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CONTRIBUTION TO THE STUDY OF CHROMITES OF THE VERMION - VORA AREA

by

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Summary: *In the western borders of the Axios zone and in the subzone of Almopia occurs an extended branch of ophiolitic rocks, in many parts of which chromite ore deposits are observed. The ore deposits of the Vermion - Vora area not studied so far, show a great variety of types but generally they belong to the polymorph type. The form of the ore varies from the massif to the scattered type. The reflectivity of the studied chromites show slight changes with the chemical composition. The lowest reflectivity is shown by the argillaceous chromites of Giannakohori. In the fissures of the mineral occur parts with higher reflectivity. In rare cases inclusions of uvarovite, magnetite, pyrrhotite, pyrite and chalcopyrite were observed. The x - ray study showed that the lattice constant a of the studied chromites changes with the chemical composition. The highest value (*8.2977 *Å) corresponds to the iron rich chromites of Polykarpi while the lowest (*8.1960 *Å) by the argillaceous chromites of Giannakohori. The data of the chemical analyses show that the chromites of the Vermion - Vora area belong to two groups, that of Giannakohori with aluminium rich members and that of all the rest occurrences, poorer in aluminium and richer in chromium and iron. Worth noticing is the fact that the ore of Giannakohori is found in serpentinized harzburgite, while all the rest in serpentinized dunite. The fraction Cr/Fe varies between* 4.21 *(Koukouli) and* 2.87 *(Giannakohori). The results of optical, x - ray and chemical study are in complete agreement with the observations of PANAGOS (*1965*) on the chromites of Greece.*

INTRODUCTION

Extended areas in Greece are covered with basic and ultrabasic rocks, a number of which show locally rich to poor ore occurrence of chromite. Studies, descriptions and communications on the chromites, of the Greek region have been published in the past (CAYEUX 1901, DEPRAT 1904, KTENAS 1916 - 17, DÖLTER 1916, GEORGIADIS 1920, DUPARK 1928, LEPEZ 1929a, 1929b, HIESSLEITNER 1937, HIESSLEITNER and CLAR 1951, HIESSLEITNER 1937, HIESSLEITNER 1951, ZACHOS 1953, MARATOS 1960). The main investigator of the Greek chromites PANAGOS (1960, 1964, 1965a, 1965b, 1965c, 1965d, 1966, 1969) collected all the data on the known chromites in Greece and made a detailed optical, chemical and x - rays study (PANAGOS 1965e). However in this study are absent data on the chromites of the Vermion - Vora area, which extends from the northeastern area of the Alyakmon river to the Greek - Yugoslavian border, where appears a whole series of ophiolitic occurrences and corresponding chromite ores. The ophiolite and chromite area southeast of Alyakmon near Vergina were studied by DIMOU (1968).

The present paper aims at completing the research with the study of the chromitic ores of the Vermion and Vora mountains. The experimental part of the research was carried out at the Laboratory of Mineralogy and Petrography of the University of Thessaloniki.

GEOLOGICAL SETTING - PETROGRAPHY - ORE DEPOSITS.

The Vermion - Vora area belongs to the western part of the Axios zone (KOSSMAT 1924) and borders in the west on the pelagonian mass. According to ANASTASOPOULOS and KOUKOUZAS (1970) the Axios zone was overthrust on the eastern side of the pelagonian mass and consists of parallel slices overthrust from east to west. MERCIER (1973) subdivides the original Axios zone of KOSSMAT into three ~~sub~~zones from west to east, the ~~sub~~zone of Almopia, that of Paikon and that of Peonia. The ~~sub~~zone of Almopia, where the ophiolites occur, consists of a set of slices upthrust from east to west, and their cutting off was made in the base as well as sometimes at the top of the ophiolites in such a way that the ophiolitic background can be characterized as aboriginal. The general stratigraphy of the undisturbed pelagonian mass is Triassic limestones, schists, ophiolites, transgressional conglomerate Cretaceous limestones, flysch. In this general setting the ophiolites of the Vermion - Vora district occupy a considerable area to the north and south of Edessa, north and south of Naoussa and northwest to southwest of Veria. They are part of the western branch of ophiolites of the Axios zone, which begins from Yugoslavia and through Orma, Edessa, Naousa ,Veria and the Pieria mountains ends at the scattered ophiolitic occurrences of mountains Olympus and Ossa. The northern part of the above branch of ophiolites cousists of the original rocks of the chromites studied. The ophiolites of the above district are not unaffected by tectonic influences and they usually appear to be serpentinized. Generally dominates serpentinized dunite, but also serpentinized pyroxene peridotite occurs (Giannakohori of Naoussa). The later is recognized easily in macroscopic speciments from its large and unchanged pyroxene crystals. Under the microscope the pyroxene is recognized as orthorombic (enstatite) showing that the rock is a harzburgite.

The mineralogical composition of the serpentinized dunites is different types of serpentine (cellular, with intersected dikes, fibrous) traversed usually by veinlets, consisting of aggregates of magnetite grains which proves that the original olivine contained enough iron. Rests of the original olivine is preserved at rare instances only and the size of its crystals is so small that it is impossible to determine the optical constants. Next, single crystals of chromite are observed, and rarely crystals chlorite, kemererite and uvarovite. In some samples we observed magnetite in thin veinlets within the serpentine. Occurrence of chrysotile is not rare and sometimes it forms typical concentrations which can be characterized as ore deposits (Lycohori of Edessa).

The mineralogical composition of the serpentinized harzburgites is again different types of serpentine, without any original olivine. Characteristic is the occurrence of large crystals of enstatite of a size up to 1.5 cm. The crystals are easily distinguished macroscopically from the rest of the rock because of the characteristic yellowgreen to honey brown colour. Under the microscope they are colourless and a little serpentinized at the rim. They are euhedral with a short prismatic form and occur always in single crystals. They have a weak birefringence, about 0.008, optic axial angle 60° - 65° and a very weak dispersion $p < V$. Characteristic is the presence of numerous very thin platelets of diopside, arranged along the (100) direction of enstatite.

These were evidently formed from exsolution, and they are so thin, numerous and perfectly arranged that at first sight they give the impression of cleavage.

In the serpentinized harzburgites also appear grains of magnetite as well as single crystals of chromite. At several points of these ophiolitic masses have been occasionally recognized concentrations. Thus, LEPEZ (1929) reports a chromitic ore in serpentine north of Veria; OSSWALD (1938) mentions, chromitic occurrences in Polykarpi, Edessa, Naoussa and Veria. According to our investigation the concentrations of chromite appear scattered at various points and differ from simple occurrences to ore deposits.

Small ore deposits, partly exploited in the past, were found in the districts Polykarpi of Edessa, Giannakohori of Naoussa and Fytia of Veria. According to what local people say the last exploitation took place during the German occupation.

There are also numerous small occurrences in some of which research mining was made in the past. The ore deposits show a great variety of types which may be generally described as flask - like to lenticular ores with wedging ends.

Tubular bodies as well as sill like formations are rarer. Many of these formations appear to be inclined and distorted or completely irregular, a fact showing that the tectonic influence was considerable during and after the original crystallization period of the magma and the derivation of chromite crystals from this.

Considerable and extremely variable is the inclination of the chromitic bodies but it does not generally follow a certain law in the Vermion - Vora area.

The shape of the ore shows a smaller variation of types. Generally dominates the massif ore deposit of chromite, which in some cases are surrounded by scattered chromite (Fytia, Veria). The SCHLIEREN plate type is rare. The scattered ore type is also rare, while the leopard ore type or bulb type has not been observed in any of the investigated deposits and occurrences.

The form, occurrence of the ore deposits and their connection with the neighbouring rock shows that it is undoubtedly about ores of podiform type. This type of chromite ores is met in basic and ultrabasic rocks of alpine type.

These data are in absolute agreement with the observations of PANAGOS (1965) on the chromite ore deposits of all Greece.

OPTICAL STUDY

Under the microscope the chromite crystals appear either as independent grains, of size 0,1 - 2 mm, or as aggregates with difficult to distinguish borders Eugedral crystals are nearly absent. Usually they occur as hypidiomorphic with slightly rounded rims. The magmatic erosion is usual in chromites of the scattered type (Fig. 1) but it is also observed in the SCHLIEREN type. On the contrary it is absent from the chromites of the massif type, but many times the original hypidiomorphic crystals are later broken on the (III) plane. Fissures of the mineral filled with serpentinic material, are very usual. Rarer is the case of fissures without intersecting serpentine. Besides, many times there are observed very small pores spread regularly in the whole mass the mineral. In polished sections chromite appears with a greyish colour and a slightl brown shade. Internal reflections are rare in the iron and chromium rich chromites, while the opposite happens with the argillaceous ores (Giannakohori). The latter can better be distinguished with oil immersion and they always appear brownish red.

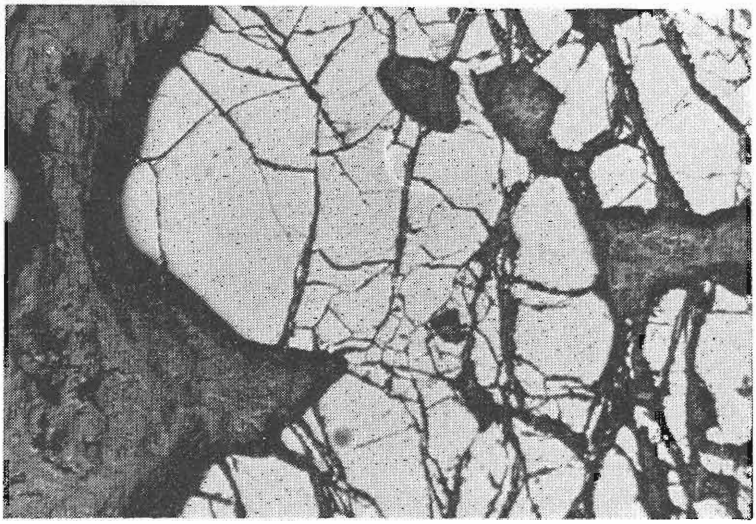

Fig. 1

Hypidiomorphic crystal of chromite showing magmatie erosion and slight cataclasis. Koukouli. Polished section 73 X Nicols//.

The reflectivity of the mineral is weak to usual, and varies slightly in the different types. The highest (but always weak) reflectivity was observed in the chromites of Koukouli and the weakest in the argillaceous ores of Giannakohori. Zonal change of the reflectivity was not observed anywhere. On the contrary in the chromites of Fytia was noticed a considerably increased reflectivity along the fissures of the mineral (Fig. 2).

This fact was also observed by Dimou (1968) in the chromites of the neighbouring Vergina. There, however this fact is connected with penetration of serpentine in the fissures and their enlargment, a fact which changes the reflectivity in the bordes of the mineral.

Thus, this investigator connects this phenomenon with serpentinization and considers that during serpentinization takes place a gradual substitution of the chromium and aluminium atoms by iron atoms released during, serpentinization.

According to Ramdohr (1969) the case of increased reflectivity in the fissures is due to erosion or to hydrothermal decomposition with formation of iron rich chromspinel. Routhier (1964) describes the phenomenon as «limonitization» of chromites because of solutions which circulate through the fissures. According to our observations the pre-

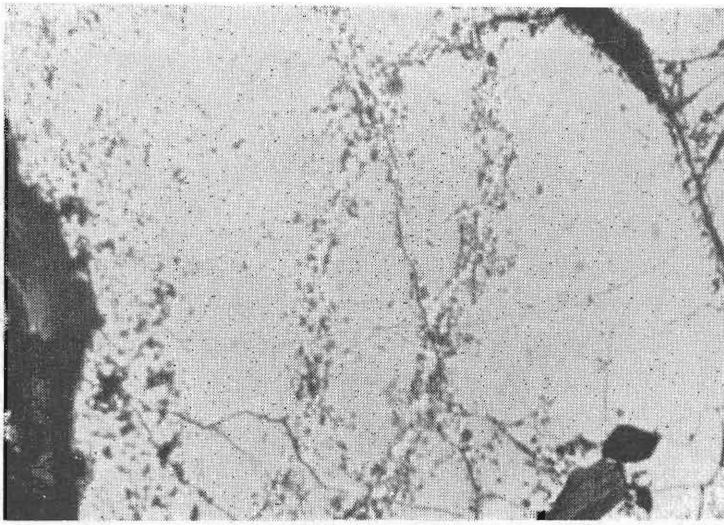

Fig. 2

A chromite crystal with breaks where we observe an increased reflectivity. Fytia. Polished section 73 X Nicols //.

sence of serpentine was never noticed in the fissures, nor was observed any correspondence between the phenomenon of increased reflectivity of the mineral along or near the fissures and the phenomenon of serpe-

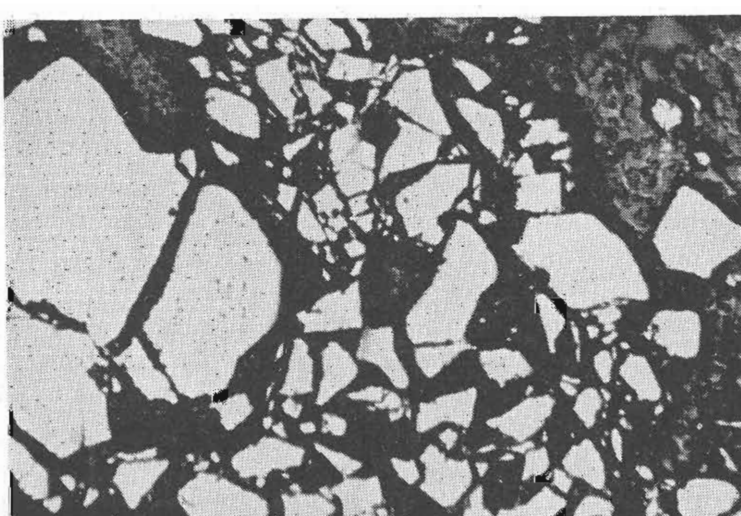

Fig. 3

Strong cataclasis of a chromite crystal with a eomplete breaking of it. Giannakohori. Polished section 73 × Nicols //

ntinization. At all events the reflectivity of those parts never reaches that of magnetite.

Hence we can not characterize these parts as magnetite but as an intermediate product. Cataclastic events are not rare. Breaking of the mineral due to serpentinization of dunite have already been described. Apart from these, strong breaking due to absolutely tectonic reasons was also observed. The chromites of Giannakohori show in the borders of the ore body a zone of strong mylonitization. The corresponding polished sections show under the metallographic microscope broken and pulverized crystals of chromite (Fig. 3 and 4). The change is limited only in the tecture of the ore and is not acompanied by a change of composition or of reflectivity. Inclusion of other minerals in the chromite crystals are rather rare.

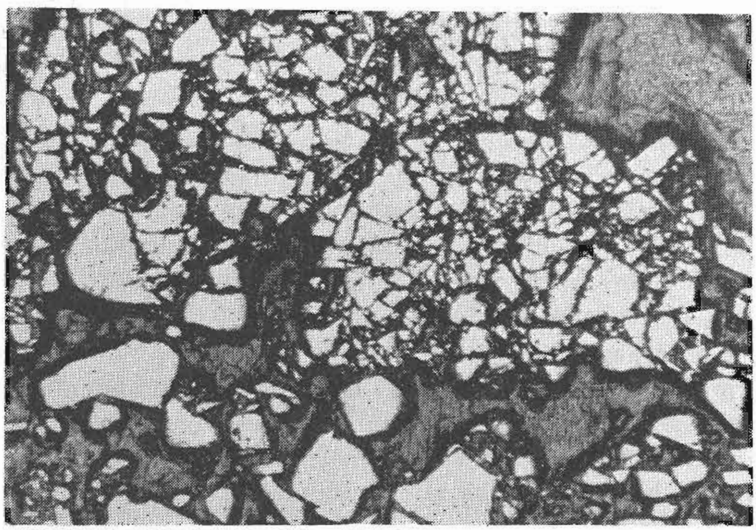

Fig. 4

Very advanced cataelasis of a crystal of chromite (pulverized crystal), Giannakohori. Polished section 73 X Nicols //.

A part from the serpentinized olivine there ware observed small inclusions of uvarovite, pyrrhotite, pyrite, and chalcopyrite. Exsolution of ilmenite or myrmekitic texture with magnetite were never observed.

X - RAY STUDY

The x - ray investigation aimed at finding the lattice constant a of the chromites studied. The value of this parameter varies with the chemical composition (Clark and Abde 1932) and usually is smaller in the argillaceous members of the group. Powder diagrams from the chemically analyzed samples were taken so that a comparison of the values obtained with the chemical composition could be rendered possible. The diagrams were taken with a Phillips powder diffractometer with Fe Ka (Mn filter) radiation.

The parameter was calculated from the 113 reflection, which is the strongest line in chromites. The results are given in the following Table 1.

Table 1

Latice constant of chromites of the Vermion - Vora area

Sample	Locality	a(Å)
1	Polykarpi	8,2977
2	Koukouli	8,2955
3	»	8,2965
4	Giannakohori	8,1960
5	»	8,2040
6	Fytia	8,2774
7	»	8,2932

From the Table follows that:

1) The highest value of the constant is shown by the chromites of Polycarpi, which are also the richest in iron from the group of non - argillageous chromites of the Vermion - Vora area.

2) A little smaller but neverthless high value is shown by the chromites of Koukouli, which are the chromium richest from the non - argillageous group.

3) The lowest value is shown by the chromites of the argillaceous group of Giannakohori, which have been thus characterized from the results of chemical analysis.

These data are in absolute agreement with the conclusions of Panagos (1965) regarding the rest of the Greek chromites.

Chemical study

To determine the chemical evolution of the Vermion - Vora area chemical analysis on 7 samples were made. The iron was determined in the total as ferrous, but this does not cause error since no crystal chemical calculations were necessary. The results of the analysis are given in the following Table II.

TABLE II

Analysis of chromites of the Vermion - Vora area

Sample	Cr_2O_3	Al_2O_3	FeO	MgO	SiO_2	Total	Locality
1	58,96	10,33	15,28	14,41	traces	98,98	Polykarpi
2	62,43	8,17	13,06	15,67	»	99,43	Koukouli
3	59,91	7,52	13,58	18,25	»	99,26	»
4	46,63	14,32	13,29	24,19	»	98,43	Giannakohori
5	49,98	15,10	15,31	18,80	»	99,19	»
6	55,98	7,81	16,71	17,78	»	98,28	Fytia
7	59,41	7,06	15,60	16,93	»	99,00	»

Analyst: G. TRONTSIOS

Since the analysed samples of chromites were carefully separated from the coexisting serpentine, the SiO_2 does not enter in the results except as traces. Thus it was not necessary to calculatet the «final MgO» that is the resulting MgO after the substraction of MgO corresponding to the serpentine molecule, from the total determined value. From the chemical data the partial totals $Cr_2O_3 + MgO + FeO$, $Cr_2O_3 + Al_2O_3 + FeO$ and $Cr_2O_3 + Al_2O_3 + MgO$ were calculated as well as the percentage of the above components in each partial total. The following Table III gives the partial totals of Cr_2O_3, MgO and FeO from the analysis of Table II as well as the percentage of the above components in the total.

TABLE III

Partial total and percentage of Cr_2O_3, MgO and FeO according to the analyses of Table II.

Sample	Locality	$Cr_2O_3 + MgO + FeO$	Cr_2O_3 %	MgO %	FeO %
1	Polykarpi	88,65	66,51	16,25	17,24
2	Koukouli	90,96	68,63	17,01	14,36
3	»	91,74	65,30	19,90	14,80
4	Giannakohori	84,11	55,44	28,76	15,80
5	»	84,09	59,44	22,35	18,21
6	Fytia	90,47	61,88	19,65	18,47
7	»	91,94	64,62	18,41	16,97

From the calculated values of Table III the projection diagram of them an equilateral triangle, shown in Fig. 5 (page300).

Table IV gives the partial totals of Cr_2O_3, Al_2O_3 and FeO from the analyses of Table II, as well as the percentage of the above components in the total.

TABLE IV

Partial total and percentage of Cr_2O_3, Al_2O and FeO from the analyses of table II

Sample	Locality	$Cr_2O_3 + Al_2O_3 + FeO$	Cr_2O_3	Al_2O_3	FeO
1	Polykarpi	84,57	69,71	12,22	18,07
2	Koukouli	83,66	74,62	9,76	15,62
3	»	81,01	73,95	9,29	16,76
4	Giannakohori	74,24	62,81	19,29	17,90
5	»	80,39	62,17	18,78	19,05
6	Fytia	80,50	69,54	9,70	20,76
7	»	82,07	72,39	8,60	19,01

From the values of Table IV the projection diagram on an equilateral triangle shown in Fig. 6 (page300).

Table V gives the partial totals of Cr_2O_3, Al_2O_3, and MgO from the analyses of Table II as well as the percentage of the above components in the total.

TABLE V

Partial total and percentage of Cr_2O_3, Al_2O_3 and MgO from the analyses of Table II.

Sample	Locality	$Cr_2O_3 + Al_2O_3 + MgO$	Cr_2O_3 %	Al_2O_3 %	MgO %
1	Polykarpi	83,70	70,44	12,34	17,22
2	Koukouli	86,07	72,54	9,49	17,97
3	»	85,68	69,92	8,72	21,30
4	Giannakohori	85,14	54,77	16,82	28,41
5	»	83,88	59,58	18,01	22,41
6	Fytia	81,57	68,63	9,57	21,80
7	»	83,40	71,24	8,46	20,30

Fromthe calculate values of Table V the projection diagram of their projection on an equilateral triangle, shown in fig. 7, (page300).

Finnaly, Table VI gives the percentage of the metallic elements according to the analyses of Table II as well as the franction Cr/Fe.

TABLE VI

Percentage of mettallic components and fraction Cr/Fe.

Sample	Locality	Cr %	Fe %	Al %	Mg %	Cr/Fe
1	Polykarpi	40,34	11,88	5,47	8,69	3,39
2	Koukouli	42,72	10,15	4,32	9,33	4,21
3	»	40,99	10,56	3,98	11,01	3,88
4	Giannakohori	31,91	10,33	7,57	14,59	3,09
5	»	34,20	11,90	7,99	11,34	2,87
6	Fytia	38,31	12,99	4,13	10,72	2,95
7	»	40,65	12,13	3,73	10,21	3,35

From the diagrams we conclude that the chromites of the Vermion - Vora area are divided into two groups: the group of Giannakohori chromites and that of all the others. The distinction is very clear in the diagrams of Figs 2 and 3 and mainly along the line Al_2O_3 - Cr_2O_3. The group of Giannakohori includes chromites rich in aluminium and iron. It is remarkable the fact that the parent rock of chromites of the Giannakohori group is serpentinized pyroxen peridotite (harzburgite), while that of all the others is serpentinized dunite. THAYER (1940) and BATEMAN (1950) found out in the chromites of Oregon that the aluminium rich members are connected with feldspar parent rocks, i.e. with gabbros and norites, while the chromium rich are connected with rocks without feldspars and poor in iron and aluminium. PANAGOS (1965) concludes that the Greek argillaceous chromites are connected with pyroxen peridotites and the chromium - rich chromites with dunites. This conclusion is in absolute agreement with our observations as already mentioned above.

The chromites of the Giannakohori group show, as mentioned, the smallest fraction Cr/Fe. From the members of the other group the highest chromium composition as well as the highest fraction Cr/Fe is shown by the chromites of Koukouli. In the same group the lowest fraction Cr/Fe is shown by the chromites of Fytia while those of Polykarpi occupy an intermediate position.

The results of the chemical study are in complete agreement with the optical results as regards the reflectivity and with the x - ray analysis as regards the lattice parameter.

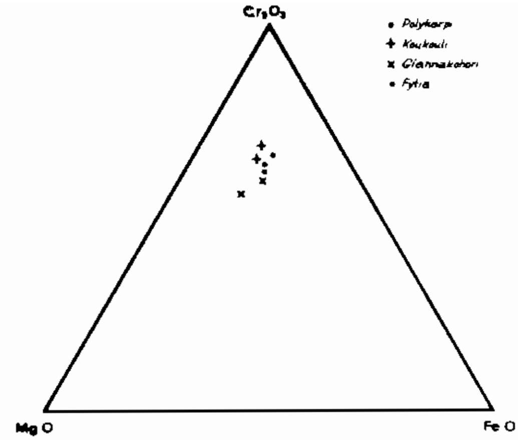

Fig. 5

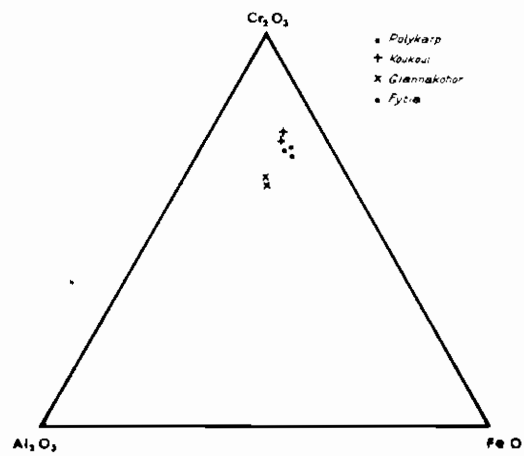

Fig. 6

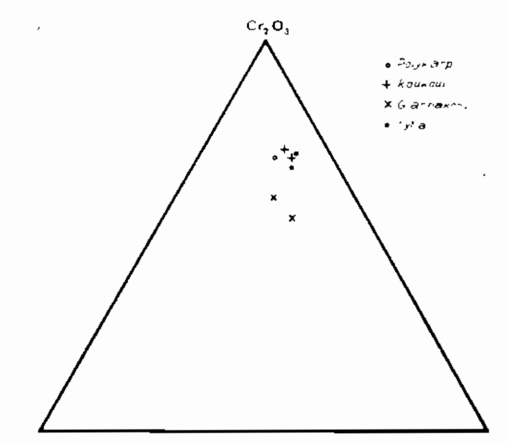

Fig. 7

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ΠΕΡΙΛΗΨΙΣ

ΣΥΜΒΟΛΗ ΕΙΣ ΤΗΝ ΜΕΛΕΤΗΝ ΤΩΝ ΧΡΩΜΙΤΩΝ ΒΕΡΜΙΟΥ - ΒΟΡΑ

Ὑπὸ

Α. ΠΑΠΑΔΑΚΗ καὶ Γ. ΤΡΩΝΤΣΙΟΥ

(Ἐργαστήριον Ὀρυκτολογίας καὶ Πετρογραφίας τοῦ Παν/μίου Θεσ/νίκης)

Εἰς τὰ δυτικὰ κράσπεδα τῆς ζώνης τοῦ Ἀξιοῦ καὶ δὴ εἰς τὴν ὑποζώνην τῆς Ἀλμωπίας ἐμφανίζεται ἐκτεταμένος κλάδος ὀφειολιθικῶν πετρωμάτων εἰς πλεῖστα σημεῖα τοῦ ὁποίου ἔχει ἐπισημανθῆ ἡ παρουσία χρωμιτικῶν κοιτασμάτων. Τὰ κοιτάσματα τῆς περιοχῆς Βερμίου - Βόρα, τὰ ὁποῖα μέχρι τοῦδε δὲν εἶχον μελετηθῆ, παρουσιάζουν μεγάλην ποικιλίαν μορφῶν, γενικῶς ὅμως ἀνήκουν εἰς τὸν λοβόμορφον τύπον. Ἡ μορφὴ τοῦ μεταλλεύματος ποικίλει ἀπὸ τοῦ συμπαγοῦς ἕως τοῦ διασπάρτου τύπου. Ἡ ἀνακλαστικὴ ἱκανότης τῶν μελετηθέντων χρωμιτῶν ἐμφανίζει μικρὰς διακυμάνσεις μετὰ τῆς χημικῆς συστάσεως. Τὴν μικροτέραν ἀνακλαστικὴν ἱκανότητα δεικνύουν οἱ ἀργιλλοῦχοι χρωμῖται τοῦ Γιανναχοχωρίου. Ἐντὸς ρωγμῶν τοῦ ὀρυκτοῦ ἐμφανίζονται τμήματα μὲ μεγαλυτέραν ἀνακλαστικὴν ἱκανότητα. Μετὰ τῶν χρωμιτῶν παρετηρήθησαν εἰς σπανίας περιπτώσεις ἐγκλείσματα οὐβαροβίτου, μαγνητίτου, μαγνητοπυρίτου, σιδηροπυρίτου καὶ χαλκοπυρίτου. Ἡ ἀκτινογραφικὴ ἔρευνα ἔδειξεν ὅτι ἡ σταθερὰ α τοῦ πλέγματος τῶν μελετηθέντων χρωμιτῶν μεταβάλλεται μετὰ τῆς χημικῆς συστάσεως. Τὴν ὑψηλοτέραν τιμὴν (8,2977 Å), παρουσιάζουν οἱ πλούσιοι εἰς σίδηρον χρωμῖται τῆς Πολυκάρπης, ἐνῷ τὴν χαμηλοτέραν (8,1960 Å), οἱ ἀργιλλοῦχοι χρωμῖται τοῦ Γιανναχοχωρίου. Τὰ δεδομένα τῶν χημικῶν ἀναλύσεων δεικνύουν ὅτι οἱ χρωμῖται τῆς περιοχῆς Βερμίου - Βόρα ἀνήκουν εἰς δύο ὁμάδας, τὴν ὁμάδα τοῦ Γιανναχοχωρίου μὲ πλούσια εἰς ἀργίλλιον μέλη καὶ τὴν ὁμάδα ὅλων τῶν ὑπολοίπων ἐμφανίσεων πτωχοτέραν εἰς ἀργίλλιον καὶ πλουσιωτέραν εἰς χρώμιον καὶ σίδηρον. Ἄξιον προσοχῆς εἶναι ὅτι τὸ κοίτασμα Γιανναχοχωρίου εὑρίσκεται ἐντὸς σερπεντινιωμένου χαρτζβουργίτου, ἐνῷ ὅλα τὰ ὑπόλοιπα ἐντὸς σερπεντινιωμένου δουνίτου. Ὁ λόγος Cr/Fe κυμαίνεται μεταξὺ 4,21 (Κουκούλι)καὶ 2,87 (Γιανναχοχώρι). Τὰ συμπεράσματα τῆς ὀπτικῆς, ἀκτινογραφικῆς καὶ χημικῆς ἐρεύνης εὑρίσκονται εἰς ἀπόλυτον συμφωνίαν μὲ τὰς παρατηρήσεις τοῦ Πανάγου (1965e), ἐπὶ τῶν χρωμιτῶν τῆς ὑπολοίπου Ἑλλάδος.