UNESCO
AN INTERNATIONAL SYMPOSIUM ON METALLOGENY OF MAFIC AND ULTRAMAFIC COMPLEXES: THE EASTERN MEDITERRANEAN-WESTERN ASIA AREA, AND ITS COMPARISON WITH SIMILAR METALLOGENIC ENVIRONMENTS IN THE WORLD

VOLUME 3

Under the Auspices of the Minister of Colture and Sciences

National Technical University of Athens
Department of Mineralogy - Petrology - Geology
42, October 28th St. Athens, T.T. 142
GREECE

IUGS UNESCO IGCP

ATHENS
OCTOBER 9 - 11
1980

Project No 169

Published in Athens 1981

Magnesite occurences at the areas of "Basilika" and "Galarinos" of the Chalkidiki province / Greece

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Thessaloniki 1980

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Introduction

The origin of magnesite is a main problem for the researchers, so it is necessary to speak shortly about the main points of this problem. We generally distinguish two categories or types of magnesite: (a) coarse-grained magnesite of hydrothermal origin, regarding to the source of the chemical elements (Mg) and chemical combounds of (CO_3^{-2}), which is in isomorphous impurities with the siderite ($FeCO_3$) in the Eastern Alps and also (b) fine-grained microcrystalline magnesite, the magnesium (Mg) of which comes from ultrabasic rocks, which consist of minerals rich in Mg, while the origin of its (CO_3^{-2}) solutions is not known.

For the first case of magnesites there are many authors, who have published about the magnesite problem, such as: Petrascheck (1932), Meixner (1953), Friedrich (1968) and Chatzimitriadis (1969,72).

Location of the area

The areas which were investigated are three: two of them are at Basilika, the one at a 1.000 meter-distance NNE and the other at a 500 meter-distance at the northern part of Basilika (fig 1). The third area is at a distance of 1.000meters ESE from Galarinos. The above two villages are situated at distances of about 30 and 25 kilometers at the southeastern of Thessaloniki.

Geological setting

The magnesites of the above areas are located within igneous rocks of the ophiolite group, which show sites of intense serpentinization. This ophiolite occupies a quite large extent and has a large length. It occupies the area from Bavdos (Chalkidiki) up to the Doirani lake as far as Greece is concerned. The ophiolite body has an attitude from NW to SE (see fig 2, geological map). According to Osswald (1938) the area that was studied, geologically belongs to the Axios zone and especially to the subzone of Doirani. The age of the ophiolites is thought (Osswald, 1938) to be younger than the Triassic and older than the Middle Cretaceous.

Kockel - Mollat and Walther (1977) enlist the studied area geologically to the ultrabasic zone and about the age of the ophiolites they accept that it could be Upper Jurassic.

Petrography of parent rocks

According to the petrological study of thin sections of rocks and ore, we found that the parent rocks of the magnesites are composed of serpentinized dunites, in which there are saved only boundaries of olivine crystals and some ones of orthopyroxene. There are observed serpentine minerals, especially of antigorite and chrysotile. In the boundaries of the main minerals and in the empty spaces of the sheety minerals a small quantity of crystalline is observed or amorphous in some places quartz, (opal type).

The study of the rocks shows that at the first stage of alteration there are produced serpentine minerals and as a second generation mineral quartz in very small veins. The above description concerns serpentinized dunite without magnesite, which is at a small distance from the magnesite outcrops. The situation changes completely in thin sections, which contain thin veins of magnesite and parent rock. A quite stronger alteration is observed in the olivine, which shows almost no crystal boundaries, the serpentine minerals are increased and the rock contains much quartz especially like veins small in thickness. Not only the rock without magnesite but the one with magnesite as well, have enough grains of opaque, metallic minerals (chromite). Generally the rock is crossed by thin bands of unaltered ultrabasic rock, which was defined as pyroxenite. Apart from the pyroxenite there are also observed dolerite veins, in which there are saved only serpentinized boundaries of clinopyroxene (augite), which are surrounded by numerous calcite veins (see fig 3). It is possible that the calcite was formed because of the calsium release from the augite and maybe from the basic plagioclases, none of which is saved. X-ray diffraction was used to determine the sheety like minerals.

The ophiolite group shows a quite clear differentiation at the studied area. Its southwestern members are peridotite, dunite and pyroxenite, while the northeastern members are gabbro.

The relief of peridotites and especially the one of dunites is quite low on the contrary to the relief of the gabbros.

The serpentinization of dunite is a problem for the area, which has been searched. Angel (1929) proposed that there are two ways of serpentinization: the one takes place at the end of the crystalization of the magma as autohydratative breaking off, so chrysotile is produced as the main mineral. The second type of serpentinization is connected with the metamagmatic tectonic data of the rock, so antigorite is produced and is considered as mineral "stress".

Other authors as Helke (1955) do not accept the previous ways of serpentinization, which Angel F. (1929) reports.

However we think that the serpentinization at the areas, where magnesite was studied, is connectd with the macro and microtectonic deformation of dunite and with a quite strong influense from the superficial cold solutions. We might express our previous idea about the serpentinization as a "retrograde metamorphism" of the dunite, which as known was formed in a quite high temperature and high enough pressure.

Description of the ore deposits

The magnesite ore was studied microscopically with X-ray diffraction and also it was analysed chemically (see table 1):

Table 1 Chemical analyses of magnesite ore

Locality	MgO	CaO	SiO_2	Fe_2O_3	Al_2O_3	CO_2
Vasilika	46,55	0,45	3,2	–	–	49,7
*Galarinos	43,4	2,6	3,3	0,26	0,18	49,4

The study of thin sections showed that the magnesite appears as a typical carbonate mineral, with small or relative anisotropy and the magnesite is nearly amorphous.

It seems to fill small veins from 3mm to 15 cm - thick. In thin sections magnesite appears like a small vein, that seems to cover or to substitute the quartz. If we accept generations of formation of the various minerals in the serpentinized dunite, we have the following order: in the interstices of the crystal boundaries of dunite there are met serpentine minerals and especially antigorite and little chrysotile, then we have a younger generation of quartz enough in quantity regarding to the serpentinized peridotite without magnesite and afterwards magnesite follows as formation of younger generation. The X-ray diffraction research shows that magnesite is crystaline.

Under the microscope except for types of vein we also observe scattered islets of magnesite. Macroscopically it is observed that at the two areas at Vasilika, magnesite is found having the form mainly of veins and stockwork (see fig 4, fig 5).

It is about a system of infilled fractures, which have main strike NNW - SSE, N - S, NNE - SSW. The NNW - SSE system is the most common. The above is also obvious from the strike rododiagram (see fig 6, diagram 2, D2 - cross section fig 7).

The most usual veins that is to say the most usual ones with strike NNW - SSE, show small dip of 20° to NNE. At the same area there are also observed fold axes with strike NNW - SSE, in which the veins of the NNW - SSE form hol planes.

At the magnesite area of Galarinos village there are only magnesite veins (infilled fault) with strike WNW - ESE to W - E of 40-degree dip from SSW up to S (see fig 8, fig 9 diagram 3, cross section fig 10). The same veins are intercepted by a 15 centimeter thick vein of altered dolerite and another one of talc with characteristics 20/40 WSW (fig 11). The strike of the vein group is obvious on the diagram (D_3) fig 9 and on the photographs of the schemes (fig 8, fig 11). Magnesite veins show at some places folds with data 100/40° ESE (see fig 12). That is to say magnesite veins are ab - ool surfaces regarding to the folds. In this case the folds of magnesite veins more or less show that the infilling of the faults happened at the same time with their formation.

From the macroscopic study it is concluded that at the area of Vasilika the faults were formed by forces of S - W direction, caused deformation of the ultrabasic rock in two zones, each of which is of 300 m thick and both the serpentinization and the magnesite formation have been connected with these zones. According to Hiessleitner G. (1951) the E - W forces are of Tertiary age. According to the same author the magnesites of the same area are also Tertiary formations produced by attack of superficial waters on the deformed parts of peridotite.

At the area of Galarinos we studied magnesites which are formed in a 700 m thick deformed zone of the ultrabasic rock.

According to the strike of magnesite veins, we found that at the Galarinos area took place forces of N - S direction. We also have a vein of talc and magnesite which is considerably younger than the other veins because it crosses them (see fig 11). The system of veins at Galarinos is also of Tertiary age but maybe relatively younger than the one of magnesites at Vasilika.

Both at Vasilika and at the Galarinos area the excavation depth of magnesites does not exceed 60 meters, according to the open air studies.

Conclusions

The correlation of the various methods such as the one of petrologic thin section examination, the chemical analyses, the tectonic diagrams, the X-ray diffraction research and the open air studies drove us to the following conclusions:

1. The serpentinization of peridotite at the area, which is studied was completed gradually and depended on the tectonic deformation of peridotite in zones.

2. The above is obvious from the study of the petrologic thin sections of serpentinized dunite, in which we find traces of olivine, antigorite and some chrysotile in the boundaries of the olivine altered minerals and small quantities of quartz and opal (see fig 13, fig 14). Both the degree of the small tectonic deformation and the opal formation show that they were formed from superficial solutions.

3. Thin sections with magnesite contain traces of olivine, of dunite, few serpentine minerals especially antigorite and sufficient quantity of magnesite and quartz both in vein form, but quartz is crystaline (see fig 15, fig 16).

4. The third case shows that magnesite is connected with dunite alteration and with more breaking off of serpentine minerals in Mg and SiO_2. This may happen because of continuous tectonic deformation and more movement at the areas of deformation of cold solutions. It is now obvious that increase of the frequency of magnesite veins in the thin sections is related to release of free quartz in the rock on the contrary to the second case. Quartz of the fourth (4) case is crystaline and this is connected with the longer duration of the tectonic deformation.

5. A younger vein of talc and magnesite is observed to cut an older group of magne-

site veins. Talc and magnesite of the younger vein is found in thin bands. Free quartz in the talc vein has not been found. the talc vein should have magnesite-quartz and serpentine as old mineral paragenesis and afterwards talc is formed from the serpentine of the vein and from the free quartz of the magnesite formation by dynamometamorphism in the same vein that is to say talc is formed in the continuing stage of deformation after magnesite. There are no signs, which can show any circulation of hydrothermal solutions.

6. The existence of basic members rich in calcium minerals near the peridotite maybe takes part in the case of magnesite formation, perhaps because calcium goes into solution easily with CO_2 waters and by this way it increases the mobilization of magnesite as $Mg(HCO_3)_2$. At the area of Kato Theodoraki talc and serpentine - asbestos which are connected with clear serpentinized peridotite without basic members are described by Chatzidimitriadis E. (1977), but magnesite has not been found not even as trace. We doubt about it.

7. Drilling core examination at the Galarinos area shows that the group of magnesite veins is wedged in small depth because after 50 meter depth the cores show only peridotite up to serpentinized peridotite. Almost the same happens at the area of Vasilika as well.

We generally believe that cold solutions after tectonic deformation break off the forsterite from the dunite series into serpentine minerals and some quartz according to the equation

$$5Mg_2[SiO_4]+4H_2O \rightarrow 2Mg_3(OH)_4[Si_2O_5]+4MgO+SiO_2.$$

The MgO is leached.

As the deformation and the increase of the attack of the cold waters goes on serpentine breaks off into magnesite and quartz

$$[Mg_3(OH)_2Si_4O_{10}+3H_2O \rightarrow 3MgCO_3+4H_2O+4SiO_2,$$

so quartz increase is explained with the presence or the formation of magnesite. Generally the lack of frequent occurence of talc at the studied areas except one vein found at the Galarinos area and the formation of which is connected with dynamometamorphism and the lack of other influences typically hydrothermal made us accept that the magnesites are superficial formations. Kockel 's-Mollat 's-Antoniadis 's-Ioannidis 's (1976) observations regarding to the areas of Vavdos, Gerakini and Kastri could not explain the origin of magnesites at Vasilika and Galarinos areas. Comparing the diagrams (D_2 and D_3) of the magnesite veins, which we have studied with the one of D_1 (see fig 17, diagram 1), which represents strike of the faults of the whole area we can maintain that the magnesite veins from the areas of Vasilika and Galarinos can be compared with meta pliocene faults regarding to the age, that is to say we accept a meta-pliocene age for magnesites though we are reserved about it, because there may exist various chronological generations of magnesite formation and each of them does not have great chronological differences from the others.

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Legend

Fig 1 : Locality of the area studied.

Fig 2 : Geological map of the area.

Fig 3 : Microscopic photograph of altered dolerite (cross Nicols). There are obvious the boundaries of altered augite and calcite veins, which probably come from the alteration of augites or from basic plagioclases (Vasilika, Chalkidiki).

Fig 4 : Magnesite stockwork with typical spiral forms of the isolated veins (simultaneous infillings, Mg-NW) Macrophotograph of magnesites from Vasilika, Chalkidiki.

Fig 5 : Magnesite veins, which are parallel each other in a serpentinized rock. (Mg-V, Sp) Macrophotograph of magnesites from Vasilika.

Fig 6 : Rododiagram showing the most frequent and most common strike of veins of magnesite from Vasilika, Chalkidiki. The most dominant strike is the NNW-SSE one.

Fig 7 : Geological cross section of magnesite deposits from Vasilika.

Fig 8 : Folded magnesite veins from the Galarinos area.

Fig 9 : Rododiagram showing the most frequent and most common strike of the magnesite veins from the Galarinos area, Chalkidiki. The ESE-NWN strike is constant.

Fig 10: Geological cross section of the magnesite deposits from the Galarinos area, Chalkidiki.

Fig 11: Magnesite veins (Mg-V), dolerite vein (D) and newly formed talc vein (T) are obvious on the photograph of magnesite veins from Galarinos area, Chalkidiki. Dolerite is of old age, while talc is younger regarding to the magnesite veins (Macrophotograph).

Fig 12 : Typical syntectonic magnesite veins(Mg-V) in serpentinized peridotite at the area of Vasilika, Chalkidiki. The veins are okosurfaces regarding to the fold axes. (Macrophotograph)

Fig 13 : Microscopic photograph of serpentinized peridotite without magnesite. There are obvious the minerals of quartz and serpentine, white. The olivine boundaries cannot be seen easily.

Fig 14 : Olivine boundaries. Quartz occupies the central part of olivine crystal, while serpentine(antigorite) occupies the rim of it. Chromite grains are also shown on the microphotograph (Cr) Cross Nicols.

Fig 15 : Microphotograph in cross Nicols, showing an advanced alteration of dunite. Small olivine boundaries, fractured,much serpentine minerals (Sp),recrystallized quartz (Qu) and visible quite enough magnesite islets (Mg).

Fig 16 : Part of the photograph (15) enlarged (cross Nicols). Quartz and magnesite are well formed.

Fig 17 : Rododiagrams of the most important faults of the area under study.

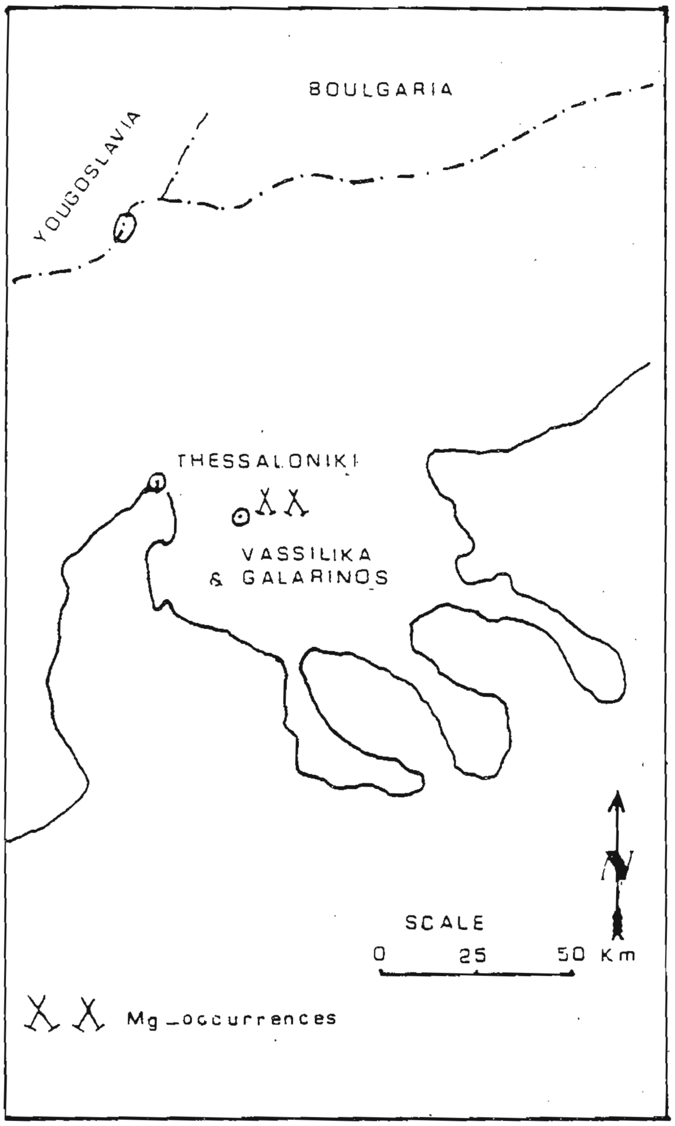
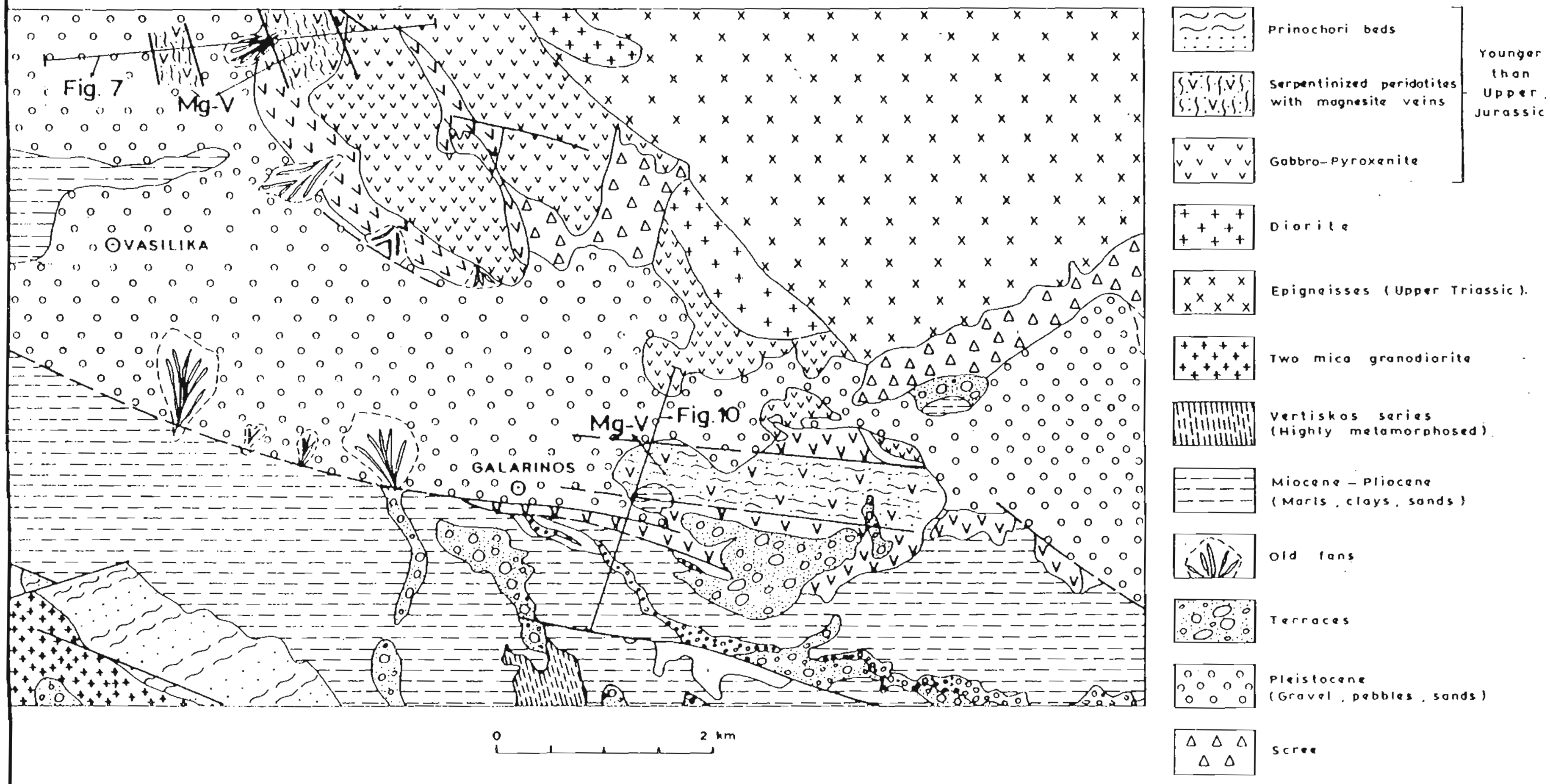

BOULGARIA
YOUGOSLAVIA
THESSALONIKI
VASSILIKA
& GALARINOS
SCALE
0 25 50 Km
Mg_occurrences

Fig. I

Fig. 2

GEOLOGICAL MAP OF MAGNESITE ORE DEPOSITS AT VASILIKA, GALARINOS-CHALKIDIKI PROVINCE, ACCORDING TO KOCKEL-MOLLAT-WALTHER (1978), MODIFIED BY KELEPERTZIS-CHATZIDIMITRIADIS-CHRISTARAS (1980). Scale 1:50.000



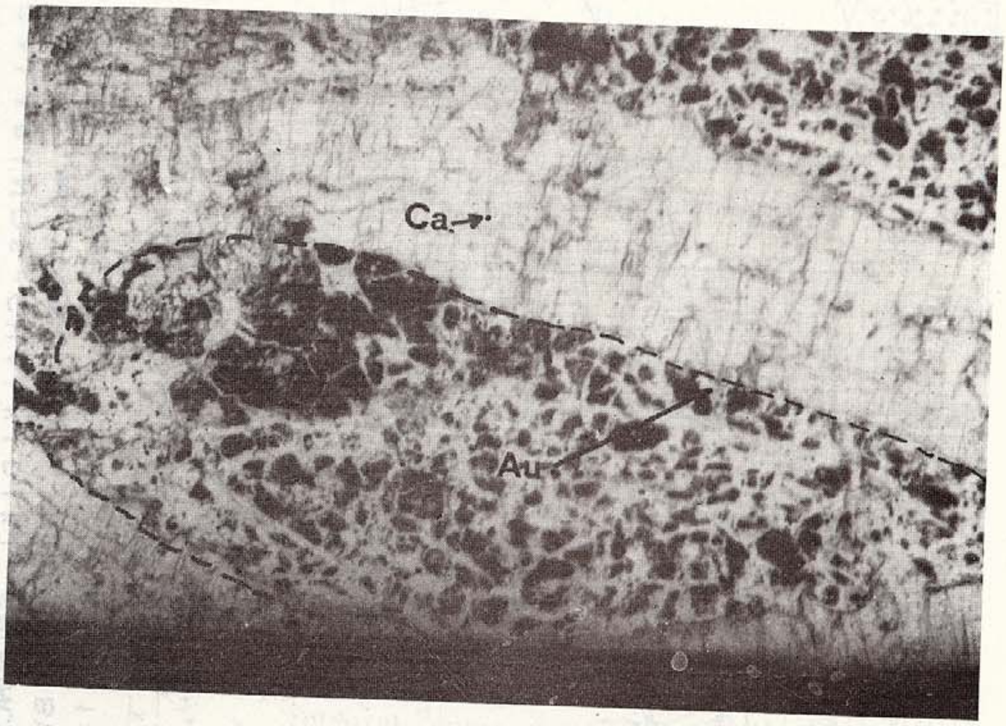


Fig. 3

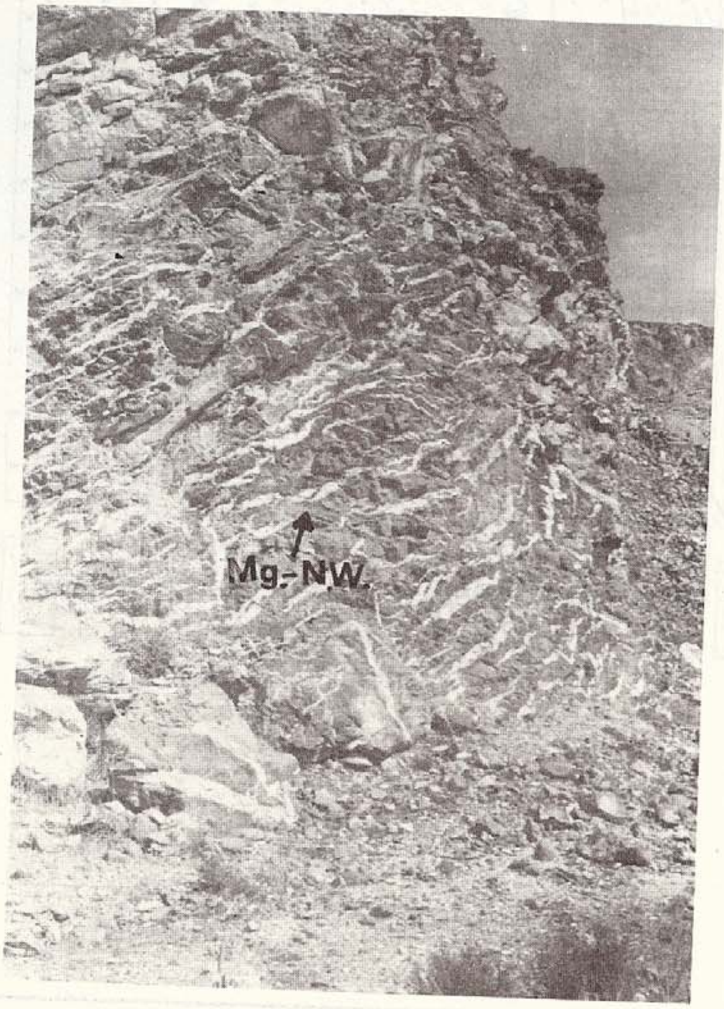


Fig. 4

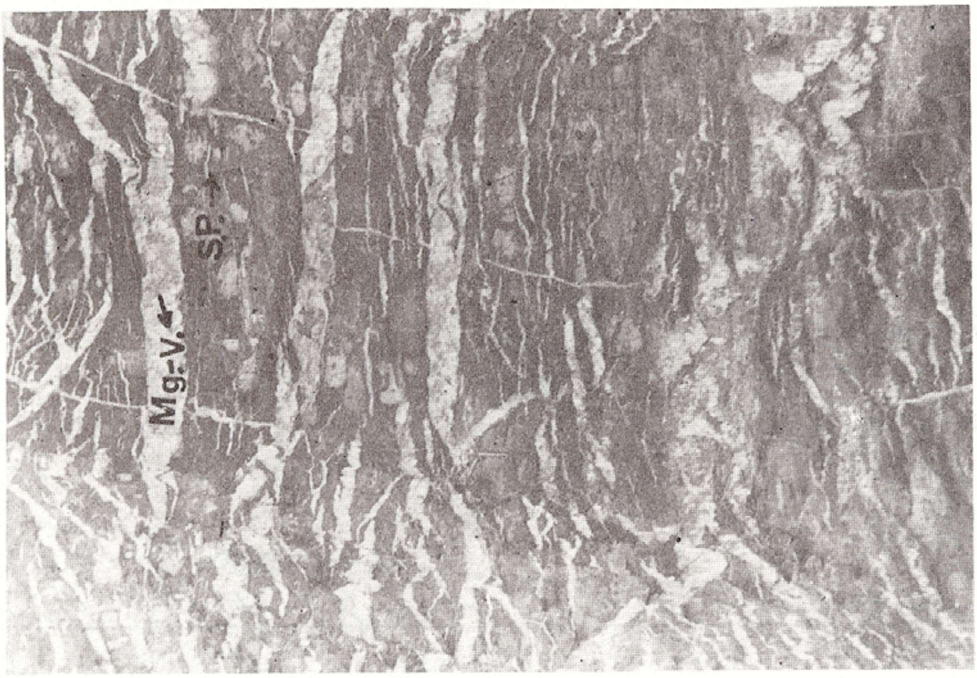


Fig. 5

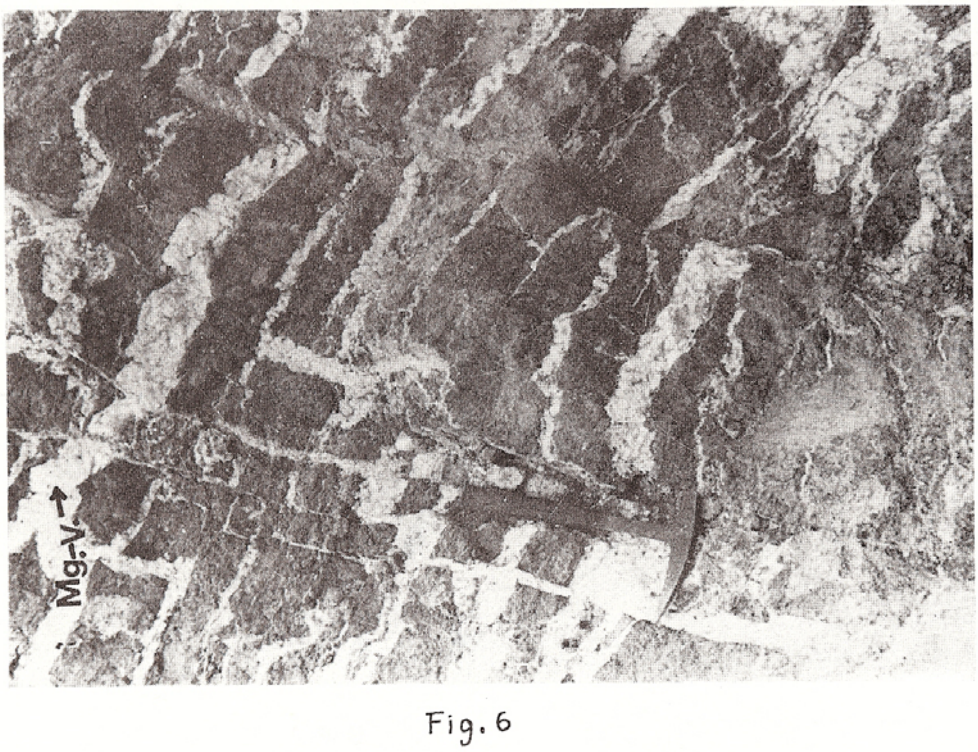


Fig. 6

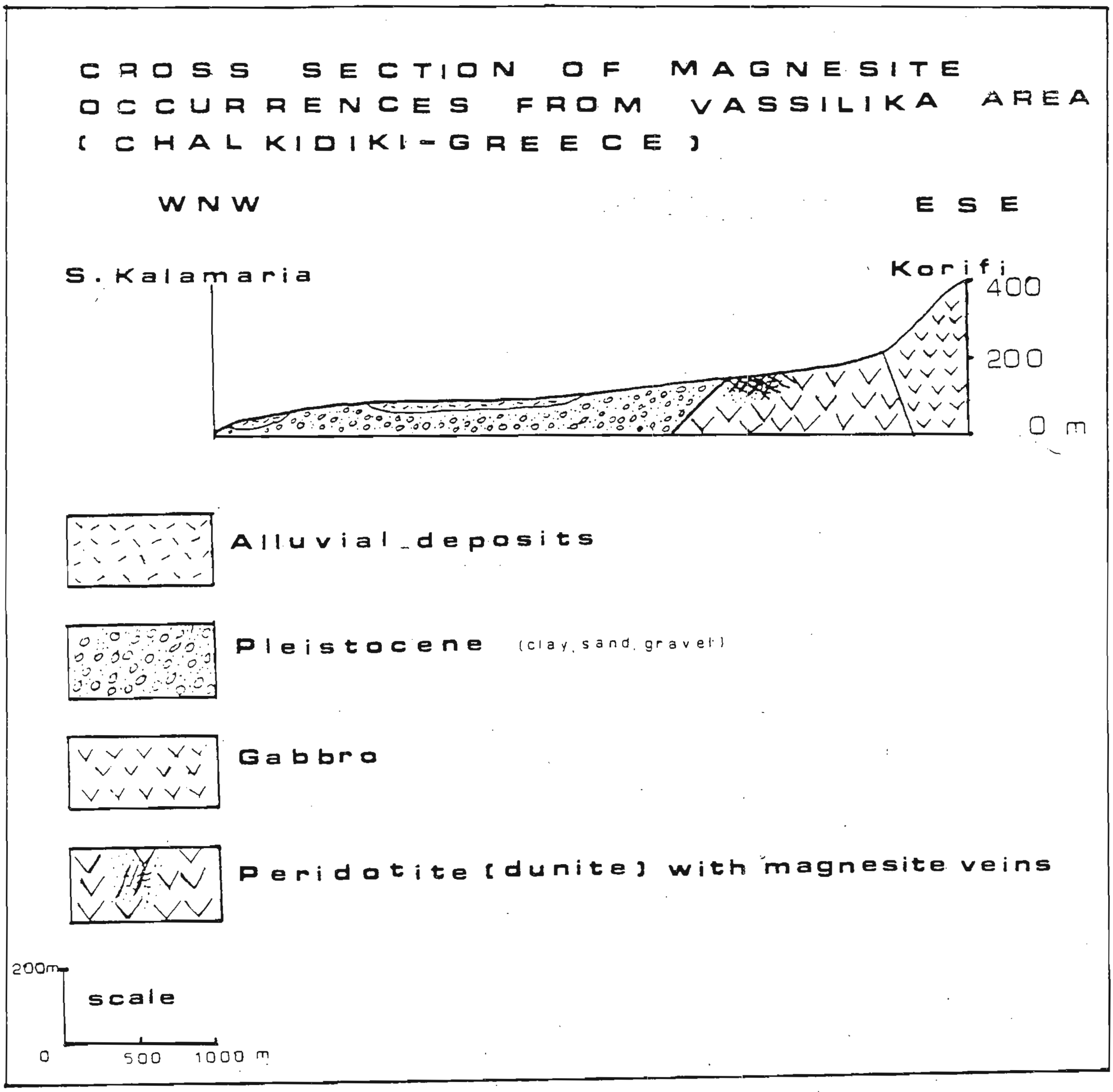
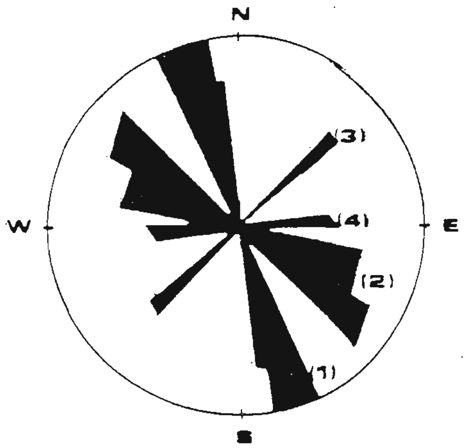
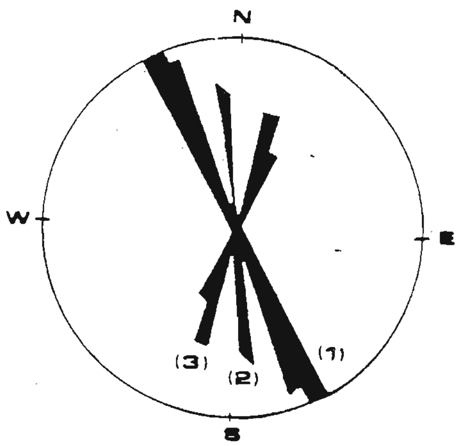

CROSS SECTION OF MAGNESITE OCCURRENCES FROM VASSILIKA AREA (CHALKIDIKI-GREECE)
WNW
ESE
S. Kalamaria
Korifi
400
200
0 m
Alluvial deposits
Pleistocene (clay, sand, gravel)
Gabbro
Peridotite (dunite) with magnesite veins
200m
scale
0
500
1000 m

Fig.7



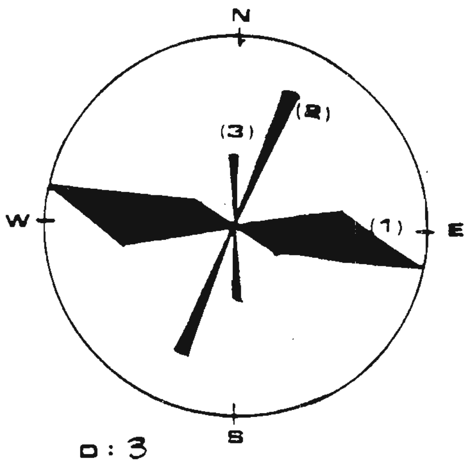
D_1:

Fig. 17



D_2:

Fig. 6



D : 3

Fig. 9

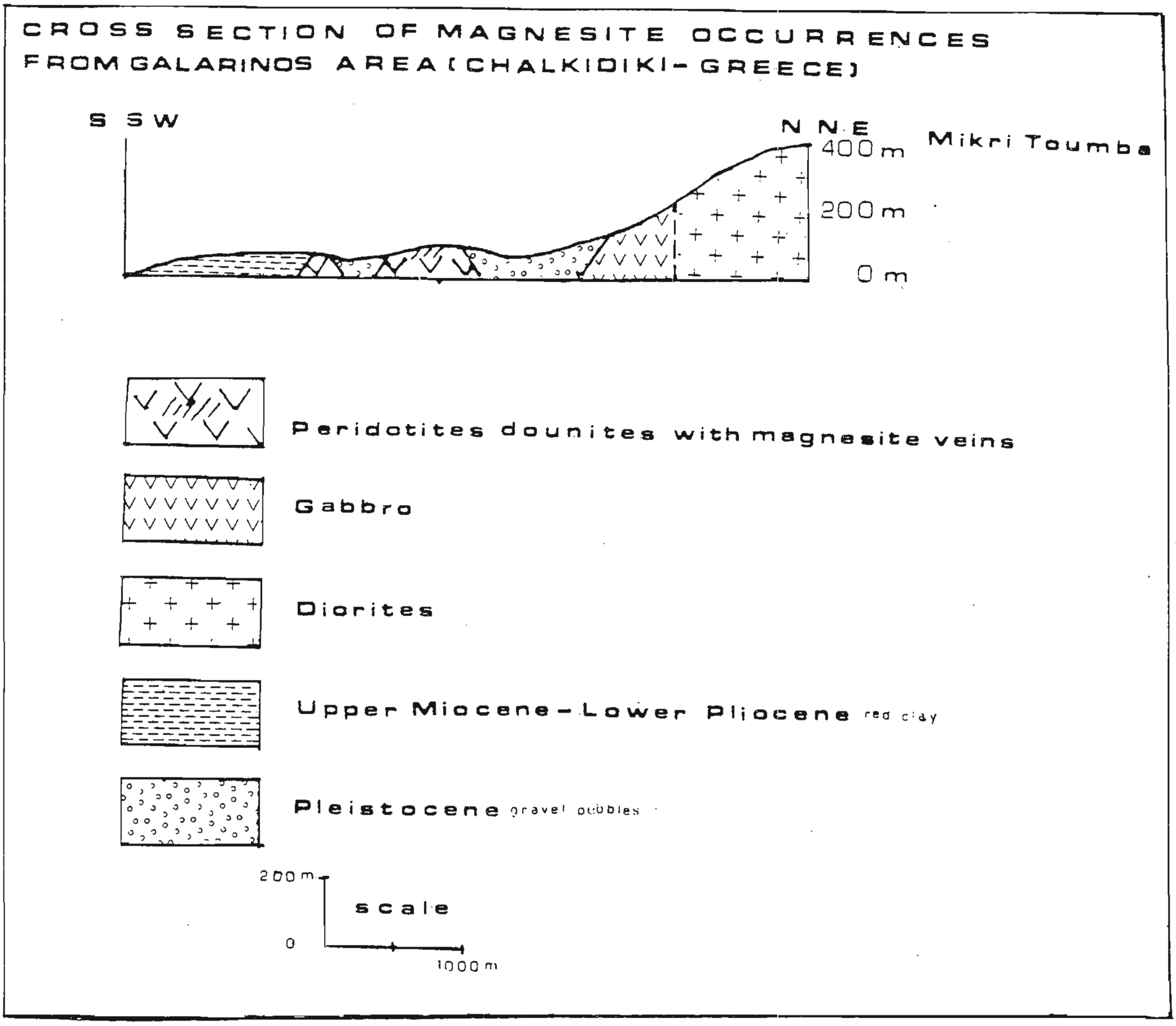

CROSS SECTION OF MAGNESITE OCCURRENCES FROM GALARINOS AREA (CHALKIDIKI-GREECE)
S S W
N N E
400 m
200 m
0 m
Mikri Toumba
Peridotites dounites with magnesite veins
Gabbro
Diorites
Upper Miocene-Lower Pliocene red clay
Pleistocene gravel pebbles
200 m
0
scale
1000 m

Fig. 10

Fig. 11

Fig. 12

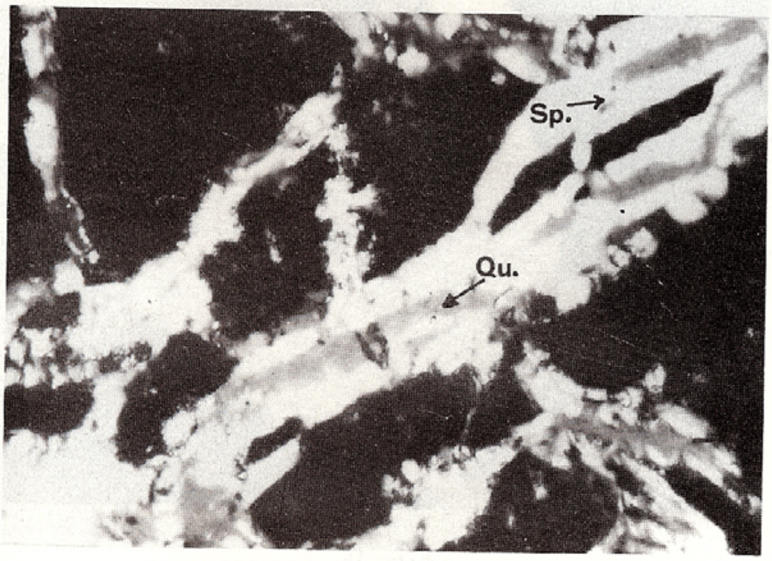


Fig. 13

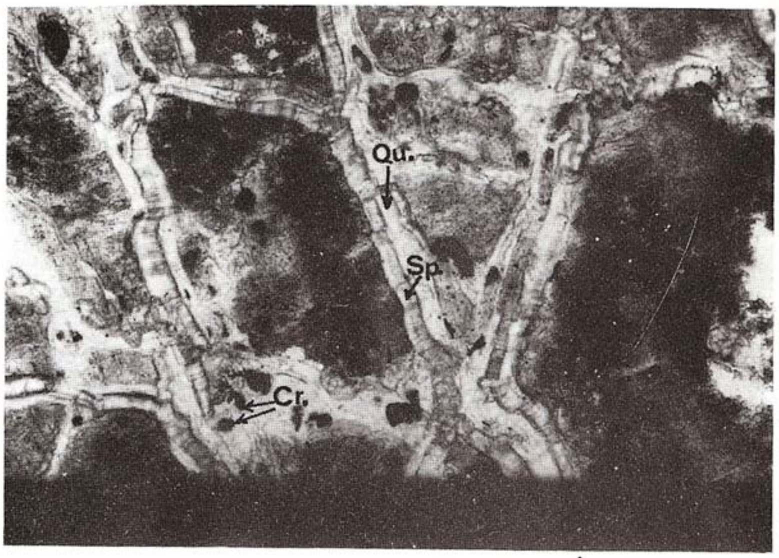


Fig. 14

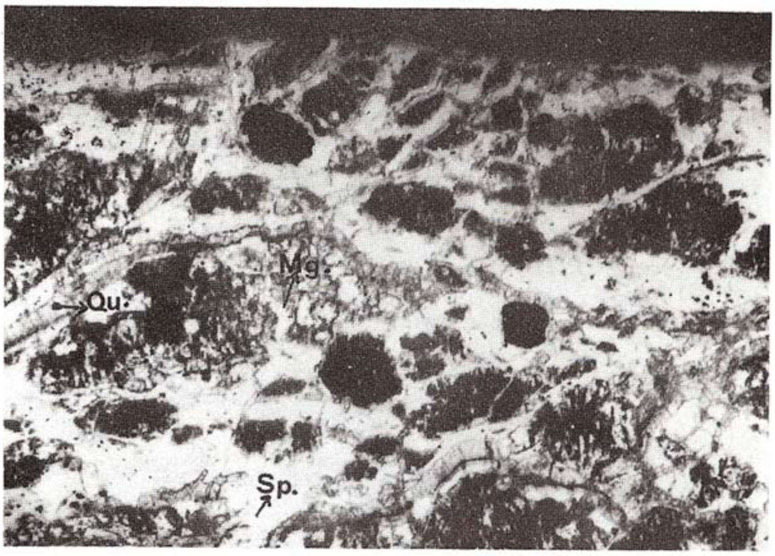


Fig. 15

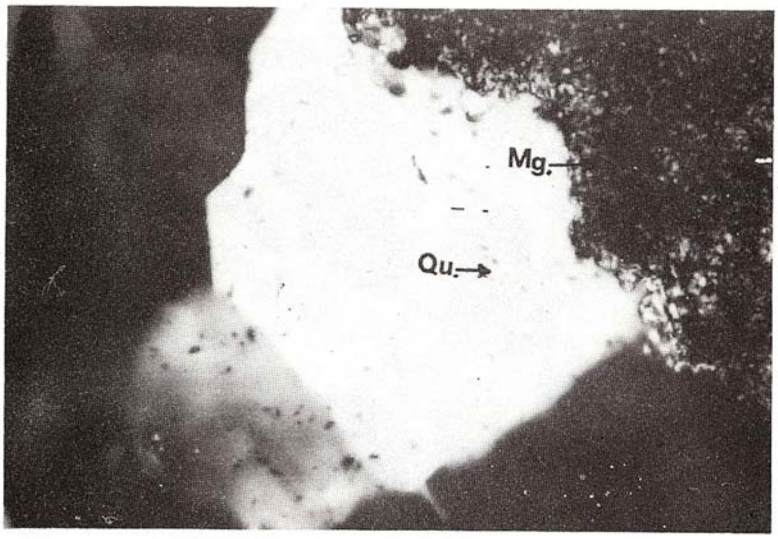


Fig. 16

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RESUMÉ

Comportement des Marbres de Nikissiani (Kavala) et de Panagia (Thassos), a des Fatigues Mechaniques et Influences Physiques et Chimiques

par

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Dr. Géologue

Le marbre est un des plus anciens matériels traditionnels, utilisés dans la construction. En depit de l'enorme developpement du beton de ciment, le marbre a defendu ses position et s'est maintenue, provoquant donc depuis la dernière guerre une augmentation du rythme de la production internationale. Mais pour son utilisation correcte, il est indispensable de bien connaitre tant sa composition minéralogique et chimique que son comportement aux fatigues mechaniques et aux influences chimiques.

But de ce travail est exactement la recherche des caracteristiques mechaniques et minéralogiques de deux types de marbre, qui proviennent des régions de Nikissiani (N), à Kavala et de Panagia (P), à Thassos, pour qu' ils soient utilisés au constructions.

Les deux régions étudiées se trouvent en Macedoine Orientale et du point de vue géologique appartiennent à l'unité de Pangaion, de la masse de Rhodope.

L'étude minéralogique et chimique a montré qu'il s'agit de deux marbres de composition différente; le marbre de Nikissiani est de type calcitique tandis que ce de Panagia est de type dolomitique en MgO = 20.63%. De plus il est determiné au microscope que les crystaux des deux marbres sont en même taille, leur disposition ne présente aucune tendance par rapport à l'orientation et leur comportement mechanique reste presque constant à toutes les directions.

En ce qui concerne les proprietés physiques des deux marbres, on a determiné le poid specifique (N: 2.75 gr/cm^3, P: 2.90 gr/cm^3), l'humidité (N: 0.05%, P:0.095%) et l'absorption d'eau (N: 0.05%, P: 0.30%) selon la normalisation allemande DIN. De plus nous avons trouvé que ces deux marbres sont assez resistants à l'altération par influence de $Na_2SO_4.10H_2O$. A L'attaque par acid chlorydrique le marbre calcaire de Nikissiani agite tandis que au contraire le marbre dolomitique de Panagia reste inattaquable.

En ce qui concerne leur comportement aux fatigues méchaniques les deux marbres sont étudiés selon les normes grècques et allemandes et il est determiné leur resistance à la compression (N: 777 Kg/cm^2, P: 1112 Kg/cm^2) á la flexion (N: 84.4 Kg/cm^2, P: 132 Kg/cm^2) et au choc (N: 1.5 kg*cm, P: 1.34 Kg*cm) ainsi que leur dureté par la methode de Shore (N: 39.16. P: 43.160).

Pour conclure, nous avons essayé connaitre ces deux marbres, du point de vue de leurs caractéristiques techniques et nous avons trouvé que les resultats tombent entre les limites prevues par la normalisation grecque.