

**Research Paper**

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**The exploitation of emery on the island of Samos: Existing data and research perspectives.**

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**Abstract**

*The possible exploitation of eastern Samos emery deposits during the antiquity is explored, taking into account the attested emery mining on the island, during the 19<sup>th</sup> and 20<sup>th</sup> c. A.D. Is it possible that Samos diasporitic emery had been used in a similar way with the diasporite and/or corundite emery of Naxos, the main and best known emery source in the Aegean archipelago? As a first step for the investigation of this question, existing geological and historical data on Samian emery are collated and then examined with reference to the Naxian mineral. As far as the mineralogical structure of the Samos emery is concerned, besides the existing data, XRD mineralogical analysis, XRF/ICP major and trace element analysis and SEM-EDS micro-analysis was conducted, in order to recognize specific features of the Samos diasporite deposit. Finally, the few known archaeological findings that may indicate a probable ancient exploitation of the Samos emery are presented, underlining the need of further geological and archaeological research in the Aegean Region and Western Anatolia, in order to draw wider conclusions.*

**Keywords:** Samos, ancient mining, metabauxites, emery, diasporites, ancient tools, REE

### **Περίληψη**

*Το παρόν άρθρο, έχοντας ως αφετηρία την επιβεβαιωμένη εξόρυξη σμύριδας στην Ανατολική Σάμο, κατά τον 19<sup>ο</sup> και 20<sup>ο</sup> αι., διερευνά την πιθανότητα αξιοποίησης των κοιτασμάτων αυτών και κατά τη διάρκεια της αρχαιότητας. Είναι πιθανόν η διασποριστική σύστασης σαμιακή σμύριδα να χρησιμοποιήθηκε στην αρχαιότητα, κατά παρόμοιο τρόπο με τη διασποριστική και κορουνδιακή σμύριδα της Νάξου, της κύριας και καλύτερα γνωστής πηγής σμύριδας στο Αιγαίο πέλαγος; Ως πρώτο βήμα για τη διερεύνηση του ερωτήματος, τα υπάρχοντα γεωλογικά και ιστορικά στοιχεία για τη σαμιακή σμύριδα συντίθενται και εξετάζονται, έχοντας ως σημείο αναφοράς τη σμύριδα της Νάξου. Όσον αφορά τη μελέτη της ορυκτολογικής σύστασης της σαμιακής σμύριδας, εκτός από τα ήδη υπάρχοντα στοιχεία, πραγματοποιήθηκε ορυκτολογική ανάλυση με περίθλαση ακτίνων-Χ (XRD), ανάλυση κύριων στοιχείων και ιχνοστοιχείων με τη μέθοδο επαγωγικός συζευγμένου πλάσματος (ICP) και φασματοσκοπία φθορισμού ακτίνων Χ (XRF), καθώς και μικρο-ανάλυση SEM-EDS. Στόχος των αναλύσεων ήταν η αναγνώριση των ιδιαίτερων χαρακτηριστικών των σαμιακών διασποριστικών αποθέσεων. Στο άρθρο, επιπλέον, παρουσιάζονται τα ολιγάριθμα αρχαιολογικά ευρήματα που ενδεχομένως υποδεικνύουν εκμετάλλευση της σμύριδας της Σάμου κατά την αρχαιότητα. Τα δεδομένα αυτά, ωστόσο, είναι ανεπαρκή για την εξαγωγή ασφαλών συμπερασμάτων. Χρειάζονται πετρογραφικές αναλύσεις αρχαίων εργαλείων σμύριδας με προέλευση τη Σάμο και άλλες περιοχές του Αιγαίου, και της Μικράς Ασίας, προκειμένου να διαπιστωθεί η εξόρυξη και χρήση της σμύριδας της Σάμου κατά τους προϊστορικούς και ιστορικούς χρόνους.*

**Λέξεις κλειδιά:** Σάμος, Αρχαία Μεταλλεία, Μεταβωζίτες, Σμύριδα, Διασπορίτες, Αρχαία Εργαλεία, Σπάνιες Γαίες

## 1. INTRODUCTION

Emery rock is a metamorphic rock which, most researchers agree, developed through the metamorphism of bauxites; thus it is sometimes characterized as metabauxite. In the Aegean Region, this metamorphism is calculated to have taken place during Alpine orogenesis, under HP-HT conditions (Feenstra, 1985; Urai and Feenstra, 2001; Iliopoulos, 2005).

Metabauxites are classified into two general categories, according to the principal constituent elements they contain: metabauxites rich in diaspore [ $\text{AlO}(\text{OH})$ ] (diasporites) and metabauxites rich in corundum [ $\text{Al}_2\text{O}_3$ ] (corundites). Corundites are formed by dehydration of diasporites; they are therefore of higher metamorphic grade (Feenstra, 1985; Feenstra, Urai, and Wunder, 2001; Urai and Feenstra, 2001). Metabauxites, can also contain iron oxides such as hematite ( $\text{Fe}_2\text{O}_3$ ) and magnetite ( $\text{Fe}_3\text{O}_4$ ), and many other accessory phases: micas, tourmaline, kyanite, rutile, staurolite, vesuvianite, pyrite, sillimanite, chlorite, feldspars, apatite and garnets (Nikolaou, 2005).

Corundites are harder (8 to 9 [pure corundum] on Mohs scale) than diasporites (6.5-7.0 on Mohs scale). The term “emery”, in its strict definition, is used for the description of corundites, but in a wider sense, it is used as a synonym for the term “metabauxites”; this wider definition is used in the present paper.

Emery has been used in the Eastern Mediterranean at least since the 5<sup>th</sup> millennium B.C. (mostly diasporite-type at that period), in lapidary and metalworking. In the form of raw material, polished tools or powder, the rock has been exploited for the cutting, piercing and polishing of stones, metals and other materials (Boleti, 2006; Boleti, 2009). Emery is used today mainly as an abrasive, for smoothing metal, glass, wood and minerals surfaces, in sand blasting and as an anti-slipping material in road construction.

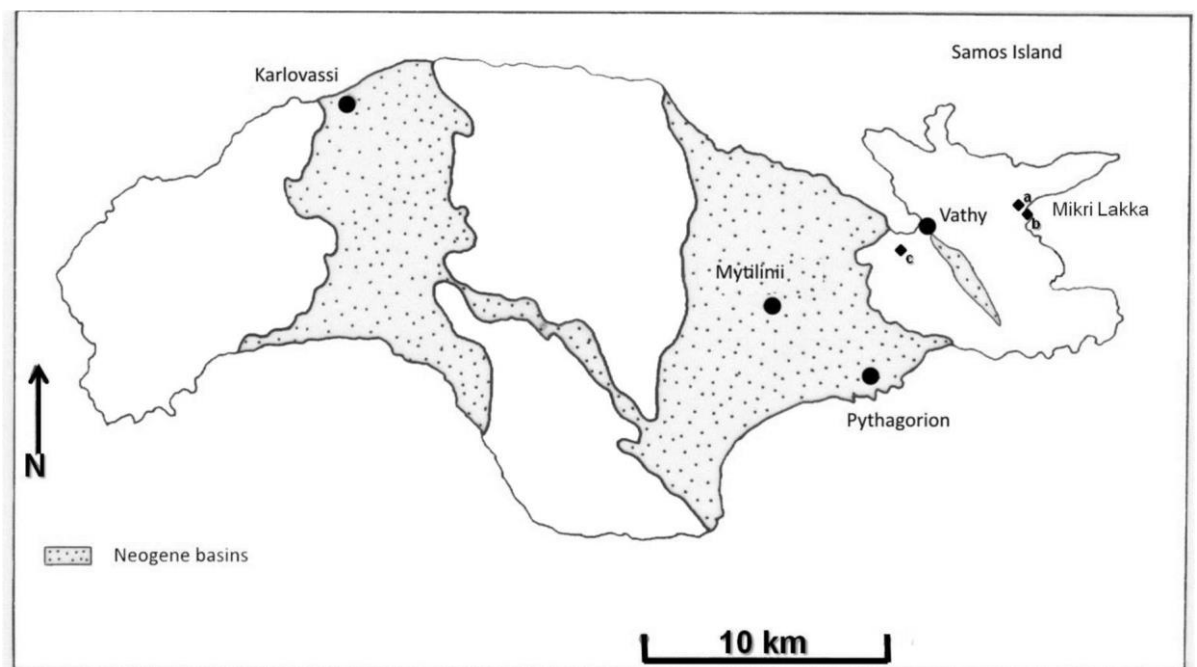
In the Aegean Archipelago, metabauxitic deposits are found in the metamorphic Attico-Cycladic massif. They are widespread in the island of Naxos, while emery can also be found in the islands of Heraklia, Sikinos, Ios, Paros, Samos, and Ikaria. Since the Cycladic complex is correlated to the Minor Asia Menderes complex, the latter also includes rich emery deposits, both diasporites and corundites (Hatipoğlu et al., 2010a; Hatipoğlu et al., 2010b). For correlation of the Cycladic and Menderes complexes, see Jolivet et al. (2004), Gessner et al. (2011).

The present paper focuses on metabauxites, particularly diasporites, located in the eastern part of the island of Samos. Hitherto existing data concerning the geological setting, mineralogy and history of exploitation of Samos emery is collated, while the question of possible Samos emery exploitation, during antiquity, is also raised. Since

the main emery source in the Aegean Archipelago is Naxos, and Naxian emery is the most studied among all emery occurrences in the Aegean and Anatolia, references to the Naxian case will be used as a comparative basis for the investigation of possible Samos emery exploitation.

## 2. GEOLOGICAL SETTING

Metabauxitic deposits are mostly found in the northeastern part of Samos, specifically in the region of Mikri Lakka, in the gulf of Mourtia, east of Vathy (Lapparent, 1937). Another occurrence of minor importance occurs SW of Vathy (see Fig. 1).



**Fig. 1.** Location map of east Samos emery occurrences [Ampelos Unit]: **Mikri Lakka** -old surface and underground quarries, sites **a.**  $37^{\circ} 45'. 32.38''$  N,  $27^{\circ} 01'.22.39''$  E, altitude 47 m and **b.**  $37^{\circ} 45'.21.98''$  N,  $27^{\circ}01'.33.48''$ E, altitude 19m. Road from **Vathy to Pythagorion** – 30 cm-thick bed of emery hosted in a thick succession of bedded marble, site **c.**  $37^{\circ} 44'.02.85''$  N,  $26^{\circ} 58'.38.83''$  E altitude 161 m. (Map by Stamatakis M.).

Metabauxites of Mikri Lakka have a diasporitic composition and form lenses enclosed in calcareous formations (Papanikolaou, 1979). The underlying beds consist of gray-black microcrystalline calcite marble. The footwall boundary between the metabauxite and the marble is intensively brecciated and calcite, diaspore, and muscovite are the major minerals present (see Fig. 2)



**Fig. 2.** Massive diasporitic emery from Mikri Lakka, Samos. Microfragments are filled with secondary calcite. (Photo by Stamatakis M.).

Hematite, rutile, chloritoid, REE-bearing carbonate minerals (bastnäsite, parisite), monazite and a recently defined mineral, gramaccioliite-(Y), a member of the crichtonite group, are also locally present in alteration zones (Theye et al., 2010). Above the emery bed, a thin-bedded layer of black crystalline limestone occurs, partially covered by Quaternary red soils, up to 1 m. thick (Aronis, 1950).

The emery reserves in Mikri Lakka are calculated to be ~35.000 tons (Dimou et al., 2006). In addition to the Mikri Lakka diasporite emery deposits, small corundite emery deposits of negligible commercial interest are located NE of Kallithea village (old Kalampachtasi) in western Samos (Mposkos, 1986). According to Gessner et al. (2011), all emery deposits occur as lenses, hosted in carbonate rocks of the Ampelos Unit.

### 3. MINERALOGY OF THE DEPOSITS IN MIKRI LAKKA

#### 3a. Existing data

The metabauxitic deposits of Mikri Lakka in eastern Samos are chloritoid-bearing diasporites, often with a characteristic pisolitic microstructure, comparable with the

metabauxites of SE Naxos (Lapparent, 1937; Feenstra, 1985, 30; Mposkos, 1986). The prevalence of diasporite, instead of corundum, in the Mikri Lakka emery is responsible for its inferior quality when compared to that of NE Naxos. In his study of 1937, Lapparent had noted the lack of corundum in the deposits of Eastern Samos, and had indicated that their hardness is due to the diasporite and iron oxides (hematite) or hydroxides they contain. Based on this, he proposed to call the Samian rock “samosite” and not “emery” (Lapparent, 1937). Variable amounts of rutile, anatase, kaolinite, paragonite, calcite, the micas muscovite and margarite, are also mentioned, and in some samples, minor chlorite, tourmaline, biotite, gibbsite, spinel and ilmeno-corundum (Lapparent, 1937; Mposkos, 1986).

Feenstra (1985, 113-4) also notes the existence of a very rare secondary mineral, högbomite, in Samos diasporites, particularly occurring in the lower contact zone between the diasporite and marble. It is directly related to green spinel and appears to be a more regular accessory in Samos than in the Naxos metabauxites. Höbgomite in Samos diasporites can be distinguished from that of other islands (e.g. Naxos, Ikaria) by the dominance of zinc in its composition (zincohögbomite) (Feenstra, 1997; Iliopoulos, 2005). However, the presence of these minerals does not affect the bulk diasporite chemistry, as the ICP analysis also proves (see Zn content in Table 2).

Macroscopically, the diasporites of Mikri Lakka can be distinguished by their bluish gray (lower parts) to brownish gray or variegated color (upper parts) and their fine grained composition that allows them to break into makro-prismatic bodies (see Fig. 3) and micro-prismatic, blade-like fragments with very smooth surfaces (see. 4 & 5).



**Fig. 3** A view of the interior of the central gallery on the easternmost (point **a** in Fig. 1) diasporite occurrences. The hard pinky diasporite emery ore body is confined between brecciated limestone beds (upper and left part of the figure), due to tectonic deformation. The diasporite mass exhibits a macro-prismatic system of orthogonal to conjugate joints that is responsible for the prismatic form that the hand specimens have. (Photo by Kotopoulou Ilektra).





**Figs 4 & 5.** Micro-prismatic, blade-like fragments of emery from Mikri Lakka. (Photo by Stamatakis M.).

According to Mposkos and Perdikatzi (1981), the other emery deposits located in west Samos contain corundum along with primary diasporite and chloritoid. In contrast to the eastern Samos diasporites, where there is no presence of ilmenite, and rutile is the main titanium carrier, in W Samos emery the main titanium bearing mineral is ilmenite. Additionally, while the E Samos diasporites are characterized by the prismatic fracturing, the W Samos emery is schistose in only a few samples. Mineralogically, they can be compared with the metabauxites in the diasporite-corundum transition zone of Naxos (Zone II & III according to Feenstra, 1985. For the zones of metamorphism in Naxos, see also Jansen, 1977).

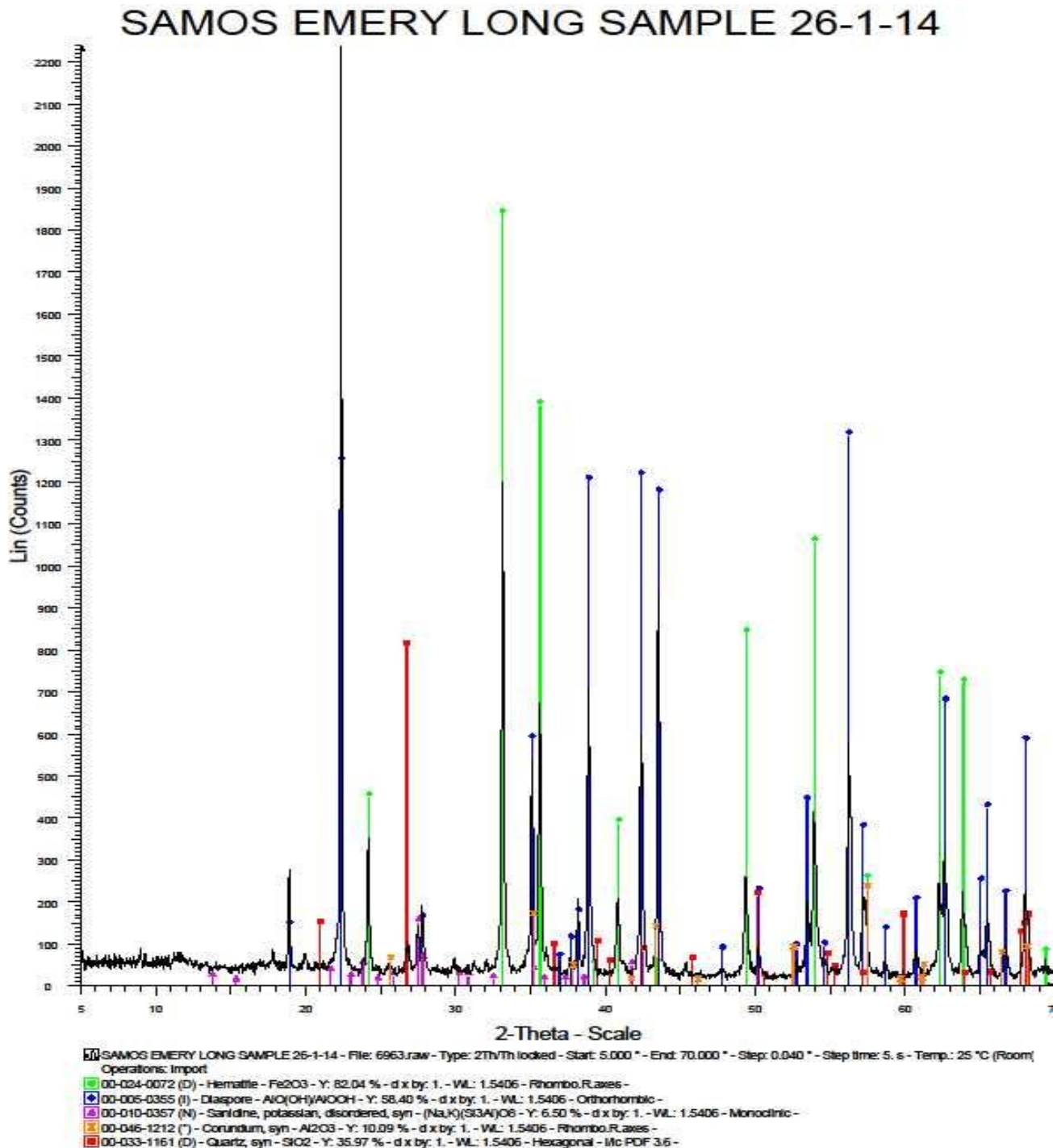
### **3b. Analytical techniques and results - XRD, XRF/ICP and SEM\_EDS Analysis**

To augment existing data on microstructure, mineralogy and geochemistry, we completed further analysis of the diasporites of eastern Samos.

Mineralogical analyses of representative ground Mikri Lakka diasporite samples were performed by TITAN SA cement plant, in Kamari Viotia and in NKUA Department of Geology & Geoenvironment laboratories. The new data confirm that the major mineral



phase is diaspore, followed by hematite and muscovite. Quartz and feldspars are also present in minor amounts. Corundum is detected in trace amounts in a few samples (Fig. 6)



**Fig. 6.** XRD pattern of a representative emery sample of Mikri Lakka.

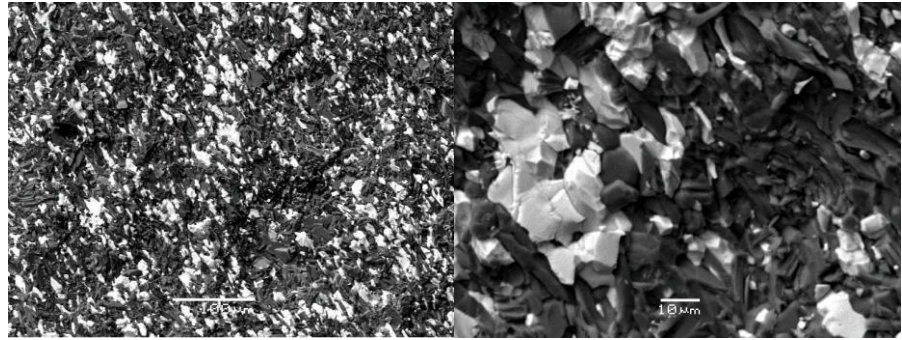
Chip samples were prepared and examined with SEM-EDS techniques in NKUA, Department of Geology & Geoenvironment. The microprobe analysis is shown in Table 1 and the SEM images are presented in Figs 7 to 12. Micro-analysis revealed that

Samian diasporites are characterized by the presence of titanium-rich hematite and disseminated crystals of Ce-monazite.

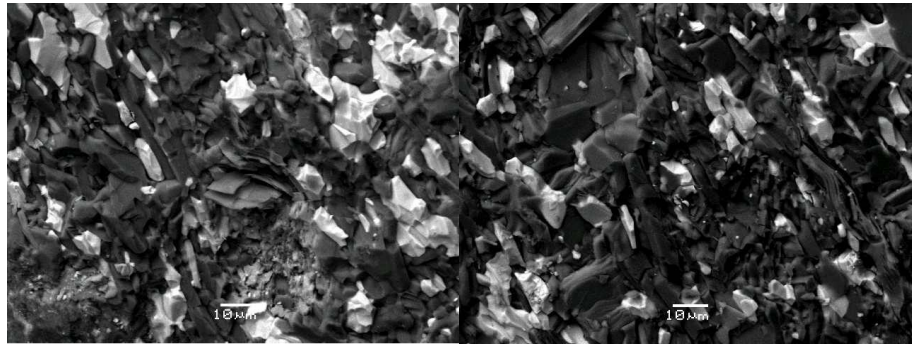
As shown in Table 1, the main minerals identified by SEM analysis were diaspore, Ti-rich hematite, muscovite and Ce-monazite.

Oxides %	Ti-rich hematite	Diaspore	Muscovite	Ce-monazite
Al <sub>2</sub> O <sub>3</sub>	0.74 - 0.77	71.45- 80.54	33.12 - 36.56	4.67
Fe <sub>2</sub> O <sub>3t</sub>	91.86 - 94.57	1.48 - 3.36		
SiO <sub>2</sub>		1.91 – 2.21	44.52 – 45.24	
TiO <sub>2</sub>	5.33 - 5.50	0.33 - 0.68		
P <sub>2</sub> O <sub>5</sub>				19.84
CaO				0.47
Na <sub>2</sub> O			0.41 – 0.91	
K <sub>2</sub> O			8.68 – 10.27	
La <sub>2</sub> O <sub>3</sub>				12.50
CeO <sub>2</sub>				26.11
Nd <sub>2</sub> O <sub>3</sub>				7.23
ThO <sub>2</sub>				1.12

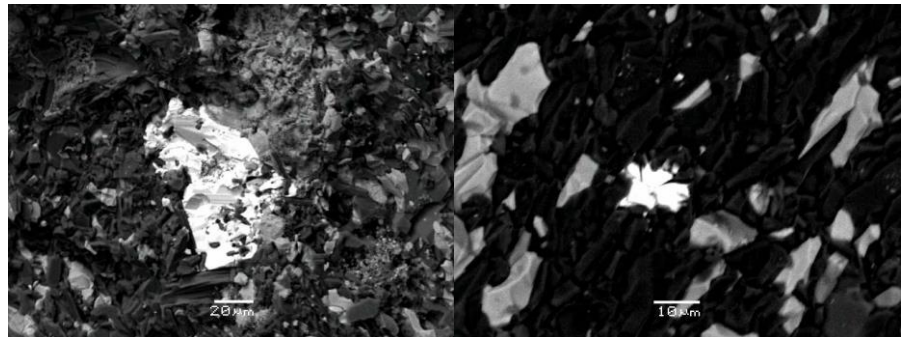
**Table 1.** SEM-EDS microanalysis of Samos emery.



**Figs 7 & 8.** Titanium-rich hematite subhedral crystals [light gray] disseminated in platy diaspore subhedral crystal aggregates [dark gray].



**Figs 9 & 10.** Titanium hematite [light gray] prismatic crystals and irregular aggregates hosted in a flaky muscovite/prismatic diaspore groundmass.



**Figs 11 & 12.** Ce-Monazite [bright white] isolated micro crystal hosted in a titanium-rich hematite [light gray] and diaspore [dark gray] groundmass.

Major elements in 4 samples were analysed by XRF (TITAN SA), and the same samples were analyzed by ICP for trace elements.

The main characteristic is the predominance of between 50-70% alumina:  $\text{Fe}_2\text{O}_3$  ranged between 10-26% and titanium oxide between 2.5-2.7% reflecting the diasporite and Ti-rich hematite mineral content. Importantly, the presence of the Ce-rich monazite provides relatively high REE content of the bulk samples [Nb, Ce, La, Y, Nd, Ne] and also Th (see Table 2 and Fig. 6)

<b>Mikri Lakka Samos</b>				
<b>XRF major elements analysis</b>				
	<b>Diasporite- 1</b>	<b>Diasporite- 2</b>	<b>Diasporite- 3</b>	<b>Diasporite- 4</b>
$\text{SiO}_2$	7.00	6.7	2.15	4.04
$\text{Al}_2\text{O}_3$	67.58	68.54	52.66	54.67
$\text{Fe}_2\text{O}_3$	11.37	10.24	26.04	22.37
CaO	0.16	0.15	0.01	0.08
MgO	0.23	0.25	0.01	0.01
$\text{K}_2\text{O}$	0.62	0.54	0.38	0.42
$\text{Na}_2\text{O}$	0.01	0.01	0.16	0.23
$\text{SO}_3$	0.01	0.01	0.00	0.00
$\text{P}_2\text{O}_5$	0.02	0.02	0.04	0.03
$\text{TiO}_2$ %	2.63	2.57	2.71	2.77
MnO %	0.04	0.03	0.04	0.04

LOI %	10.16	10.70	15.70	15.14
Total %	99.83	99.74	99.90	99.80
<b>ICP trace element analysis</b>				
V ppm	303	240	265	280
Cr	246	902	276	303
Ni	127	128	118	123
Zn	169	158	165	153
Ga	87	82	85	88
Zr	543	579	558	561
Ba	107	272	166	179
La	164	144	153	167
Ce	282	265	276	259
Nd	96	90	82	98
Th	37	31	32	38
Y	44	45	43	49
Nb	55	54	52	56
Pb	56	52	58	53
Zn	166	152	159	161
Co	46	40	42	38
Sb	7	6	6	5
Ga	89	80	88	85
Rb	64	58	67	62
Sr	27	54	46	48
Sn	11	12	11	12

Cu	25	21	22	24
Ne	85	80	87	89
As	3	3	3	4
Se	4	3	3	3
Tl	19	17	16	14

**Table 2.** XRF major elements & ICP trace elements in 4 samples of eastern Samos diasporites. According to Rietvelt method, the mineral content of the samples varies as follows: diaspore 70-80%, hematite 15-28%, other minerals 2-7%.

The above analyses, combined with previously published data, help constrain the composition of emery deposits in various areas of the Aegean Archipelago and W Anatolia. We suggest the high percentage of diaspore, the Ti-rich hematite content and the relatively high REE contents described above will help identify Samian provenance for stone tools found in archaeological contexts in Samos or other sites of the Aegean.

#### 4. EXPLOITATION OF SAMOS EMERY: HISTORICAL SOURCES

Exploitation of Naxian emery from antiquity until the modern era is well documented, but for Samian emery secure data is sparse, excepting efforts to exploit the mineral, during the Samian Hegemony (1834-1912). This brief period of mining enthusiasm was manifest in Samos as small quarries and mines that were quickly abandoned. This short lived enthusiasm is captured in a brief article of the local newspaper “FOS”, on the 31<sup>st</sup> of August 1897 (The mines, 1897).

A “Samian Mining Company” was established in 1873, but was very soon dissolved because of inadequate share-capital (Belavilas and Papastefanaki, 2009). Epameinondas Stamatiadis (1886, 439-440), author of “Samiaka” and honorary trustee of the company, describes emery mining on the mountain Kerkis, during the years 1847-49 and 1860-1. Generally, the existence of emery on Samos is a common reference in writings of the 18<sup>th</sup>, 19<sup>th</sup> and early 20<sup>th</sup> centuries (Tournefort, 1741, 98; Fenning and Collyer, 1766, 305; Dearborn, 1819, 247; Brewster, 1830, 541; Fleming 1838, 402; Kritikidis, 1869, 120; Smith, 1878; Pratt, 1906, 156; Jacob, 1928). From a publication of the local Samian newspaper “EYNOMIA” on mining licenses in Samos (Emery mine concession, 1898), there is a description of an attempt to sell an emery mine on the mountain Kerkis, specifically in the area Kalambachtasi (now village Kallitheia), to the

main emery trading company of Smyrna, “Wiltel, Wilkenson & Co”. Other sources mention the existence of emery mines at Demenaga and Koumaritsa at Kalambachtasi, from where only small quantities of emery were extracted, because of the transportation difficulties (Dimou, 2006).

There is, however, good evidence for the exploitation of the diasporitic deposits of Mikri Lakka. Even today three mine galleries can be seen there, (Fig. 13) and the remnants of rails used for transportation of the mineral are still visible leading from the mines to the shore.



**Fig. 13.** Shallow galleries of emery mines in Mikri Lakka. (Photo by Stamatakis M.).

At the seashore, a quantity of diasporitic fragments can still be found piled up next to a roughly built loading platform (Fig. 14).



**Fig. 14.** Emery still waiting to be loaded on the seashore of Mikri Lakka. (Photo by Stamatakis M.).

According to the Samian State Archives, the mine exploitation permission had been assigned to Stamatios G. Stamatiou and later to his son. During the period 1906-1914, 5.000 tons of mineral were extracted and exported to France, Germany, Austria and USA. It was characterized as emery of inferior quality and it was sold at a price of 25 drachmas/ton, when the price for the Naxian emery was 80-115 drachmas/ton, at that time. The mines of Mikri Lakka were also quickly abandoned (Belavilas and Papastefanaki, 2009).



## 5. DISCUSSION

### 5a. Insight into diachronic exploitation of emery: context from the Naxos exploitation history

In order to investigate the possibility of a diachronic exploitation of Samian emery, it is useful to understand the context from the Naxian case, which is the best known and best studied in the Aegean archipelago<sup>i</sup>.

Although there is no evidence for an ancient emery mine on the island of Naxos<sup>ii</sup>, literary sources and archaeological findings indicate that extraction occurred during antiquity. The exploitation of Naxian emery and its exchange networks can be traced back to Neolithic times (5<sup>th</sup> m. B.C.). In these times, diasporitic emery was mainly used for production of polished cutting tools (axes, adzes, chisels) alongside percussion and other tools utilizing the lower quality mineral. By the 3<sup>rd</sup> m. B.C., it is assumed that emery tools were used for the production of the protocycladic statuettes (Casson, 1933, 19; Oustinoff, 1984; Getz-Preziosi, 1994, 50-51).

Later, during the Geometric era, in the Oligarchically organized Naxian society, power seems to have been in the hands of those who took advantage of the fertile earth and the two major Naxian prime materials: marble and emery (Zafeiropoulou, 2006). During the archaic period, emery used as an abrasive, seems to have been the means that allowed sculptors to create the technique of very elegant sweeping lines in statue drapery, a technique that is also observed in Samian statues of the same period (Casson, 1933, 98ff).

The exploitation of Naxian emery continued during the classical and Hellenistic period, as confirmed by ancient authors who use the term «ναξία ακόνη»<sup>iii</sup> (Naxian whetstone) to refer to the mineral. The same term was still in use in the first centuries A.D. Pliny the Elder (1855), in *Historia Naturalis* 36.9-10, is the first known ancient author to mention the use of sand from Naxos and other places in combination with a saw for cutting marble; he also underlines the long standing use of this sand for polishing marble statues, cutting and polishing precious stones. The medical uses of emery mentioned by authors of the roman era are impressive. Dioscorides (2000, 825), in *De materia Medica* V.5 168, mentions that Naxian whetstone can help hair regrowth after alopecia, impedes premature growth of breasts in girls and testicles in boys, and also has beneficial properties for epileptics. It is interesting, though, that he distinguishes the Naxian whetstone from emery, for which he underlines a use in antiseptic and caustic medicines and for moist gums and cleaning teeth.

Little is known about the exploitation of Naxian emery during the middle Ages. During the Frankish domination, references to emery and emery mining indicate that the mineral and its mining right belonged to the feudal lord of the area. During the Turkish domination, after long-lasting struggles of the poor orthodox peasants that inhabited the Naxian villages, the mining rights became their privilege (Kotsakis, 2005). At about that time (at least since the 17<sup>th</sup> century), European travelers and the Jesuits of Naxos, inform us that “smyrigli” (the Naxian name for emery) was once again export trade merchandise to Smyrni, Venice and Marseilles. Until the 18<sup>th</sup> c. though, emery seems to be a material of low price. In 1700, Tournefort mentioned that Naxian emery was so cheap that it was sold as ballast for English ships. The increase of its use in European industry naturally caused the recovery of its price. Literary sources of the 17<sup>th</sup> century say it was used at that time in the arms industry for cleaning rotten swords, while emery powder was also very important for manufacturing telescopic lenses, grinding steel needles and producing glass (Slot, 2008; Slot, 2013). In the early 19<sup>th</sup> century, emery became property of the Greek State, and emery mining was defined as an exclusive privilege of the villagers of the Municipality of Apeiranthos and Koronos. Even today, these villages are the only ones that can mine, transport and deliver emery to the Greek State (Archontakis and Giannoulis, 2001, 87).

Emery was a mainstay of Naxos’ prosperity mainly for the first half of the 20<sup>th</sup> century (Archontakis and Giannoulis, 2001; Archontakis and Giannoulis, 2006). Emery, after being extracted, was transported to Moutsouna port, in eastern Naxos, by donkeys, for loading into barges for transport to Greek or foreign markets. Between 1926 and 1929, the construction of “Enaerios” enabled the transportation of emery from the mines to Moutsouna. “Enaerios” is an aerial system of transportation using wire ropes and buckets (Polyzos et al., 1997). It began functioning in 1929 and consisted of 72 pylons, wagons, buckets, loading installations, engine rooms and depositories (Balodimou, 2005). This aerial system of transportation is one of the few that still exist in Greece. It was in use until 1978, when it became uneconomic (Fragkiskos, 2006). Since then, emery has been transported with trucks.

### **5b. Possible exploitation of Samos emery during antiquity**

The island of Naxos has long been the main emery production centre of Europe. Crucially emery is considered to have played a decisive role in the development of Greek sculpture (Casson, 1933). The creation of valuable stone artifacts like the proto Cycladic statuettes (Casson, 1933, 19; Oustinoff, 1984; Getz-Preziosi, 1994, 50-51),

the stone vessels in the Bronze Age Mediterranean (Betancourt, 1990; Bevan, 2007), the Cretan-Mycenaean seals (Younger, 1981; Boulotis, 1983), and later engraved gems (King, 1866, 103-107, 112-117, 472-5; Caley and Richards, 1956; Lazarov, 2008) and the famous marble statues of the archaic period are all connected with the use of emery (Philaniotou, 2006).

The large quantities of emery on Naxos, but also the prevalence of metabauxites rich in corundum are the two reasons that made Naxos the main emery source in the Archipelago. Especially during the industrial era, when emery was mainly used as an abrasive or anti-slipping material, corundum gave the mineral its value. Even today qualities of emery are classified according to the quantity of corundum it contains: 55-65%, in the highest quality, 50-55%, in the secondary quality, and finally < 45% for the lower quality (Nikolaou, 2005).

However, comparative analysis of archaeological material (Boleti, 2009; Boleti, 2013), suggests the evaluation criteria have changed through the ages. Metabauxites rich in diasporite were the first to be exploited during prehistory, being easier to find than metabauxites rich in corundum. It is thus possible that Samos diasporites were exploited during ancient times, for local or more general use. It is interesting that P. Warren, who has identified powdered emery residue in manufacturing debris from Minoan Crete, proposed either Naxos or Samos as its provenance (Warren, 1969, 190).

In order to address the above question, the uses of metabauxites during antiquity need to be understood. Archaeological material dated to the Late Neolithic/Final Neolithic and Bronze Age in the Aegean (Boleti, 2009; Boleti, 2013) indicates likely usage of metabauxites rich in corundum, for the construction of millstones and percussion tools used for working with hard materials (for this type of emery tools see also Boleti, 2014). In the form of powder/sand they were used for cutting purposes in combination with saws (for the use of powdered emery with toothless saw, also see Lambraki, 1983), for drilling, in combination with drills, and for polishing, most probably since the Middle Bronze Age period. Diasporites, on the other hand, being hard but less tenacious, can be easier broken into smooth blade like surfaces for the creation of sharp tools such as axes, adzes and chisels. These diasporitic polished tools were suited to working wood and maybe also bone and marble (Boleti, 2013).

The diasporitic polished tools, found both in prehistoric sites of the Cyclades and Anatolia (Boleti, 2009), seem to constitute a common cultural element between the two regions. The production of diasporitic polished tools had probably been the privilege of the inhabitants of certain settlements situated near diasporitic deposits. Latmos, for

example, situated in Anatolia, may have been a centre of diasporitic tool production. On the island of Naxos, (A)Malia, near the NE coast, may well have been a similar tool production centre. Craftsmen of (A)Malia could have possibly obtained their raw material from the diasporitic deposits situated in the vicinity (Boleti, 2009).

Taking into account, the importance of diasporitic metabauxites since Neolithic times, the possible exploitation of Samos diasporites by the inhabitants of the island seems reasonable to infer. Would the Samians have taken advantage of the local deposits or used emery coming from the rich and widely exploited deposits of Minor Asia? The cultural uniformity of early Bronze Age eastern Aegean islands and Anatolia, and the cultural interaction between these areas, Cyclades, Mainland Greece and Crete (Kouka, 2013; Kouka, 2014a; Kouka, 2014b) must be taken into account while debating this issue. As diasporitic prehistoric tools constitute a common cultural attribute between Naxos and Anatolia, it is not unlikely that Samians, living on a geographical bridge between the two regions, also shared the same know-how. This inference might be best considered in the context of the expansion model for the colonization of the Cyclades from the SE Aegean (Broodbank, 1999; Broodbank, 2000).

An additional argument that might support ancient exploitation of Samian diasporites is the large number of ancient quarries on the island. A use of diasporite for smoothing soft rocks (limestone, marbles, schists) is possible. Furthermore, on Samos, as on Naxos, a school of sculpture made its appearance in the 7<sup>th</sup> c. B.C. that used a special technique for the creation of elegant drapery striations. This technique is connected by St. Casson (see also 5a) with the use of emery tools. Finally, the engraving of gems, as exercised in Samos during the Polycrates' era and traditionally connected with the famous architect Theodorus (King, 1866, 10; Lazarov, 2008), could possibly have been effected with local diasporites, in case of gems being not of the hardest compositions.

### **5c. Evidence of exploitation of Samian emery in antiquity and Middle Ages?**

As far as the ancient and medieval times are concerned, only a few scattered findings point to an exploitation of Samos metabauxites. Two prehistoric stone tools, exhibited at the new Archaeological Museum of Pythagoreion in Samos, macroscopically resemble diasporites of Mikri Lakka (observation made by Stamatakis M.). This poses questions about the provenance of raw materials and demands further detailed study and petrographic analysis. In addition, the occurrence of numerous rock splinters, 8 to 10 cm in length, sometimes with worn-out ends, is mentioned by the German

archaeologist Robert Heidenreich, as a remarkable finding from the Neolithic Tigani. Heidenreich (1935, 171) recognizes their prime material as hematite and suggests these fragments could have been used as burnishers during the production of burnished pottery. These hematitic fragments arouse suspicions about a possible coincidence of their raw material with the Mikri Lakka metabauxites that are known to break into blade-like fragments and contain a high percentage of hematite.

Another finding possibly connected to Samian diasporites is a round-faced object (diameter 46 to 53 mm) from the protopalatial phase of the palace at Malia, Crete. It proved to be made of “emery without corundum”, according to the petrographic analysis of IGME, who proposed Samos as a possible provenance (Pelon, 1983, 692, Fig. 17).

Finally, a discovery in NE Samos also poses questions about possible exploitation of Samian diasporites, during the Byzantine era. In 1983, the incidental finding in Megali Lakka (situated next to Mikri Lakka), of a Byzantine hoard containing 300 Byzantine coins (Tsakos and Viglaki, 2012, 347), dating from Maurice to Heraclius, together with two pairs of gold earrings, led archaeologists to trace a hitherto unknown archaeological site. Byzantine graves, a building complex with semi submerged foundations, metallic objects and sherds dating from the Roman to the Byzantine era, are some of the findings mentioned in the publication of Megali Lakka exploration (Oeconomides and Drossoyianni, 1986; Caramessini-Oeconomides and Drossoyianni, 1989).

Among these findings many scraps of emery were mentioned; it is unknown, though, whether they were extracted recently or if they are in some way connected to the Byzantine findings. A detailed study of the semi submerged building complex in Megali Lakka is certainly needed so that its character and a possible connection to the nearby emery deposits is clarified.

## 6. CONCLUSIONS

The modern characterization of the Samian diasporites as emery of “secondary quality” opposes the historical and archaeological data that indicate an extensive use and importance of diasporites, at least during prehistory.

The various archaeological findings and the existing data relative to them are at present insufficient to draw firm conclusions about an ancient exploitation of Samian emery. Since no other references to archaeological findings made of emery have been traced,

further investigation of unpublished material from the Samos excavations is needed. One could first look for a possible existence of diasporitic tools among material coming from the prehistoric settlements at Tigani (for the prehistoric settlement of Tigani, see Felsch, 1988) and Heraion (for the prehistoric settlement of Heraion, see Miložčić, 1961; Kouka 2012; Kouka, 2013; Kouka, 2014a; Kouka, 2014b), whose inhabitants had possibly taken advantage of the Mikri Lakka deposits. If such tools are found, petrographic analysis is needed to confirm or reject a provenance from Mikri Lakka. Additionally, the comparison of existing and/or new petrographic data of diasporitic tools found elsewhere in the Aegean Archipelago and W Anatolia (for a corpus of LN/FN and Bronze Age emery tools see Boleti, 2009) with the Mikri Lakka diasporites data could support or exclude the possibility of a Samian provenance and clarify whether this raw material was included in the trade networks of Samos, especially during prehistoric<sup>iv</sup> but also during historic times<sup>v</sup>.

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<sup>i</sup> For a recent critical synthesis of already available and new data (geological, petrographic and mineralogical, literary, historical, archaeological, experimental and ethnographic), as well as for the set-up of a methodological basis for a global approach for the study of emery exploitation applicable regardless of geo-cultural contexts, see Boleti, 2009.

<sup>ii</sup> An emery quarry at Kızıl Çağ ıl Tepe, in the territory of Aphrodisias, approximately 4.0 m deep and 5.0 m wide, seems to be ancient and can give us insight into the form of emery mines during antiquity (Long, 2012, 176-7 and 199).

<sup>iii</sup> The term «νάξια ακόνη» has been interpreted in various ways, provoking confusion on the provenance of this whetstone. So, Pindar’s scholiast and Suda suggest the mineral comes from the Cretan town Naxos, an opinion accepted by Adamantion Korais (Korais, 1835, 234).

<sup>iv</sup> For the Samos trade networks during the 4<sup>th</sup> and 3<sup>rd</sup> m. B.C., see Kouka, 2014a. For the relations of the islands of the Aegean with Bronze Age Crete, see Niemeier, 1984; Niemeier, 2009; Davis, 2001.

<sup>v</sup> An overview of the commercial relationships of Samos during antiquity can be found in Tsakos and Viglaki, 2012.