to uniformity of production they are of a standard quality, i.e. they have uniform mechanical properties.

It is probable that we may never know when Naxian emery was used for the first time. Maybe it was that settlements in the mountains were created before the potential of emery mining was realised. It is know that in Naxos, as well as in other Aegean islands, fortifications during the Middle Cycladic period were created to guard against seaborne raids. This must have been a rather tumultuous period, since there is marked decline in sculpture, metallurgy and luxury goods manufacturing [66].

In antiquity, as well as in the Middle Ages, Naxos was arguably the most important island of the Cyclades, if not of the Aegean, in terms of political and economic power. Understandably, more evidence for emery use and export exist after the 18th century. However, piecing together what little is available for earlier periods, it is possible to form a rather comprehensive view of the matter.

A. The Mining of Emery from Ancient Greece to the 20th Century:

In the absence of specific evidence on ancient Naxian economy, it is difficult to quantify the effects of emery mining. In Ancient Greece, the emery of Naxos, also known as Naxian Stone, was used for marble abrasion to created fine detailed sculptures. The first evidence of possible emery export exist in Minoan Crete, where [67] identified powdered emery and suggested that it may originate either from Naxos or from Samos. According to the research of [68], Samos is the only other Aegean island, where emery might have been exploited in Ancient times.

What is known is that Naxos was at its peak, between 750 and 490 BC, due mostly to exports of marble. Although not of direct interest in the context of this study, it is interesting to remark that Naxos enjoyed even then, the benefits of its rich geological resources. Not only emery, but marble existed to supply the local economy via exports in most of the known world of the period. It is even conceivable that emery was used as an abrasive for the first time in Naxos, for marble surfacing, it being readily available close by the marble quarries. [69] notes that financial and political power at Naxos lay with those who quarried marble and mined for emery, so it can be documented with a degree of certainty that part of the Ancient Naxian economy depended upon emery exploitation. During these times, emery was transported to the ports of Smyrna and Piraeus, for further distribution to inland markets.

At any rate, Naxos was so wealthy as to maintain a fleet of four triremes, which took part in the naval battle of Salamis in 480 BC, at a time when most Aegean islands did not have the ability to maintain even a single warship [70]. Subsequently, Naxos participated in the Delian League, only to be destroyed in 471 BC, when it tried to secede. It was subsequently sacked, its fortifications destroyed and its fleet confiscated. After this, Naxos fades into obscurity for hundreds of years, becoming a rather unremerkable Cycladic island. During the Alexandrine and the Roman era, no definite evidence of emery mining and use exist. In the Byzantine era, Naxos was an important economic and administrative centre, although there are is still a dearth of relevant evidence.

After 1000 AD, the Byzantine Empire was in decline, and steadily losing control of the Aegean. Imperial rule in the Aegean was more nominal than actual, and many fortified positions, such as the castle of Apaliros, were under the control of pirates - the castle having been built originally for defence against pirate raids. Naxos comes under Italian control in 1207 AD, having been conquered by Venetian forces under the command of nobleman Marco Sanudo. The Naxians resisted fiercely, being also assisted by the Genovese, but in the end were forced to succumb. Any and all resistance had been stifled by 1210 AD, and the nascent Duchy of Naxos expanded, as more Cycladic islands came under Italian control (Fig. 2). However, after only a century of Venetian rule, infighting between Italian forces - back then there were numerous competing Italian states - as well as clashes with the temporarily rejuvenated Byzantine Empire weakened the Venetian forces. After the fall of Constantinople in 1453 and the nominal end of the Empire, the Ottomans concentrated their efforts in conquering any and all European held territory in the Aegean [71].

Fig. 3: The Duchy of Naxos in 1214, and the various administrative units and sovereing territories of Central Aegean and Greece (after [71).

Under Ottoman rule, emery mining was not included in administrative reports, only Melos being of sufficient economic interest to arouse Ottoman interest. However, according to contemporary reports, the mining rights for emery were given solely to the members of the surrounding villages, which were about 600 in number [72]. Around that time, emery was mentioned by Dutch accounts as a good abrasive for swords. Also, between 1700 and 1900, emery powder was used for glass abrasion, to create lenses to manufacture spyglasses and telescopes. Christian Huygens himself praised its properties and considered it indispensable [73].

Towards the 18th century, many emery mining sites belonged to the French consul and to foreign landlords. However, emery was still mined by the locals, the production being transported to the Bay of Moutsouna, to be loaded as ballast in English ships. As emery had still few other applications, it price was extremely low. In 1780, the Turkish governor

decreed that the residents of the mountain villages would have the sole mining rights of emery [74]. Still, emery demand was fairly low, although it was used in manufacturing sewing needles, in England and France [73].

This century is a rather active one, from a mining perspective, as there are larger of smaller mining and quarrying endeavours recorded in many islands. In Melos sulfur mining remained a profitable endeavour, while sulfur salts - known by the Ancient Greek name «stypsi» - and gupsym were also mined. This «stypsi», also known as «styptiria lithos», was mentioned by numerous ancient authors, as well as Hippocrates and Dioscurides, in relation to medical matters [75].

During the Ottoman occupation of Naxos, there was no tax imposed on emery mining or export as it was not considered valuable enough. Only in 1824 AD did the Ottomans impose such a tax and this lead the people of Naxos closer to joining the revolution in the ongoing War of Greek Independence. After 1826 AD and the creation of the Modern Greek State [76], the potential of emery for the national economy was quickly realised, and it was from the very beginning considered as a national resource, thereby being under direct state control.

In the 1830s the first abrasive emery papers were manufactured, while emery is also used in planishing the barrels of rifles. It is interesting to note that the workers undertaking this task were called «schmirglers», a name remarkably akin to the Greek colloquial term «smyriglas», used to indicate a person mining emery. It is in these decades, with the expansion of industrial units and the extended used of steel in manufacturing processes, that the name of Naxos will be known across all European factories [73].

In the 19th century, Naxos was remarkable in that it was amongst the few places producing emery on a large scale. However, up until 1862 AD, mining and quarrying activities in the Aegean were in effect private ventures, and emery mining in Naxos and the exploitation of the geological resources of Melos, were all regulated by the private initiative of the locals. In 1864, Greek interest in mining spiked with the establishment of the Roux-Serpieri-Fressynet C.E. mining company at Lavrion [77][78]. Rapidly, following the mining frenzy at Lavrion, geologists and mining engineers roam the Aegean islands and rediscover mines lost since the times of Ancient Greece [74]. As for emery, it had become State owned in 1845 AD, with the villages of Apeiranthos, Koronos, Danakos, Mesi, Skado and Keramoti maintaining their sole mining privileges. It is interesting to examine the reasoning behind this paradox legislative scheme. As emery was deemed of national importance it was believed that the existence of competing small mining private ventures would lead to lower export prices due to internal competition. This was true during those early years, but this scheme was never effectively altered afterwards.

When in the 1860s AD, the bonded grinding well was developed, the need for a high-quality abrasive became paramount. Abrasive cloths also soon became a staple accessory of large and small scale industries, which further increased the need for a hard durable abrasive, namely emery. Turkey initiated emery production and export in the 1880s AD, and soon became the leading emery exporter, taking advantage of the large emery deposits and low production costs. In 1868, the first emery mine in the USA opened, followed by a few others, but some would cease their operations by the 1920s, and what few remained generally produced emery of inferior quality. There were proposals, by state officials and mining engineers to employ modern machines for tunnel opening and mining, but as there were no available funds, the propositions were dropped, and mining continued using outdated methods. The situation was not helped by the financial ramifications of

the disastrous Greek-Ottoman War of 1897, in which Greece was summarily defeated.

At the dawn of the 20th century, it was calculated by [79] that the annual production of emery was in the region of $2 \cdot 10^5$ t/year, although this number seems unrealistically high. This was an era where, apart from other industrial sectors, the automobile industry was on the rise, and it alone accounted for a significant amount of the emery demand. While the properties of the Naxian emery where highly valued by engineers and metallurgists, its replacement by synthetic products had already started [80]. Around this time, discussions about whether to make use of a foreign mining venture as happened in Lavrion, were under way. It would be possible for the State to keep the sole ownership the emery deposits, while foreign investors would build and organise a modern mining operation, paying an annual tribute to the State. It was beyond argument that in such a way production would increase drastically, and so too would increase State finances. However, this meant that the individual mining rights and privileges of the aforementioned villages would have to be abolished.

Another acute problem existed, which raised production costs and hence emery price. The docking and loading facilities of the island were woefully inadequate. Emery could be loaded to waiting cargo ships in the Bay of Lyonas or in the Bay of Moutsouna. The Bay of Lyonas was sufficiently deep to accommodate deep draught cargo ships, albeit being accessible roughly 40 days per year, due to adverse winds. It was also unsuitable for conversion into a small-scale commercial port, for geomorphological reasons. The other option, the Bay of Moutsouna, which was in any case more frequently used, could be used to construct modern harbour facilities. However, this would require a sizeable investment, and it was therefore an unrealistic undertaking considering the dismal finances of the Greek State, which, between 1912 and 1922 was constantly in a War footing, notwithstanding the financial deficiencies due to political upheaval. Consequently, emery would be loaded into small ships, which would then dock at Syros, where the emery warehouses were located. Emery would be unloaded there and then loaded again to cargo ships using the local port facilities.

In any case, there remained the acute problem of emery transport towards either Bay. At the time, emery was carried by donkeys, through an arduous journey via narrow steep paths. Those miners which were too poor to purchase beasts of burden, even carried the emery themselves. After 1920, the general emery issue came to the foreground, due to it being one of the few major export sources. At the time, Petros Protopapadakis was a leading member of the Parliament, and eventually would become Prime Minister of Greece, between May and September 1922. Being born in Naxos, he was interested in the welfare of the island and the exploitation of emery, for practical as well for sentimental reasons. Having great influence, he was able to promote some modernisation schemes on this matter.

There was a proposal to build a railway, starting from Ammomaxi Mountain, connecting all the mines and ending in the islands' capital. This was deemed as too extensive a project and was dropped. There was another proposition to build a small railway, and some supporting roads, connecting the mines with the two Bays. This too was dropped. In the end the most expensive, and possible the less practical solution of an air cable railway was adopted, which was to be funded by the State budget in its entirety.

Such grandiose schemes however would have to be put on hold, checked by the ever worsening political, financial and military situation of Greece, the country having fought in the First and the Second Balkan War. When, in 1914, the First World War broke out, Greece

maintained its neutrality, despite being courted both by the Entente and the Central Powers. Almost immediately, an ideological and political dispute broke out between the King of Greece, Constantine I, and the Prime Minister Eleftherios Venizelos. To analyse here the situation would be to stray away from the purposes of the paper. Suffice it to say that the treatment of Greece by the Entente, which will being an ostensible ally, invaded Greece, brought about a civil strife known as National Division. The ramifications of this acute and deep schism between parts of the society would be felt until 1936, when democracy was, once more, replaced by an authoritarian regime. Naxos, being on the losing side of the confrontation between Venizelos and the King, paid dearly for its choise. The Venizelists landed in Naxos, and demanded that the island surrender to them. Initially most people declined but after arrests of local dissidents, most of the island surrendered to the Temporary Government. However, some villages around the emery mines refused and the confrontation resulted in the massacre of numerous civilians of Apeiranthos, in the 2nd of January 1917 [81][82]. While the First World War had resulted in an increased demand for emery, in the end the profits would be paid for in blood.

While in 1920, Venizelos would lose the elections, and Protopapadakis would become Prime Minister, he too would shortly lose its position after Kemal defeated the Greek Army in Asia Minor, in 1922. The ensuing political turmoil would bring the Venizelists back in power, and they would set in motion a courts-martial against those believed responsible for bringing about such a catastrophe. Former Prime Minister Protopapadakis was deemed guilty and executed along with five other political and military leaders. With him died any possibilities for an effective countermanding of the future decline of emery mining.

B. Mining Operations from the Interwar years to the Present Day:

The air cable railway system (Fig. 4a), one of the most well-know manmade features of Naxos, was constructed between 1926 and 1929. It certainly improved emery transport but at an excessive cost. One important restriction was that it was unusable during strong winds, a fairly common feature of Naxos and the Cyclades in general. This frequently lead to significant delays, and ships had to wait in safe nearby ports for the winds to subside, in order to be loaded. The whole structure consisted of 71 iron pillars, covering a distance of about 8 km, with five stops to load its cargo, at the five emery concentration stations of Pigi, Pezoulia, Stavolagada, Kakoryaka and Aspalathropos. The emery was unloaded at Moutsouna Bay (Fig. 4b), to be loaded into waiting ships.

It is probable that in Greece, which more often than not was a technological backwater, the potential of machines for industrial and mining purposes had not been realised. It is also true that, the road network in mainland Greece was in some places poor and in most places non-existent.

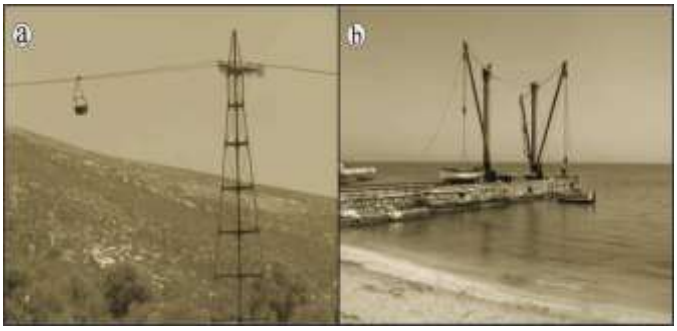

Fig. 4: Photos from the emery transport system: (a) The aerial cable railway, with a basket carrying emery; (b) the loading facilities at Moutsouna Bay (from [9]).

In the Cyclades, what roads existed, were gravel or sand paths, trodden by donkeys and horses, and automobiles were unheard of in the mountain villages. While in its time the air cable railway was regarded, and in a sense was, a technological and mechanical feat and was

viewed as the herald of progress for the island, it was, in reality, a colossal failure considering the amount of money spent and the end result.

For a mere twenty percent of the cost of the railway, it would have been possible to construct a modern road network, from the villages to the Bay of Moutsouna. This would have had two additional effects. First and most importantly it would connect the villages with the rest of the island and with the port, making it possible to transport emery loads via trucks to the shores of the Bay. Secondly, it would provide an impetus of the introduction of motor transport in Naxos, thus modernising the island somewhat. It is interesting to contemplate that such a costly venture was undertaken, at a time when Greece was close to bankruptcy, after a disastrous conflict, civil strife and tens of thousands of refugees waiting to be resettled.

Just as the railway finished completion, Europe and the USA faced the now infamous financial crisis of 1929. This was in many ways a result of the First World War, whereupon Europe, from the centre of the world's financial power was now partly dependent on American funds to survive. And while USA transformed into the greatest creditor of the world stage, the short-term loans were used in long-term projects. At the same time, the prices of agricultural products - which made up a sizeable part of the export potential of most European nations - spiralled downwards. This created a domino effect, since exports could not cover imports, from a fiscal point of view, and so most countries resorted to further loans, which would not be repayable in the short term. As the flow of capital from the USA was curtailed in 1928, investments and consumption in European economies diminished. By 1932, the industrial output of the whole Western world would have been reduced by about 65 %. Unemployment and civil unrest naturally occurred and the tension soon affected international relations as well [83].

Predictably, with this «industrial collapse», came a drastic decrease in emery demand, and in Greek exports in general. The number of the miners decreased as well, so much so, that contemporary Naxian newspapers mention that the regions and villages around the mines had become deserted. During the 1920s, chemical breakthroughs occurred, which would pave the way for the creation of artificial corundum and therefore artificial emery. From this point onwards, the emery mines of Naxos would live on borrowed time, as the expression goes. Still, the Naxian miners who remained, awaited the resurgence of industrial activity, which would lead in increased demand. In 1932, Greece abandoned the gold standard causing mass monetary inflation. The financial situation was most certainly the result of the international financial crisis, but was not helped by the more than 30 changes in government, many of which were brought about by revolts and counter-revolts [84].

Towards the turn of the decade, with the clouds of war hanging heavy over Europe, the Greek government increased its demand, to $8 \cdot 10^3$ tonnes in 1938, $10 \cdot 10^3$ tonnes in 1939, and $15 \cdot 10^3$ tonnes in 1940. It was believed, in consequence, by the mining communities, that war would provide them with opportunities of increased income. Alas, they were to be cheated from such wild fantasies and awaken into a financial nightmare. First of all, artificial abrasives already covered many of the needs of the international wartime industry, and at any rate Greece would not remain neutral for long. With the formal capitulation of Greece, the Italians initially took over the island. They ordered that mining activities should be ceased and the already accumulated emery was shipped off to Germany. There were even proposals by the occupying forces to dismantle the cable railway, and use it steel cables in their war economy. In such times they were extremely valuable. This did not come to pass however, and

while this was a relief at the time, its dismantling could have been beneficial of the communities in the post-war environment.

During the war, the village residents were in a dire situation. With virtually no source of income, and with the population swelled, by those returning from the front and those who took refuge in these villages, to avoid potential German and Italian transgression in the main residential centres of the island. What little agricultural production and livestock farming there was, could sustain maybe one third of their number. So, perhaps predictably, these communities had the unwanted distinction of sustaining the sole deaths from famine, in Naxos during World War II. Many people even resorted into trading the metal doors of their houses for food with other communities.

The mining communities emerged from the war, decimated and carrying the physical and mental scars of the wartime ordeals. Gradually, the Greek State increased its demand up to $8 \cdot 10^3$ tonnes per annum. In 1953, the miners succeeded in obtaining public health insurance and a special pension regime.

But, this was to be a brief respite, as with the demand for natural emery falling, so too the prices would decrease and after the 1960s the price paid by the State was not be enough to sustain the miners, who had to supplement their income from other sources. The erstwhile thriving mining enterprise was demoted to a political field of vote seeking, by opportunist politicians, who promised better times in exchange for the political confidence of the miners. But just as it seemed that maybe there was a new lease of life for emery mining, the USA, regarding emery as a material of strategic importance forbade emery export to the countries of the Iron Curtain.

Despite the financial help from the European Recovery Program, also known as the Marshall Plan, the financial situation in areas far from mainland Greece was rather bleak, as evidence by the massive waves of Greeks leaving for the USA, as well as for other destinations, in hopes of a better future [85][86]. Certainly, post-war Greek economy was improved, compared to 1940 [87], but financial growth rates reflected more the situation in city centres, notably Athens and Thessaloniki, rather than provincial communities and islands. The political instability between 1955 and 1967, as analysed by [88], did not permit for large scale modernisation in many aspects of both everyday life and industrial production. At that time the political situation in Greece could be described as a paternalistic illiberal democracy, deficient in rule of law [89].

Perhaps those who run the mines should have seen the writing on the wall, since estimates in the early 1980s predicted that industrial emery needs in the year 2000 would not exceed 2800 tonnes. One of the principal regulators of emery demand was the USA, which consumed around 4 % of the worldwide emery production in the 1970s. Probably, the last chance for the locals to reverse the terminal decline, were the seven years of the Military Junta, between 1967 and 1974. Political considerations and opinions aside, it was a relatively stable period from a political point of view. In addition, it was a financially prosperous period with the Government fostering industrial growth and private investments, while also working towards a more decentralized government [90]. As happens with most authoritarian regimes, one of the principal aims of the Junta was to promote a highly transnationalized pattern of economic growth [91]. The notable changes in GNP and investment rates created auspicious circumstances for investments. Had there been an initiave from the Naxian mining community it is probable if not likely, that a foreign investment could have been discussed as well as a change in the State monopoly of emery acquisition. It would also have been feasible to construct an abrasive production plant locally, to obviate transport costs, so as to either produce natural

emery abrasives, or use natural emery as a basis for hybrid natural-artificial emery products. Alas, such possibilities would go unexplored too.

The cable railway was not used after 1982, trucks being a cheaper and more convenient mode of transport. Shortly after emery mining decline further still, to the point that it would take place only during the summer months, more as a secondary income source than a main occupation for those miners still remaining. When the mines ceased large-scale operations, they emery reserves were estimated to range between 10^6 and $2 \cdot 10^6$ tonnes. With the current emery demand and the estimated reserves of Naxos, it can be calculated that they alone can cover industrial demands for about 150 to 200 years.

Today, the emery mines are still under the possession of the Greek State, and up until the ceasing of large scale mining activities, only the inhabitants of the surrounding villages could be provided with mining rights. In effect, these miners were all state employees, and were depending upon emery production. Their insurance costs were all borne by the Greek State. Miners could work in self-managed groups but in any case they were obliged to sell their production individually to the State. Characteristically, the expected profits from emery sales in 2015 where estimated to be about $480 \cdot 10^3$ €, or $0.165 \cdot 10^{(-5)}$ % of the country's GNP of 290.2 10^9. In the year 2012, emery production had fallen to 4250 t, only to rise a little, to 4800 t in 2013 [92].

Currently, there are about 400 emery miners, and they mostly work from May to October, hence avoiding the wintertime adverse weather, which can become dangerous especially during heavy rain. While emery production is not even an issue for the rest of the Greek economy, it is nevertheless important, now as ever, for the remaining miners. Nowadays, in light of the tumultuous political situation in Greece, the so-called «emery issue» has donned the mantle of a social problem, where it is linked to the abandonment of the mountainous regions of Naxos. While, undoubtedly, the radical reduction of mining activities has had the aforementioned result, it is not productive to describe it as a social problem. The mines should not work detrimentally to the State, just so they can support the local communities. Rather, the existence of prosperous mines should be the impetus for the creation of sustainable local economy.

IV. DISCUSSION AND CONCLUSIONS:

The Aegean islands have had a long history of mining and quarrying since Ancient times. Indeed, was it not that the illustrious Greek sculptures, adorning sadly not Greek but foreign museums, were made using marbles from Naxos and Paros? Marble quarrying must have been the oldest such activity in the Aegean, dating back almost 2600 years. In general, the mineral wealth of Greece is entirely out of proportion, if one takes into account its relatively small size [93].

Given the wealth of industrial mineral deposits (e.g. [94][95] [96][97]), and of the porphyry and epithermal deposits in the Aegean (e.g. [98][99][100][101]), as well as other types of metalliferous ores (e.g. [102]), the wealth of documented mining activities in the Aegean is understandable. Even the ophiolites of Crete were utilised for pottery production [103]. And, one wonders, how many smaller mining enterprises, from centuries long passed by, still remain to be uncovered?

Conversely, the downfall of the insular mining communities must not come as a surprise. While in Europe a vast road network and infrastructure existed to support Industrial Age mining, the Aegean islands were for many decades lagging in financial, technological and organisational terms. In mainland Greece, there were instances were mining activities spanning over a century - such is the case of Lavrion for example - were the

impetus for the creation of cities and towns, and in other cases, like in Ptolemaida, mining activities continue to this day. But in the Aegean, more parallels can be drawn to the gold rushes of the 18th century rather than to any European precedent. Mines and their associated settlements appeared and disappeared like shooting stars, with their tentative start, the subsequent mining frenzy and abrupt decline constituting a sad daguerreotype of an era long gone.

The emery mines of course did not result in widespread environmental destruction, as has been the case in other mining endeavours (e.g. [104][105][106][107][108][109] [110]), neither the emery itself was inherently dangerous to the health of the miners and the residents, as other industrial minerals, like carbonatites are due to their radioactivity (e.g. [111]) - save for the risks associated with mining. For decades, they provided a part of the Naxian population with an adequate income, albeit it is probable that the miners themselves were always underpaid. Being a state-owned enterprise it was unavoidable that the constant political, financial and social turmoil would upset mining activities, which would also be plagued with a combination of fund shortage and mining knowledge absence.
The Greek State, once more managed to devalue and underexploit a major source of national wealth. The foolish, foolhardy and ineffectual legal and ownership regime failed to motivate the miners and precluded meaningful private investments. Many times did the international industrial and economical situation hinder at the grim future which lay ahead. As many times, it was summarily ignored. Today, the air cable railway, the most prominent remnant of the golden emery mining era, is a now famous landmark of Naxos, and perhaps the only extensive surviving railway system of its kind in the world.

In the end, two questions linger unanswered: how the island of Naxos could have progressed if not for the emery mines and how could emery have been meaningfully exploited? History, of course, should not and cannot be written on assumptions. Neither is always fair and proper to judge past actions in the present with the benefit of hindsight. However, some estimation based on existing data can be made. Regarding the first question, it is more or less probable that after the 18th century, Naxos could have developed an insular economy analogous to Lesvos, Chios or Rhodes, albeit at a smaller scale, had it maintained the populace and the willingness to do so. The second question is a rather more complex one. Even the most commercially successful mining enterprise of the era, the Lavrion mines had in the end devastating effects of Greek economy. Emery deposits of course were, in that era, useful if less valuable per se, and it is not likely that a private mining venture would have had the same results. Even at a later stage it would have been possible for the Greek State to ask for foreign support for its mining endeavours. After all, in the 1910s, French and British foreign committees were frantically reorganising the Greek Army and the Hellenic Navy respectively [112]. It would then not have been so much of a deal to ask for help in industrialising the country. But alas, with the National Division, the First World War, the turmoil of the Interwar Years and the Second World War, the situation in Greece would never be suitable for such endeavours. The emery mines were doomed, owing to a multitude of factors, some avoidable and some not so.

Despite their relative abandonment they could still be made profitable if only there is the necessary public and private will. While the possibility of using the emery mines, the Enaerios and the mining heritage of Naxos as a tourist attraction have not gone entirely unnoticed, this too is a case of unrealised potential. In some tunnels there is the possibility of organised visits while efforts for the preservation of mining buildings and

infrastructure are made, but mainly through individual initiatives, and not by any State-funded endeavour.

In Greece, the legal framework has, as has frequently been the case, lagged behind international standards. Sites of special geological interest were for decades protected only within the context of archaeological site legislation. The concept of geosites was brought into legislative reality recently with the introduction of Law 3937/2011 [113].

There is the lingering question concerning if it would be right to invest such sums, especially given the current situation of the economy in Greece. There are two aspects under which this issue can be analysed. The first, and for many people the most important, is the financial one. While it is true that restoration, conservation and promotion of said geoheritage requires a significant investment, this could well bear fruit even in the short term. It must not be forgotten that Naxos is a prime tourist destination, and while recreational tourism is likely to remain the major source of income for the local society, the possibilities for thematic tourism are also remarkable. Already, quite a lot foreign university students and scientists visit the island, to study its distinctive petrology and mineralogy, as well as its rich history. From a geological standpoint, there exist the migmatites of [114][115], its gem quality corundum deposits [116][117], and its famous marbles [12]. From a historical perspective, there are over 100 archaeological sites, and over 500 monuments, dating from the Byzantine era. Interestingly, the number of monuments with wall painting in Naxos is greater than that of all the other Cycladic islands combined [118]. Surely, such geological, geohistorical, archaeological and historical wealth must be enough to sustain such a venture. It is further possible to contemplate alternative and innovative georoute options such as those proposed in the case of Melos island by [119]. Even, a thematic cruise with stops in major ancient and old mining Aegean centres, namely those mentioned by [74] can be contemplated. At any rate, visits within the mines themselves should be regulated carefully, both for visitor safety as well as for any potential degradation of tunnels due to anthropogenic factors - an analogous case is that of show caves in Greece [120]. Finally, it is possible that the emery mines may fulfil at least some of the criteria, as mentioned by [121], to be included as a World Heritage Site, which will entail significant financial and organisational aid. It is certainly eligible to be included in the catalogue of geosites of Greece, based on the criteria mentioned by [122].

Regarding the cultural aspect, in the words of [123] mines and quarries are «extremely effective as a means of connecting communities with their geoheritage, and in turn, in building the support required to achieve successful geoconservation». In effect, mines represent the material aspect of times long gone by, in that they were used to support distinct socioeconomic entities and in turn were instrumental in shaping them.

As it is, the cable railway and the mines stand vigil as silent witness to a not so distant past, both tragic and glorious, interwoven with the very essence of the Greek psyche and its peculiarities.

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