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KAOLINIZED ROCKS ON THE ISLAND OF LESBOS (GREECE)

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ABSTRACT

A description is given of the mineralogy and geology of the kaolin deposits of Lesbos (Greece) which are caused by the action of hydrothermal fluids on volcanic rocks, lavas and tuffs, having dacitic, rhyodacitic, latitic, andesitic, etc. chemism.

The major deposits are *Magaros-Arghenos, Aspres Petres, Stipsi* and *Mesotopos;* the first three are located in the northern part of the island, near the centre of Petra, the last one near the southern coast and the centre of Mesotopos.

Inside these deposits, through diffractometric and thermal (DTA and TG) methods and direct E. M. and S. E. M. observations, the following minerals were detected: kaolinite (type from pM to T), smectite (montmorillonite), a mixed-layer mineral of the I-MO type, open-layer illite, alunite, jarosite, cristobalite and marcasite, surely newly-formed, while quartz and feldspar are to be considered as "residual".

On the whole, the deposits of Aspres Petres and Mesotopos show a rather homogeneous mineralogy, where the always present kaolin minerals can be associated with sulphates, alunite and jarosite, or with silica phases, quartz and cristobalite; the remaining deposits, instead, feature a significant "zoning". The latter has kaolin in the central part while, at the periphery, essentially smectitic minerals can be noted, mostly associated with feldspar and sometimes illitic.

This diversity of alteration products is to be ascribed to the different degree of alterability and thus of acidity of the fluids altered. Indeed, the different rock permeability due to differentiated porosity and fracturing as well as temperature variations, allow the same fluids to undergo modifications, including the hypothesis of becoming enriched with ions derived from the same rocks subjected to alteration.

The chemism of the original rocks does not seem to have determined any substantial influence on the formation of the altered terms.

Finally, all the deposits formed "in situ" fall within the typical deposits resulted by the actions of hydrothermal fluids connected with a late volcanism. Additionally, they are arranged along the structural alignments typical of the island and of the adjoining region of Asia Minor (Turkey).

INTRODUCTION

It has been known for a long time that the island of Lesbos has first quality clays which resulted in mining processes of a certain interest. These special clays were used above all as refractory material and also, at times, for white cements with satisfactory results..

Although the industry used such materials and they were commonly referred to as "kaolin", there was no knowledge on their actual mineralogical composition.

This work purposes to cover this aspect by providing some essential data.

There are no recent deep studies on the island of Lesbos with the exception of those conducted by PRAGER [1966], which refer above all to the petrographic aspects of outcropping volcanites and by KANARIS [1976], who was the first to consider the kaolin deposits, supplying some data on their mineralogy, ore deposits and also on geological aspects. Except for von HAUER [1873] and FOUQUE' [1894], DE LAUNAY

[1897] was the first to provide detailed indications and petrographic descriptions on the island rocks. Other studies were made by PHILLIPSON [1910], with new interpretations to the geologic maps of the previous authors.

More recently, GEORGALAS [1949] studied some volcanites on the island, providing further chemical and petrographic indications. Furthermore, MARINOS [1953] described the deposit of Aspres Petres, considering the clays as refractory material.

Finally, geologic maps of the island are available on a scale of 1 : 50 000, published by the National Institute of Geologic and Mining Research of Greece (I. G. M. R.) in 1974.

GEOGRAPHIC ASPECTS

The island of Lesbos or of Mytilene belongs to Greece and more specifically to the group of islands of the northern part of the Aegean Sea. It is located 10 km from the Turkish coast and about 250 km north-east of Athens *(Fig. 1)*. It has a surface area of 1630 km² and it is the largest island among those of the northern Aegean Sea.

The island is like a right-angle triangle, where the longest side has a NW-SE direction. There are two important gulfs, Kalloni and Yera; the former allows the island to be divided in two areas, North-West and South-East, respectively.

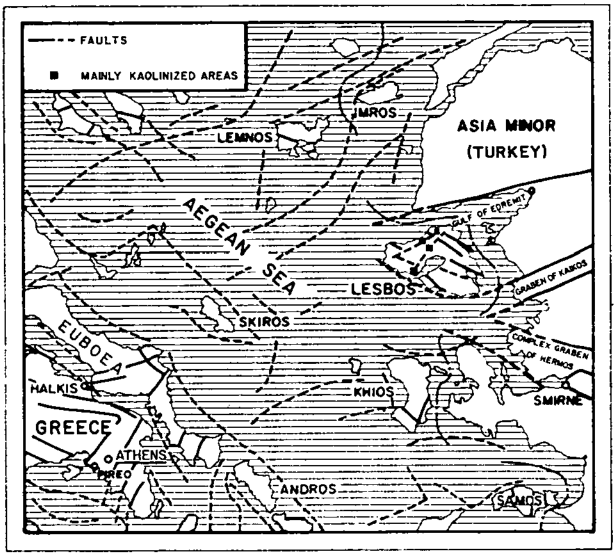

Fig. 1

GEOLOGICAL ASPECTS

The oldest outcropping rocks which form the island substratum are essentially made up by re-crystallized limestones of a white, gray and at times bluish color, of phyllitic rocks interbedded with arkoses and sandstones, sometimes with green schists, etc. The age attributed to this complex is from the Upper Carboniferous to the Permian *(Fig. 2)*.

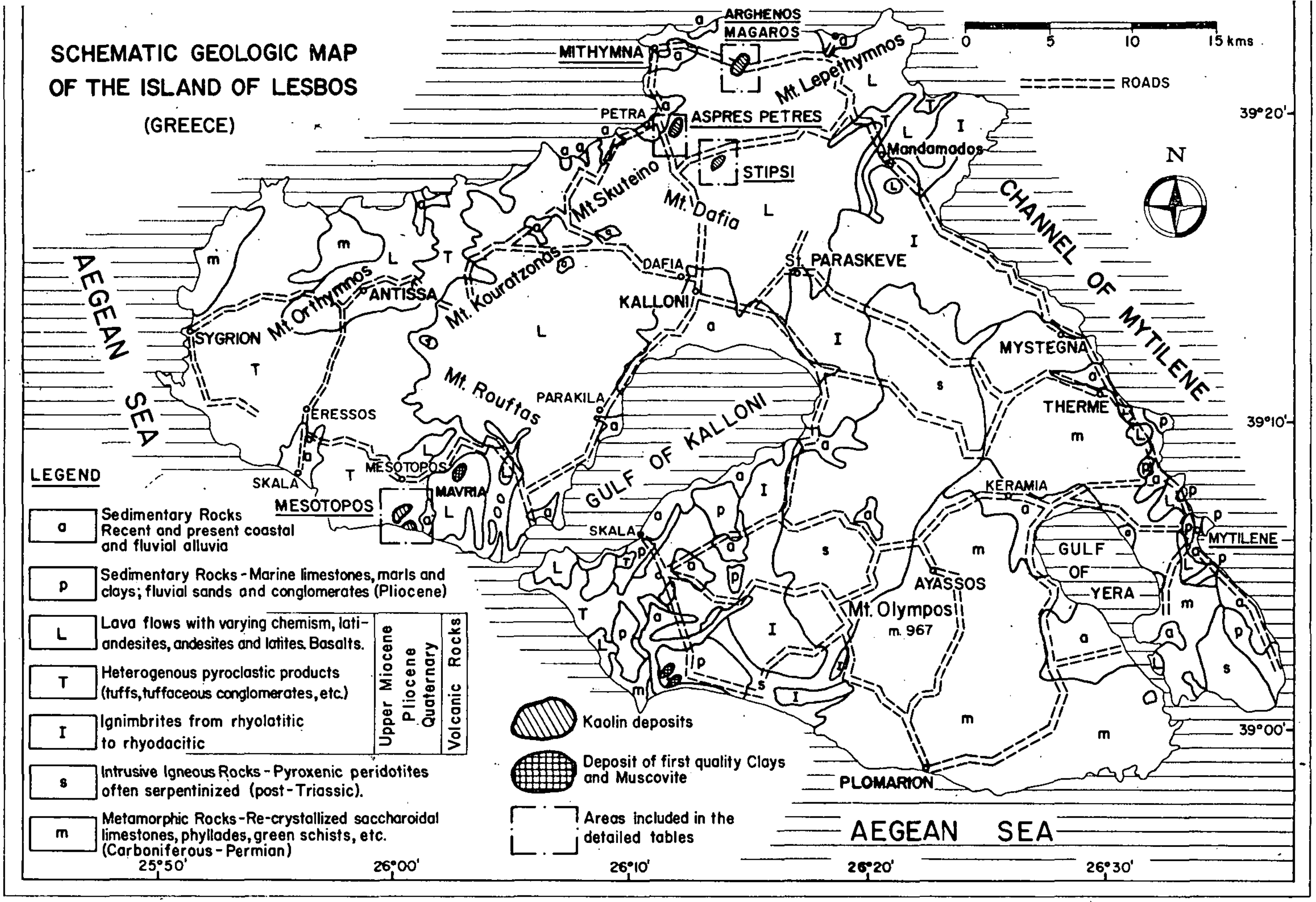
SCHEMATIC GEOLOGIC MAP
OF THE ISLAND OF LESBOS
(GREECE)
0 5 10 15 kms
ROADS
N
ARGHENOS
MAGAROS
MITHYMNA
Mt. Lepethymnos
PETRA
ASPRES PETRES
STIPSI
Mandamados
CHANNEL OF MYTILENE
Mt. Skuteino
Mt. Dafia
Mt. Kouratzonas
Mt. Orthymnos
ANTISSA
DAFIA
St. PARASKEVE
KALLONI
SYGRION
AEGEAN SEA
Mt. Rouftas
PARAKILA
MYSTEGNA
THERME
ERESSOS
GULF OF KALLONI
SKALA
MESOTOPOS
MAVRIA
KERAMIA
MYTILENE
GULF OF YERA
AYASSOS
Mt. Olympos
m. 967
PLOMARION
AEGEAN SEA
39°20'
39°10'
39°00'
25°50'
26°00'
26°10'
26°20'
26°30'
LEGEND
a Sedimentary Rocks Recent and present coastal and fluvial alluvia
p Sedimentary Rocks - Marine limestones, marls and clays; fluvial sands and conglomerates (Pliocene)
L Lava flows with varying chemism, lati-andesites, andesites and latites. Basalts.
T Heterogenous pyroclastic products (tuffs, tuffaceous conglomerates, etc.)
I Ignimbrites from rhyolatitic to rhyodacitic
Upper Miocene Pliocene Quaternary
Volcanic Rocks
s Intrusive Igneous Rocks - Pyroxenic peridotites often serpentinized (post-Triassic).
m Metamorphic Rocks - Re-crystallized saccharoidal limestones, phyllades, green schists, etc. (Carboniferous - Permian)
Kaolin deposits
Deposit of first quality Clays and Muscovite
Areas included in the detailed tables

Fig. 2

The main outcrops are located near the eastern sector of the island; only two modest outcrops occur almost at the end of the western sector.

Then, a complex is found, with igneous intrusive rocks, defined as pyroxeni peridotites. Most of these rocks feature various degrees of serpentinizations an consequently a high degree of "alteration". The age of this intrusion is suppose to be essentially post-Triassic. This type of rocks outcrop with a rather elongate shape near the central-eastern sector. They are delimited eastwards by the Carboniferous-Permian complex and are covered westwards by successive volcanics fro the eastern sector of the gulf of Kalloni.

Since the Upper Miocene-Lower Pliocene, the previously described rock have evidenced an intense volcanic activity, heavily conditioned by epigenetic dislocations and faults, which has continued in the Quaternary; its products, more tha two-thirds of the island, have been ejected essentially in three periods.

In the first period, the volcanism was characterized by ignimbrites, locally followed also by heterogeneous pyroclastics. The main outcrops are situated near the central-southern borders NE of the gulf of Kalloni, and, with essentially tuffaceous products, in the western cape of the island.

In the second period, essentially latitic lavas were extruded, where latites, latiandesites, andesites and rhyodacites are, however, well represented. Such lavas constructed large volcanic structures which are aligned along significant structural trends, mainly E-NE and E-SE. In addition to small lava domes, large-sized lava flows ca also be found.

Within this activity, a "lower lava unit" and an "upper lava unit" were defined. The major outcrops of these products are located in the vicinity of the western an northern borders of the gulf of Kalloni and extend to the northern coast. Nonetheless, modest outcrops are present also in the southern sector.

The last period is characterized by silica-rich basalts, emitted above all by small scattered volcanic groups; they are represented by both lava flows and tuffaceous products.

From the Pliocene on, on an already essentially formed volcanic morphology, it is possible to observe locally rocks consisting of limestones, marls and clays of marine environment and sometimes clays, sands and conglomerates of continenta environment. Some of these products are occasionally interbedded in volcanic materials.

To complete the picture of the formations existing on the island, it is necessary to mention the products of the present waterway alluvia and of the coastal deposits, which have extremely varied lithologies.

TECTONICS

On the island of Lesbos, no great fault systems are evident. However, it is possible to deduce important structural alignments through volcanic occurrences, i. e. through the trend of volcanic edifices, lava emission points and dykes. Based on th above, two main alignments can be defined. The first one is along E-NE and this i the alignment of the Lepethimnos, Skuteino, Kouratzonas and Orthymnos mountains and also of some dykes close to the centre of Dafia *(Fig. 1)*.

The second alignment is along E-SE and this is the main alignment of th Rouftas and Dafia mountains and of the Petra and Eressos dykes.

Nevertheless, these alignments are significantly parallel to the directions of the large epirogenetic faults which are observed in the Turkish territory, which the island of Lesbos can be considered as closely connected to, since it is likely to be a detached limb of such territory.

In particular, the faults of Edremit and of the graben of Kaicos follow the E-NE trend; while the complex graben of Hermos follows the second trend.

Considering the above, all the occurrences of alteration on the island of Lesbos, including the kaolin deposits discussed here, belong to the structural trend mentioned above.

THE KAOLIN DEPOSITS

On the island of Lesbos there are numerous kaolinizations, especially in the central-northern sector, however, the most important ones are Magaros-Arghenos, Aspres Petres, Stipsi and Mesotopos. Significantly, all of them are arranged along or slightly depart from the structural alignments mentioned above.

The first three of these deposits, Magaros-Arghenos, Aspres Petres and Stipsi, are located a few kms east of the centre of Petra, while the remaining one, Mesotopos, is near the southern coast, about 6 kms SE of Skala, Eressos and a few kms S of the centre of Mesotopos.

Finally, all four deposits are closely connected to volcanite alteration.

Magaros-Arghenos

The deposit of Magaros-Arghenos is the northernmost one and is located approx. 7 kms NE of the centre of Petra; it has a length of approx. 600 m and a width of approx. one hundred meters. Its elongation is E-NE (Fig. 3).

The kaolin derives from the alteration of latiandesitic to andesitic lavas belonging to the "lower lava unit"; it is whitish, always lithoid and massive and sometimes difficult to disagregate.

The mineralogic study conducted on the most significant samples evidenced the presence of the following minerals: kaolinite, quartz, alunite, feldspar, smectite (montmorillonite), mixed-layer minerals of the I-MO type, jarosite and doubtfully cristobalite and marcasite.

In addition to the specific composition of the most significant samples Table 1

TABLE 1

Magaros-Arghenos kaolin deposit (Island of Lesbos), semi-quantitative mineral composition (%).

(K = kaolinite; Sm = smectite, montmorillonite; A = alunite; J = jarosite; Qz = quartz; I-MO = mixed-layer mineral, illite-montmorillonite type; Fd = feldspar)

Sample	K	Sm	A	J	Qz	Others
16	55—60		10		30	Marcasite
18	70—75			5	10	I-MO (10—15)
845	65—70			5	25—30	
11	60		tr		30—35	
110		70—80				Fd (20—30)
17	10	45—50	5—10		10	Fd (25—30); cristobalite?

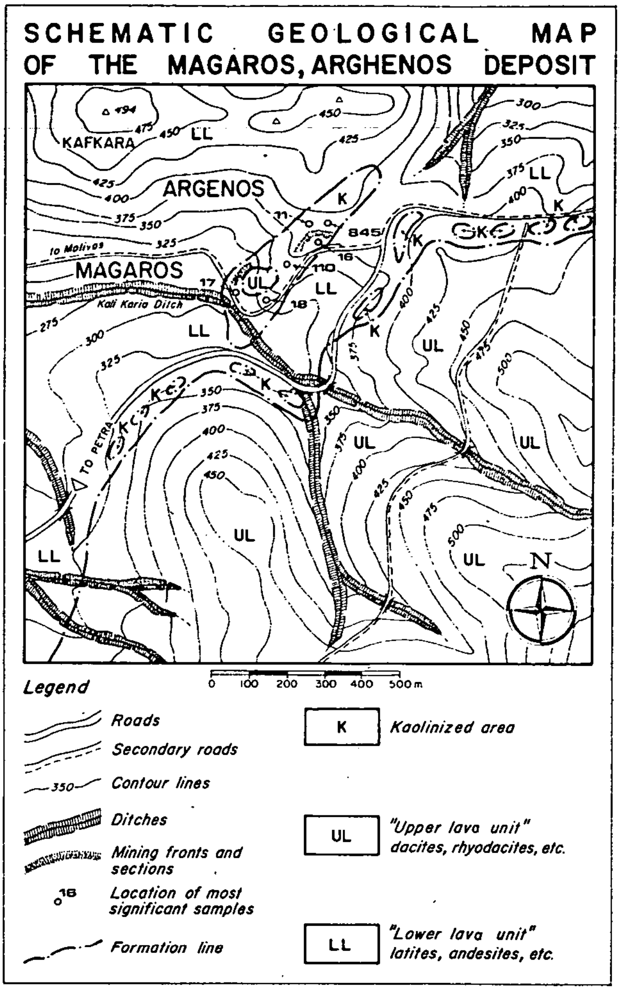

Fig. 3

also provides a semi-quantitative estimation of the various crystalline components obtained with diffractometric methods.[1]

Table 2 includes chemical analyses of the material studied from this area. Table 3, instead, exhibits some analyses of unaltered rocks from the literature related to volcanites from the alteration of which the kaolin deposits of the island are thought to be derived.

As it can be seen in Table 1, the mineralogical composition of kaolin is extremely varied. Kaolinite, usually of the pM type, is absent in some samples and reaches

[1] — The methodology of the works by Galan Huertos *et al*; [1974]; Pozzuoli *et al.* [1972], Schultz [1964], Thorez [1976] was followed using particularly X-ray diffraction and thermal methods (DTA and TG), sometimes also direct electron microscopic (EM) and scanning electron microscopic methods.

Table 2

Chemical analyses of the kaolins from the Magaros-Arghenos, Aspres Petres, Stipsi and Mesotopos deposits of Island of Lesbos (Greece)

	MAGAROS-ARGHENOS			ASPRES PETRES					MESOTOPOS						STRIPSI Halatsia		STRIPSI Toubes		
	16	17	18	20	21	22	25	24	27	28	31	33	34	36	47	48	49	50	53
SiO_2	47,7	64,8	59,9	62,2	57,8	53,95	63,00	44,50	55,30	59,20	53,7	44,5	56,3	53,6	52,2	71,0	55,8	66.4	55.5
TiO_2	1.28	0,30	1.05	1.06	1.06	0.87	0.81	1.10	0.76	0.62	0.35	0.45	0.65	0.95	0.14	0.11	1.06	0.84	0.76
Al_2O_3	31.5	17.1	23.5	22.0	25.6	28.5	21.7	37.1	26.90	21.0	21.9	29.8	27.0	25.2	23.3	11.2	23.7	17.2	18.6
Fe_2O_3	1,96	1.35	0.86	0.49	0.73	0.68	0,28	0,65	0.55	0.93	0,91	2.99	0.32	0,73	0,45	0,44	1.63	1.15	4.20
CaO	0.24	0.54	0.39	0.30	0.42	0.31	0.54	0.13	0.29	0.26	0.19	0.26	0.29	0.29	0.17	0.17	0.16	0.14	0.28
MgO	0.10	0.46	0.22	0.07	0.12	0.07	0.05	0.09	0.18	0.15	0.09	0.20	0.23	0.34	0.06	0.08	1.04	0.98	1.76
MnO	0.04	0.06	0.01	0.01	0.02	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03
Na_2O	0.03	1.38	0.04	0.04	0.05	0.07	0.05	0.04	0.07	0.08	0.05	0.10	0.18	0,50	0.08	0.10	0.05	0.07	1.14
K_2O	1.23	5.29	0.53	0.09	0.21	0.13	0.27	0.02	0.75	0.44	1,88	1.17	0.01	0.14	2.20	1.67	4.49	4.42	2.31
P_2O_5	1.44	0.71	2.11	1.69	2.20	2.06	2.27	1.03	1.88	1.72	1.72	1.99	1.03	1.81	1,72	1.42	1.21	1.49	0.89
Loss on ignition	12.50	5.40	10.35	10.38	10.70	12.30	9.03	13.90	14.20	12.10	17.22	16.90	12.70	14.70	17.70	11.00	7.60	5.44	11.55
SUM	98.02	97.37	98.96	98.33	98.91	98.95	98.01	98.62	98.81	98.61	98.02	98.37	98.72	98.27	98.03	97.20	96.76	98.15	97.02

16, 17, 18 = Kaolin from Magaros-Arghenos deposit.
20, 21, 22, 25 = Kaolin from main Aspres-Petres deposit.
24 = Kaolin from Aspres-Petres deposit, near Sizaksou.
27, 28, 31, 36, 36 = Kaolin from Mesotopos deposit.
47, 48 = Kaolin from Stipsi deposit, near Halatsia.
49, 50, 53 = Kaolin from Stipsi deposit, near Toubes.

TABLE 3

Chemical analyses of some unaltered volcanites of the Island of Lesbos (Greece)

	A	B	C	D	E
SiO_2	60.48	54.00	62.30	69.65	64.55
TiO_2	0.80	0.85	0.60	0.25	0.32
Al_2O_3	17.20	17.10	15.05	15.15	15.85
Fe_2O_3	4.25	2.86	4.10	1.35	1.85
FeO	0.85	3.60	0.70	0.55	0.85
MnO	0.15	0.28	0.10	0,05	0,08
MgO	2.58	4.90	3.20	0.35	1.40
CaO	4.30	5.20	4.65	0.90	2.05
Na_2O	3.96	3.76	3.40	3.90	3.70
K_2O	3.98	3.85	4.85	5.70	5.15
P_2O_5	0.31	0.58	0.45	0,08	0.14
H_2O^+	0.82	1.55	0.25	0.15	0.85
H_2O^-	0.04	0.02	0.75	1.10	3.20
CO_2	0.28	1.45			
SUM	100.00	100.0	100.40	99.18	99.99

A = "Andesinic doreite" by GEORGALAS [1949]
B = "Andesinic doreite" by GEORGALAS [1949]
C = "Phanero andesite" of Skala Sikamia by PRAGER [1966]
D = "Phanero andesite" east of Kliu by PRAGER (1966)
E – "Ignimbrite", Mt. Tavros by PRAGER (1966)

70—75% in other samples. Anyway, it is always associated with quartz and traces of alunite and jarosite.

Some samples have a dioctahedral smectite as single argillaceous component and then also mixed-layer minerals of the illite-montmorillonite (I-MO) type and feldspar as "residual" mineral of the original rocks. It is present in the samples containing the smectite component, whereas it is absent when kaolin minerals are predominant. The mixed-layer I-MO mineral is here associated with kaolin minerals, since feldspars are always absent.

Considering the sampling areas, the smectite-feldspar association can be supposed to be typical of a marginal or „boundary" area of the deposit of Magaros-Arghenos.

In the middle of the deposit, instead, kaolin minerals can be observe.

Additionally, in the mineralization area of Magaros-Arghenos, numerous small occurrences or evidences of kaolinization are found practically along the whole contact with the lavas of the "upper lava unit".

Aspres Petres

The deposit of Aspres Petres is located in the area SE of the centre of Petra (distance: 1.5 km).

The main part of the deposit extends for approx. 200 m, especially towards N-S, and has a length of some tens of metres *(Fig. 4)*.

Towards S-W, near Sizaksu, a modest alteration area is present, which is separated from the main part by about 300 m and closely connected to it genetically.

The rocks in the area are essentially dacitic, rhyodacitic, etc. lavas, belonging to the "upper lava unit".

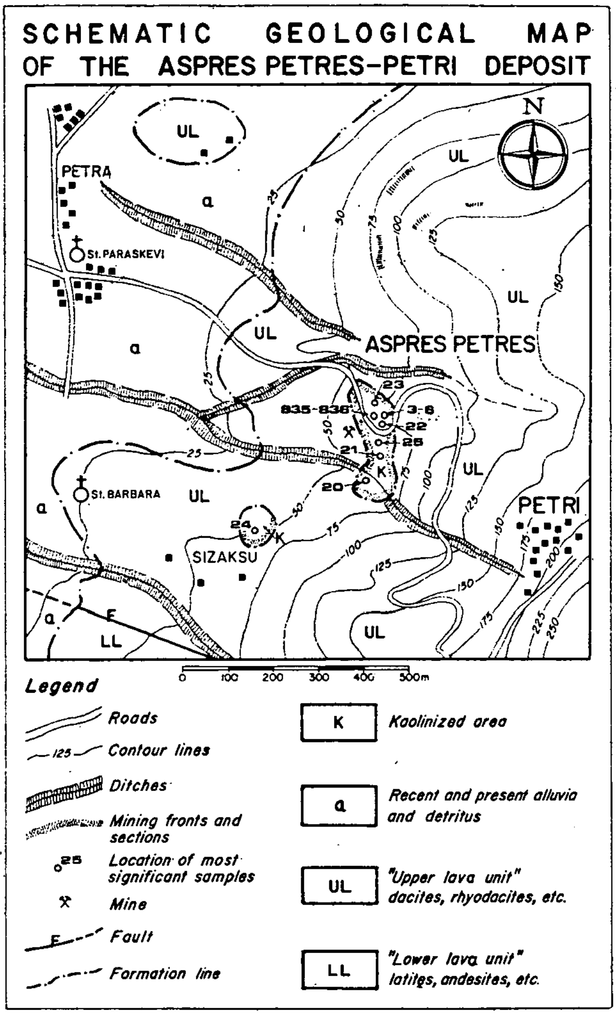

Fig. 4

Table 4 contains the mineralogical data concerning the most typical material of the deposit. The main association is kaolinite and quartz; traces or dobious evidences of alunite, jarosite, I-MO, marcasite and feldspar were detected.

Kaolinite, present in all samples examined together with quartz, proved to be the almost always predominant mineral. It has a rather varied crystallinity: in some samples it is poorly crystallized, in others it is well crystallized (T type).

Even sulphates, alunite and jarosite, although in traces, are almost constantly present.

Table 2 displays the chemical analyses of some samples studied which belong to this area.

On the whole, the material examined has a quite homcgeneos mineralcgical composition, since it is esentially constituted by kaolin minerals and quartz.

Aspres Petres kaolin deposit (Island of Lesbos), semi-quantitative mineral composition (%)

(K = kaolinite; A = alunite; J = jarosite; Qz = quartz; Fd = feldspar; I-MO = mixed layer mineral, illite-montmorillonite type).

Sample	K	A	J	Qz	Others
20	70	tr	?	25	
21	80—85	tr	?	15	
22	85			10—15	Marcasite
23	90	tr		10	Fd (tr); I-MO (?)
25	70—75	tr	tr	25	I-MO (tr)
835	70			30	
836	70—75	?		25—30	
3	55—60	?		40—45	
6	40—45	?		50—55	
24	95		tr	tr	Marcasite; I-MO (?); Fd (tr)

Stipsi

The major kaolinization of Stipsi is located at Toubes, about 4.5 kms from the center of Petra, towards E-SE, and approx. 500 m S of the centre of Stipsi. It extends in the small valley between the top (level 330 m) and the centre of Stipsi for about 300—400 m *(Fig. 5)*.

The original rocks which determined the formation of the kaolin deposit mainly consist of latiandesitic, andesitic and latitic lavas, sometimes interbedded with lithic and even incoherent tuffaceous levels, all belonging to the "lower lava unit".

Another modest kaolinization is present in the vicinity of the southern side of the relief (level 455), at Halatsia, about 500 m E of the center of Stipsi.

In the latter case, it is essentially a level which has a thickness of some metres and which extends for about 200 m, comprised in highly silicified volcanites and is very close to a small fault with an approximate E-W trend, which crosses the Halatsia relief.

Also in this kaolin outcrop, the original rocks were of the same type as those belonging to the main outcrop.

Table 5 shows mineralogical data concerning the most typical lithologic aspects of the two outcrops. Kaolinite, quartz, alunite, jarosite, illite, mixed-layer minerals of the I-MO type, smectite (montmorillonite) as well as cristobalite of significantly varied thermal state were identified.

It can be noted in Table 5 that the mineralogical composition is very varied for the Toubes area and relatively also for the Halatsia area. In some samples from Toubes, the kaolinite component may be absent, while in the samples from Halatsia it is always present with values form 30 to 60%. Always present in all the samples, instead, are sulphates, alunite and jarosite and silica phases, quartz and cristobalite. Smectite seems to appear near the outside borders of the alteration area of Toubes and thus similarly to what was observed for the kaolin deposit of Magaros-Arghenos *(Fig. 6)*.

At Toubes, illite proved to be one of the main components, however, always without feldspar and with traces of I-MO and smectite.

This considerable variability in mineralogical composition is also confirmed by

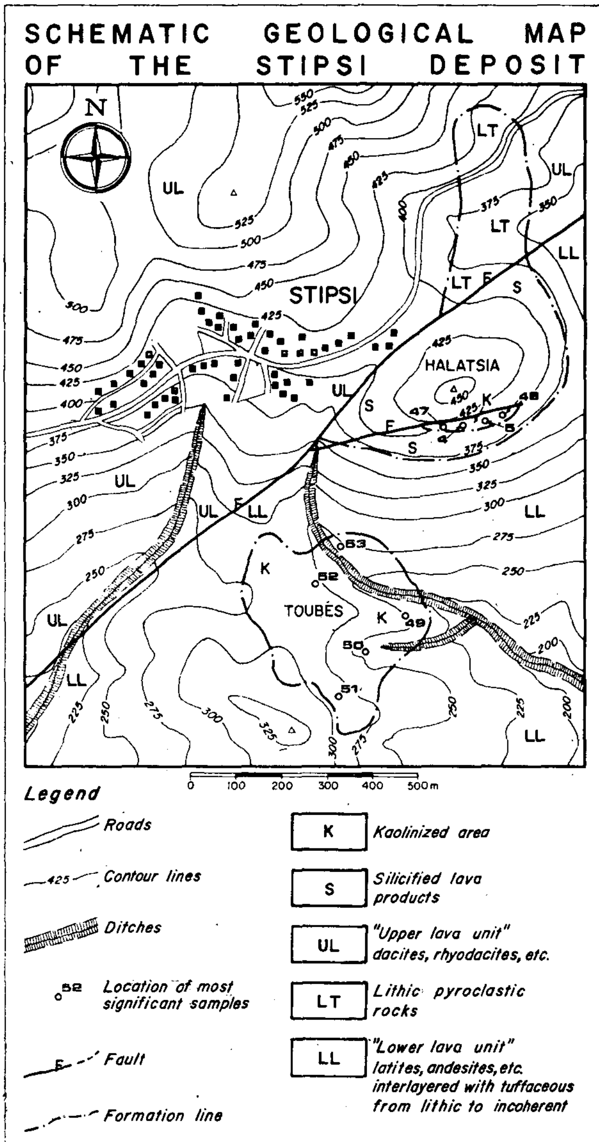

Fig. 5

the chemical analyses shown in Table 2, where the main oxides, silica, alumina, iron and potassium show extremely varied values for loss on ignition.

This variability is probably due to the considerable lithologic variation of the volcanites outcropping there; these, besides a different chemism, show an extremely variable porosity due to essentially tuffaceous and massive lava elements.

It is necessary to underline that the small Halatsia outcrop is located in a very extensive area which was subjected to an intense silicification.

TABLE 5

Stipsi kaolin deposit (Island of Lesbos), semi-quantitative mineral composition (%)

(K=kaolinite; A=alunite; J=jarosite; Qz=quartz; I-MO=mixed-layer illite-montmorillonite type; Cr=cristobalite; Fd=feldspar)

Sample	K	A	J	Cr	Others
47	30—35	30—35		30	
48	40				Cr (55—60);
4	55—60	?			Cr (40—45)
5	45—50	5		50	
49	15		10	10	Smectite (tr); I-MO (tr)
					Illite (60—65)
50	10		tr	20—25	Illite (60—70)
53			40—45	10—15	Smectite (30—35); Fd (10); Cr (tr)

Both the alteration areas, Toubes and Halatsia, can be considered as arranged on the southern side of the SW-NE-trending fault, which delimite the complex of the "lower lava unit" from that of the "upper lava unit".

Mesotopos

It is the kaolin deposit located in the vicinity of the southern coast on the western side of the island of Lesbos.

On the sides of the Malas Mountain (165 m), approx. 2 kms S of the centre of Mesotopos and approx. 6 kms SE of the centre of Skala, Eressos, numerous kaolinization occurrences can be found, some of which enabled the development of mining processes, particularly at Korakes, near the southern coast. However, the most extensive areas are near the western side of the Malas Mountain, approximately along a N-NE and S-SW alignment *(Fig. 7)*.

The most significant samples, collected in the proximity of all outcrops reported, showed a quite homogeneous mineralogy. Indeed, kaolin minerals were determined in all samples but with a percentage varying from 40—45 up to 90%, in areas where the latter minerals are also the most frequent; only one sample exhibitde a lower amount of kaolin minerals (25%) (Table 6).

TABLE 6

Mesotopos kaolin deposit (Island of Lesbos), semi-quantitative mineral composition (%)

(K=kaolinite; A=alunite; J=jarosite; Cr=cristobalite; Qz=quartz; Fd=feldspar)

Sample	K	A	J	Cr	Others
27	65—70	15	tr	15	Marcasite (tr)
28	90	10			
29	95	?			
30	25	70		?	
31	40—45	20—25		30—35	
32	95		tr	?	Fd (tr)
33	95		tr		
34	95			tr	Qz (tr); illite (tr)
35	60	tr	tr	35	Qz (tr); marcasite (tr)
36	95		tr		Qz (tr); marcasite (tr)

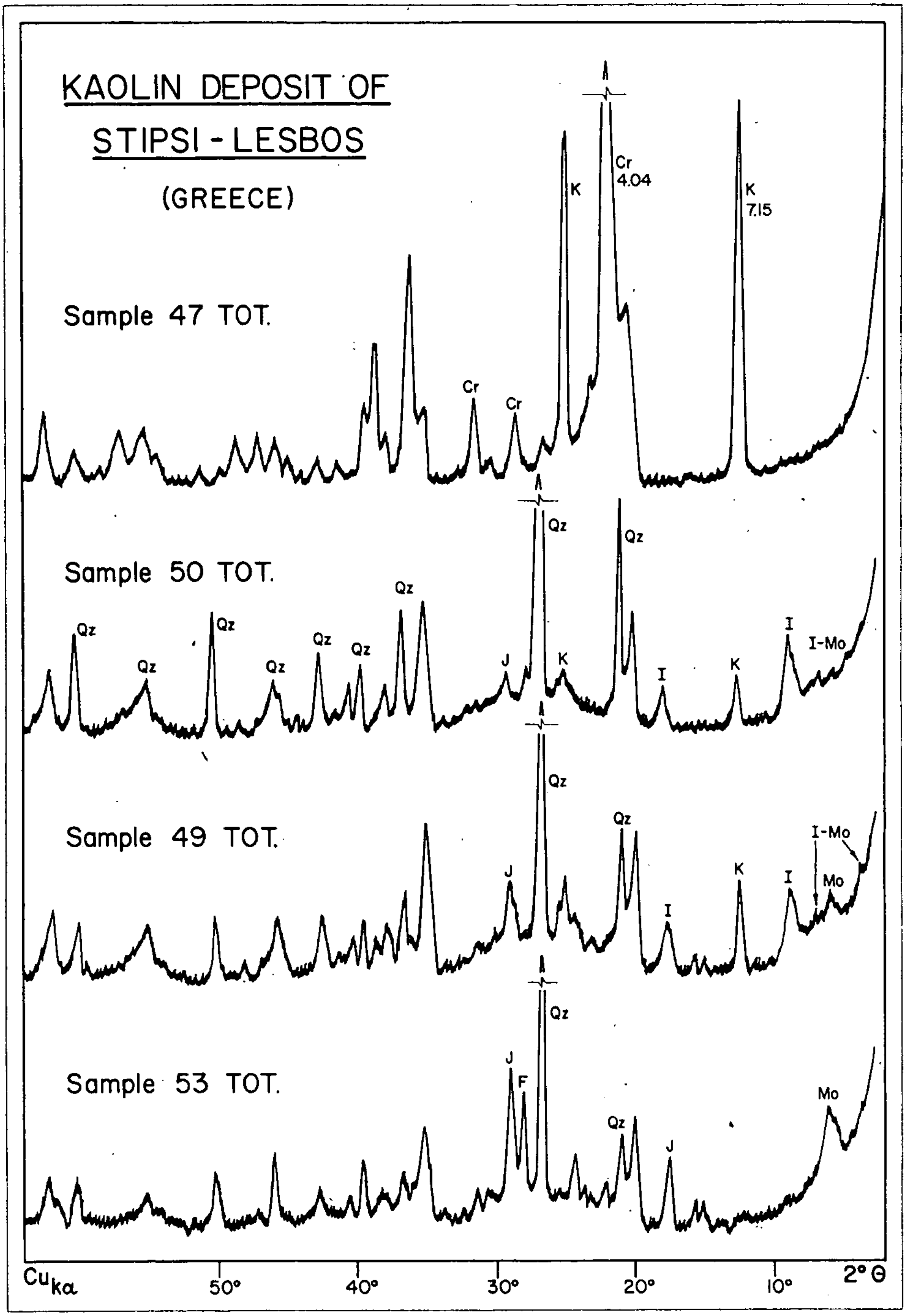
KAOLIN DEPOSIT OF
STIPSI - LESBOS
(GREECE)
Sample 47 TOT.
Sample 50 TOT.
Sample 49 TOT.
Sample 53 TOT.
Cr
4.04
K
7.15
K
Cr
Cr
Qz
Qz
Qz
Qz
Qz
Qz
Qz
Qz
Qz
J
K
I
K
I
I-Mo
Qz
Qz
J
I
K
I
I-Mo
Mo
Qz
Qz
J
F
J
Mo
Cukα
50°
40°
30°
20°
10°
2° Θ

Fig. 6

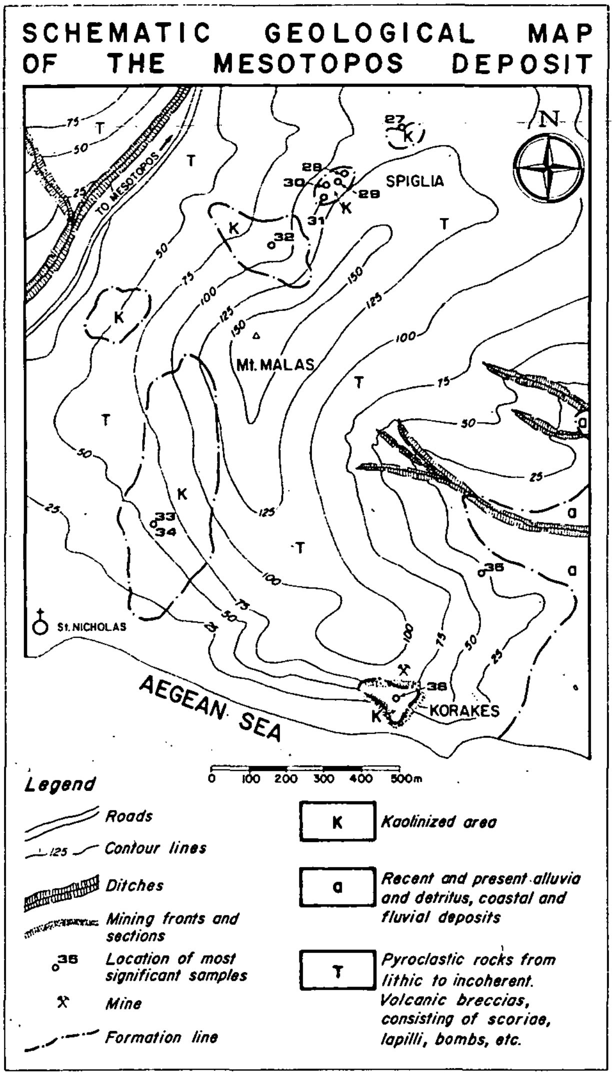

Fig. 7

Sulphates, alunite and jarosite, are constant, though in extremely variable amounts, from traces to 70%.

Crystallized silica, when present, appears almost exclusively as cristobalite. It is to be noted that this mineral occurs with a rather varied thermal state both in the deposit and in the sample examined, thus indicating the changing environmental and microenvironmental conditions. Among other minerals, mention should be made of marcasite, illite and feldspar either as dubious evidences or in traces. Kaolinite in this area is usually not well-crystallized (pM type) and sometimes the presence of halloysite was also supposed.

Table 2 indicates some chemical analyses of typical materials belonging to this area. There is a rather homogeneous chemical composition, which confirms what was observed mineralogically.

The rocks surrounding the kaolin outcrops, unaltered, consist of essentially pyroclastic products where typically cineritic levels are interbedded with lapilli levels containing blocks, volcanic bombs etc.

The relative homogeneity of the mineralogical composition, also confirmed by chemical analyses, suggests that the original volcanites have had quite constant physico-chemical characteristics and the alteration fluids must have acted on them under almost uniform conditions Moreover, there are evidences that the alteration area is much wider and that it also involves the eastern side of the Malas mountain, where significant small evidences of alteration locally appear.

DISCUSSION AND CONCLUSIONS

This study allowed to confirm that all the materials reviewed should be considered as "kaolins", except for only some of them coming from the deposits of Magaros-Arghenos and Stipsi, where the kaolin minerals can even be completely absent.

Furthermore, considering the geological-structural aspects, it can be supposed that all the kaolin deposits of Lesbos genetically belong to those of hydrothermal origin which formed "in situ" at the expense of volcanic rocks and which have a quite acid chemism. Considering the recent classification [KUŽVART, 1977], these deposits can hardly belong to those of "hydrothermal-solfatara" type. Additionally, the action of hydrothermal fluids must have occurred essentially in the final phase of the volcanic emissions on the island.

The newly formed material, i. e. kaolin, is generally massive, lithoid and difficult to disaggregate; if plunged in water it does not lose its cohesion; usually, it is whitish but sometimes it may be white-violet and white-pink.

The kaolin proved to consist of kaolinite and, almost constantly, of sulphates, alunite and jarosite, either in traces or as main mineralogical components.

Instead, when kaolin minerals are scarce or absent, there is a predominance of smectites, illites, or of silica, quartz and cristobalite minerals, in addition to sulphates.

The major possible mineralogical variations were found in the deposits of Magaros-Arghenos and Stipsi, while in the other deposits limited homogeneity was observed.

Nonetheless, even in the areas where kaolinite prevails, crystallinity is very variably; from poorly-crystallized types (pM), all transitions to well organized types (T) can be noted. This confirms that environmental and microenvironmental conditions must have been non-homogeneous, even in the kaolin alteration areas.

It is necessary to add that the cristobalite observed, with its different thermal states, suggests also the variability of environmental and microenvironmental conditions.

By comparing Tables 2 and 3, containing the chemical analyses of kaolinized and unaltered rocks, it is possible to note a general specific decrease in K, Na, Mg, Ca ions with more modest Fe values.

Silica may be very high in some cases and more reduced in others. Alumina always shows an increase and sometimes it has almost doubled values.

By examining the analyses of the mineralizations from the same deposit, the most considerable variations in compositions occur near the deposits of Magaros-

Arghenos and Stipsi, especially for silica and alumina values and partially for loss on ignition.

The K in the deposit of Magaros-Arghenos ranges from 0.5 to 5.29%, and Na from 0,03 to 1.38.

In analyses referring to the deposits of Mesotopos and Aspres Petres, instead, there is a lower variability in chemical composition. Without entering into details, all this agrees with what was observed on the mineralcgical composition of kaolin materials.

This compositional variability may be justified by the litholcgic diversity of the original rocks, especially as concerns their fracturing and porosity rather than their chemism. Indeed, while the chemism of the original rocks in all the deposits should be considered as rather homogeneous and acid when dacites, rhyodacites and andesites are present, there are, instead, considerable variations in appearence, permeability etc. of the rocks.

In particular, in the deposit of Magaros-Arghenos, a wide "zoning" was observed; from a core essentially made up of kaolin, i. e. where kaolinites are prevalent, there is a gradual transition towards areas where micaceous, illitic and smectitic minerals predominate. Smectite is associated with feldspar, which is entirely absent, instead, in the central alteration area. This observation allows to consider that alteration was more intense in the core, whereas, in marginal zones, the fluids acted progressively in a less aggressive way, so that it was possible to find feldspar.

Then, taking into account the mineralogical associations identified, especially in the zoned deposits, the development of the alteration process can be reconstructed.

First of all, it is possible to consider the condition when the abundant and acid fluids attack feldspathic volcanites having physically and chemicallyl homcgeneous characteristics, including fracturing, porosity and thus permeabiltiy. In this case, the alteration process gives rise to kaolinite minerals and possibly, at the local level, to silica-rich minerals, especially in areas where the actions were more intense.

If the fluids, always originally acid, are not particularly abundant and have difficulties in permeating feldspathic rocks, they can directly produce kaolinite minerals close to their emission area. Towards the outside, instead, their influence and aggressivity become gradually modified, leading to the neoformation, for these areas, of essentially micaceous minerals (illite). Even if the fluids are less aggressive, their energy is sufficient, als in this case, to bring about a complete alteration and transformation of feldspars.

Then, towards the outside, there is an area where feldspars are present, thus showing a decreased altering capacity of the fluids. The newly formed components of this area are smectitic, therefore belonging to a pH environment more basic than that in the preceding areas. It should be underlined that sometimes mixed-layer minerals of the I-MO type were found, which can be interpreted as newly formed minerals marking the transition between illite and smectite areas. Due to the progressive variation in the environment, these minerals may form, considering the strong structural analogy between the two minerals, with the progressive modification of the interlayer space. In conclusion, these minerals express conditions of transitional environments, where illite is not entirely stable and, at the same time, where smectite does not reach its typical conditions completely.

Mixed-layer minerals, instead, cannot be present between illite and kaolinite areas, where the structural patterns of the two minerals show too marked differences. But it should be emphasized that the literature reports occasional finds of a mixed-layer mineral of the kaolinite-smectite type, however in particular genetic environments, where the alteration conditions discussed here do not occur SCHULTZ, L. G. *et al.*, 1971; WIEWIORA, A., 1971; WILSON, M. J. *et al.*, 1972].

The alteration evolution might be characterized by the following sequence of newly-formed mineral areas:

— kaolinite areas (with different crystallinity)
— illite areas
— area with mixed-layer I-MO minerals
— smectite area (montmorillonite, possibly with feldspar).

The relative zoning was directly checked on site in the deposits of Magaros-Arghenos and at Toubes, deposit of Stipsi.

The existence of possible "zonings" in the kaolin deposits has been known for a long time. They were described in deposits from alteration of both instrusive igneous rocks [SALES *et al.*, 1948; KERR *et al.*, 1950] and volcanic rocks [LOVERING, 1949].

MINATO recently [1976] reported these characteristics for the kaolin deposit of Itaya (Japan), where the kaolin „mine" is surrounded by a belt of smectitic materials, all generated by the same hydrothermal events.

It should thus be admitted that the fluids with marked acid and, therefore, agressive characteristics may have become enriched in ions deriving from the same rocks during their flow from the central area and their lateral permeation, in connection with the local permeability. This fact led to a variation of the chemism of the same fluid towards more basic elements, with a consequent variation of its aggressivity, showed by the "residual" feldspar. Temperature values, too, may have decreased accordingly.

As concerns the kaolin deposits of Aspres Petres and Mesotopos, zonings affecting the whole outcrop were not noted, perhaps because the physical characteristics of the rocks are rather homogeneous, especially their permeability.

A characteristic more or less common to all mineralizations is a possible compositional variability of altered rocks, without excluding, however, the existence of "cores" with a homogeneous composition.

If the trend of the outcrops in the mineralized areas is examined, a preferential orientation can be generally noted, which agrees with the large regional tectonic trends of the Asia Minor territory. And the island of Lesbos is obviously affected by these trends.

In particular, in all the deposits, the NE trend should be regarded as preferential in the development of the mineralization process and thus belonging to the large tectonic trends.

The mineralization of Aspres Petres, too, is characterized by the above direction when the main alteration area is connected with the area of Sizaksu.

These structural geological considerations were drawn based only on surface survey data. In the light of all the observations, it can be stated that the deposit of Mesotopos is the most important, followed by Aspres Petres, Magaros-Arghenos and Stipsi.

To complete these considerations, it should be mentioned that on the island there are other alteration areas, the most important of which is Mavria.

In these areas, which can always be connected to the regional tectonics, smectitic minerals seem to prevail; in this instance, the alteration process should be considered in the light of the above, as a rather "initial" phase or better a phase where the ifluds are more markedly basic.

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