Mineral Res. Expl Bull , 117, 17-28, 1995

GENESIS OF THE DİVRİĞİ IRON ORE DEPOSIT, SiVAS, CENTRAL ANATOLIA, TURKEY-AN ORE MICROSCOPY STUDY

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ABSTRACT - Divriği A-Kafa iron deposit is tectonically located at the contact between serpentinites, and limestones and/or granitic rocks, while Divriği B-Kafa iron deposit lies between serpentinites and limestones Both deposits were formed during hydrothermal alteration of serpentinites Magnetite constitutes the dominant ore mineral of A-Kafa with up to 5 vol. % disseminated pyrite The main ore mineral at B Kafa is a maghemitized and martitized magnetite cross-cut by carbonate and silicate veinlets Textural relationships of ore minerals indicate that iron is derived from serpentinites The iron is enriched by serpentinization processes and further concentrated by hydrothermal convective cells caused by the intrusion of the Murmano pluton. These convective cells exert important influence on the shape of the ore bodies The suggested model implies that the region has potential for future exploration wath a good chance for finding additional iron ore reserves

INTRODUCTION

The iron ores of the Divriği area of Central Anatolia are the most important in Turkey. Unlu and Stendal (1986, 1989a, 1989b) and Stendal and Ünlü (1988,1991) described the genesis of these iron ores from a geochemical point of view. In this paper the ore mineral textures are studied. Previous field investigations in the area and its close vicinity have been carried out by Koşal (1973), Bayhan (1980), Ozgul et al: (1981) and Gultekin (1993). Detailed geochemical studies of the ore deposits and its surrounding have been described by Gümüş (1979), Stendal and Unlu (1988, 1991), Ünlü and Stendal (1986, 1989a, 1989b), Unlu et al. (1989), Zeck and Ünlü (1987, 1988a, 19886, 1991), and Unlu (1989). Ore microscopic investigations have been made by Gysin (1938), Klemm (1960), Gümüş (1969), Bozkurt (1974, 1980), Çağatay (1975), Çağatay and Arda (1976), Bayhan (1980), Bayhan and Baysal (1981).

GEOLOGICAL SETTING

The host and country rocks of Divriği iron deposits are mainly represented by serpentinites tectonically related with Mesozoic limestones, hydrothermally altered serpentinites and granitic rocks The ore deposits occur in extensively hydrothermally altered serpentinites bordering the contacts to intrusive rocks.

The alteration processes have affected the iron ores at different stages by remobilization of Fe and recrystallization of the iron ore minerals. The main processes are the serpentinization of ultramafic rocks followed by the intrusion of the Murmano granitic pluton. The latest changes of the ore happened during weathering processes.

In this study, the formation of the ore deposit will be discussed, based on the textural relationships between ore minerals in Divriği A-and B-Kafa.Textural features of ore minerals in the Divriği-Güneş-Soğucak region, especially in serpentinites sampled away from the granitic rocks and serpentinites cut by the Murmano pluton (Fig.1) and thus hydrothermally altered, will be discussed as well. Serpentinites of Divriği iron ore deposits are extensively altered by hydrothermal fluids. Both magmatic and meteoric water circulated in a convective system activated by heat from the intrusion of granitic rocks. In this study, the role of two different stages of alteration, the serpentinization and the hydrothermal alteration of the serpentinites will be discussed by means of their reflection in mineral textures.

Lithologies represented. by serpentinized ultramafic rocks and mafic rocks of Güneş, ophiolite and Mesozoic aged limestone blocks crop out around Soğucak. Serpentinites are the host rocks of disseminated and vein type mineralizations.

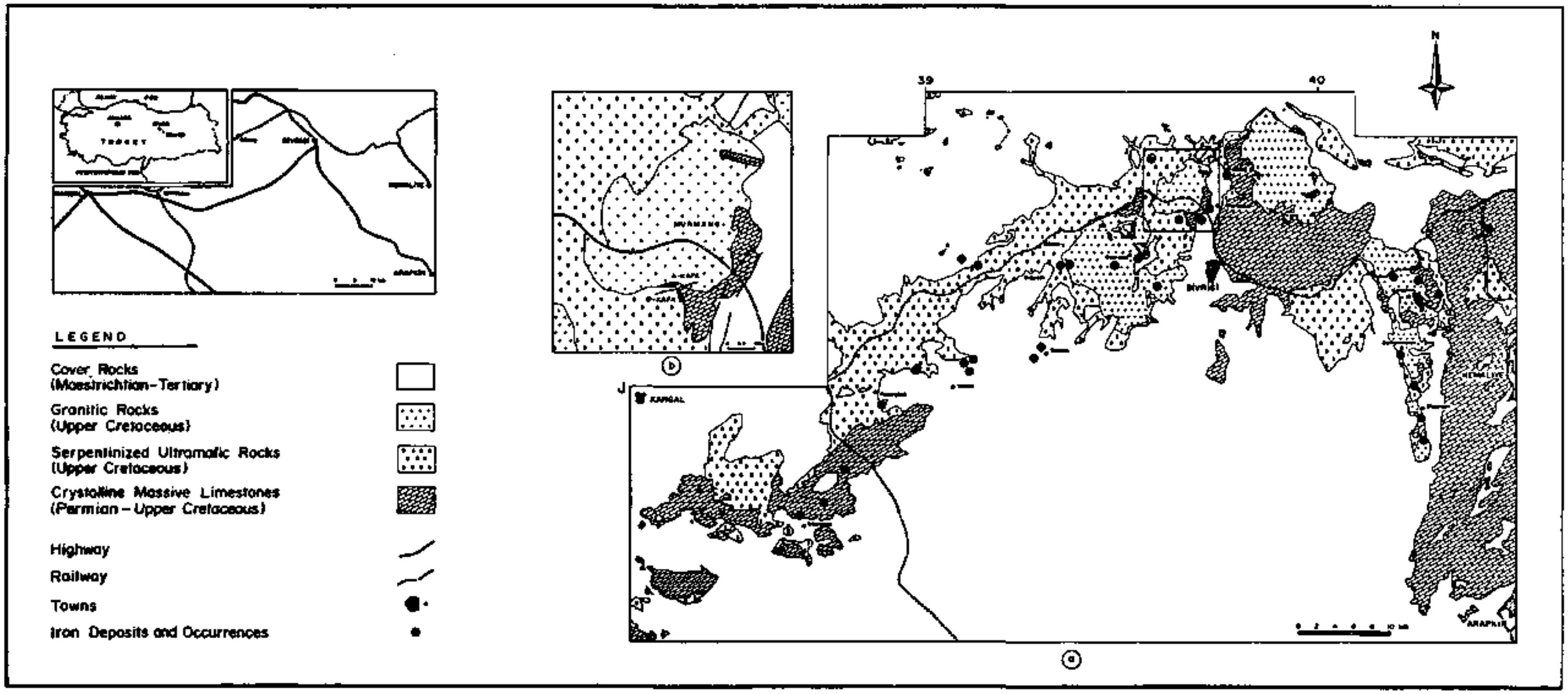

Fig. 1a- Geological map of Sivas-Erzincan iron sub-province (simplified after geological map prepared with the aim of iron exploration studies-registered by 42465 number at MTA archive).

Fig. 1b- Geological map of Divriği A- and B- Kafa iron deposits (simplified after Koşal, 1973).

ORE PETROGRAPHY

DİVRİĞİ IRON ORE DEPOSIT

A- and B-Kafa serpentinites

Serpentinites crop out close to the Divriği iron ore deposits and are generally derived from peridotites. Pyroxenites are also pervasively serpentinized. Serpentinites contain olivine relics together with lizardite, chrysotile, antigorite, bastite and uralites as well as disseminations and veinlets of opaque minerals. Serpentinites are the host rocks to the Divriği A- and B-Kafa iron ore deposits.

The dominant opaque mineral in the serpentinites is magnetite. Magnetites with various crystal forms reflect different formation conditions. Massive magnetite contains irregularly scattered, anhedral pyrite and silicate inclusions. The magnetite underwent secondary replacement by goethite and lepidocrocite.

A second magnetite type in the serpentinites occurs as rims of euhedral to subhedral and locally cataclastic chromites (Plate III, fig. 2). A transition zone between magnetite and chromite is illustrated in Plate I, fig. 5-6 and Plate V, fig. 4. In addition, magnetites occur in cracks of the chromites. A third kind of magnetite is apparently localized along the borders between olivine and orthopyroxene relics in the serpentinization texture of the rock.

These magnetite types are formed during serpentinization and are characterized by inclusions of minor amounts of pyrite (± Ni-sulphides) and abundant silicates (Plate III, fig.1). Other forms of magnetite are often observed as rınglike shapes surrounding silicate pseudomorphs. Limonite as another replacement product (Plate II, fig. 1-4) is concentrated in small cracks of above mentioned silicates (Plate IV, fig.4).

Euhedral magnetites without any ore mineral inclusions are younger than the above mentioned magnetites and occur in small amounts in veinlets cross cutting the host rock.

Pyrrhotite is observed occasionally in the serpentinites.

Hydrothermally altered serpentinites of A-and B-Kafa

Hydrothermally altered serpentinites dose to the contact of granitic rocks near the Divriği iron ore deposit can be distinguished from the unaltered serpentinites by their lighter colour and lesser amounts of disseminated opaque minerals. Breccias in serpentinite and in veinlets are frequently seen in the hydrothermally altered serpentinites and veinlets filled by magnetite with sulphide, silica and carbonate minerals cutting the rock intensively.

Disseminated, fine grained anhedral magnetite occurs together with pyrite and chalcopyrite. Some magnetite is replaced by goethite. Pyrite contains pyrrhotite, magnetite, chalcopyrite and silicate inclusions. Chalcopyrite is accompanied by anhedral millente and linneite (violarite) minerals.

Magnetite occurs also at the outer rim of euhedral to subhedral and partly cataclastic, rounded chromites like those described in the serpentinites. This type of magnetite surrounds the chromites and is also emplaced in the cracks of chromites (Plate V, fig.3). A transition zone with various colours exists between chromite and surrounding magnetite (Plate V, fig.2). Silicate inclusions are observed in some chromites. Magnetite- chromite occurrences are associated with fine-grained euhedral and disseminated pyrite, chalcopyrite and magnetite. Most of the magnetite is cataclastic and withoutinclusions.

Another magnetite generation is characterized by transition from magnetite with abundant silicate inclusions to one without any inclusions. This stage indicates the most important feature distinguishing hydrothermally altered serpentinites caused by granitic rocks from the primary serpentinites. Silicate mineral inclusions in magnetite gradually disappear, resulting in a magnetite rim without any inclusions. The pure, recrystallized magnettite is sometimes associated with pyrite without any inclusions, but frequently with coarse grained, angular silicate minerals. Intergrowths between magnetite, pyrite and silicate do exist and magnetite is usually surrounded by silicates.

Veins and veinlets with magnetite contain abundant silicate inclusions. This young generation of magnetite is coarse grained, displays very weak anisotropy and equilateral quadrant-like sectorial zoning. It should be taken into account that this zoning can be formed as a replacement texture of orthopyroxene by magnetite (Plate VII, fig. 2). This type of magnetite is associated with angular, fine-grained and tabular mica minerals (e.g. phlogopite). Sulphide minerals are absent in this paragenesis, only magnetite arid silicates occur together.

Rutile is found in the hydrothermally altered, partly serpentinized and chloritized mafic rocks. Rutile is also found as inclusions in pyrite surrounded by silicates. Rutile is occasionally transformed to sphene. The rutile formation is interpreted as alteration of primary titanomagnetite and ilmenite.

Extensively hydrothermally altered serpentinites have a few late stage veins with sphalerite, chalcopyrite, chalcosite, digenite, tetraedrite-tennantite and galena.

A-Kafa ore deposit

Divriği A-Kafa is the largest known ore body in the Divriği region (100 mill. t). It occurs at the contact of granitic rocks and serpentinites and the host rock is hydrothermally altered serpentinite (Fig.1). The contacts between the different rock units are sharp. Extensive crushing and brecciation are observed at the contact of the ore body and the granitic rocks. The magnetite ore includes disseminated pyrite ranging between 1-5 % by volume.

The oldest generation of magnetite in the ore body contains abundant silicate-but rare sulphide inclusions. Most of the sulphide inclusions are dissolved and replaced by limonite. Only a small part of the pyrite exists as relics.

The magnetite ore is cataclastic and the grain size varies from very fine to very coarse (Plate V, fig. 5). Cataclastic grains are zoned more extensively than in the hydrothermally altered serpentinites. The inner part of the grain has more silicate and less sulphide inclusions, whereas the outer part consists of more pure magnetite (Plate V, fig. 6). This pure magnetite is formed as a result of recrystallization of older magnetite. The magnetite occurs generally as angular to subhedral, rounded grains and is located in a matrix of fine-grained silicate and carbonate. Pyrite without silicate inclusions is scattered among these pure magnetite crystals. This indicates the relationship between iron dissolution from older generation magnetite and the- conditions for the precipitation of new minerals. The higher is the oxygen content, the richer is the sample in magnetite. Interplay between the formation of magnetite, pyrite and silicate minerals depends on the oxygen and sulphur fugacities (Plate VI, fig. 1-6). This three component texture constitutes an important part of the crude ore mined from the Divriği A-Kafa iron deposit.

The A-Kafa magnetite is generally fresh but in some places martitization and less maghemitization occur. The youngest generation of magnetite is fracture fillings.

Pyrite with magnetite and silicate inclusions forms droplike, anhedral and very finegrained aggregates. Coarse-grained pyrite without any silicate inclusions is found together with pure magnetite. The coarse-grained pyrite is associated with chalcopyrite and pyrrhotite. Pyrite might contain chalcopyrite and pyrrhotite as inclusions (and/or veinlets) in some places. Chalcopyrite and pyrrhotite are often dissolved, whereas pyrite is more stable. Gold particles are detected very rarely in the youngest pyrites.

Chalcopyrite occurs in pyrite with pyrrhotite as inclusions and veinlets. Coarse-grained chalcopyrite shows lamellar twinning and encloses millerite and linneite (violarite). Cubanite and valleriite exsolutions are seen in coarse-grained chalcopyrite. In addition, anhedral to subhedral chalcopyrite in silicates are accompanied by marcasite and bravoite which replace pyrrhotite and pentlandite, respectively.

Millerite, linneite (violarite) and pentlandite-bravoite occur together with pyrite, chalcopyrite and pyrrhotite. Further, millerite and linneite (violarite) inclusions are observed in chalcopyrite and vice versa. Beyond the alteration phenomena between millerite and violarite, the original textural relationship represents solid solution crystallization.

Subhedral to euhedral pyrrhotite crystals contain frequently chalcopyrite inclusions. Pyrrhotite is replaced by pyrite and marcasite. Inner parts of pyrrhotite are dissolved and hydrogoethite is developed (Plate VII, fig.5). Two constituents represented by marcasite and pyrite are formed as rootlike transitional layers creating bird's eye texture.

The secondary anhedral bravoite originating from pentlandite is observed in pyrrhotite and is further altered to pyrite-marcasite. In the marcasite and pentlandite, mackinawite exsolutions are observed. Angular, euhedral, fine-grained linneites (perhaps carolite ?) are scattered in the silicate and the chalcopyrite.

Lepidocrocite, goethite and sometimes hydrogoethite minerals develop as secondary products at the sites of sulphide minerals. Abundant limonite occurrences as well as covellite are observed in cracks.

Most of the coarse-grained silicates consist of biotite, phologopite and muscovite. Very fine-grained and unrecognizable, silicate and carbonate minerals are found in the cataclastic magnetite.

B-Kafa ore deposit

The B-Kafa ore body is placed at the contact between serpentinite and limestone. The serpentinites are hydrothermally altered and extensively cut by cm to dm thick magnetite veins and in some places by silica and carbonate veins with ore minerals as well. The magnetite is partly maghemitized and martitized. In addition, various sulphide minerals occur.

Two kinds of magnetite can be distinguished in the B-Kafa ore body. One magnetite is pure, without maghemitization and martitization and the other displays these alterations. Different generations of magnetites are found in samples with no alteration. The first generation, anhedral magnetite, contains inclusions of fine-grained sulphide minerals such as pyrite and pyrrhotite and some silicate. A younger generation of pure magnetite occurs together with minor amount of pyrite. Euhedral grains of chalcopyrite occur disseminated and in veinlets with little amounts of pyrrhotite associated with pyrite. Millerite inclusions and very fine-grained sphalerite are observed in chalcopyrite.

Cataclastic magnetite is altered by martitization and accompanying maghemitization (Plate VII, fig. 3). Martitization advanced in two different stages. The first stage envelopes the grains while the younger generation forms needlelike martitizatipn aggregates perpendicular to the gram, developed at the inner part of the grains and cutting the earlier martitization. Martitization is developed at the eddes, cracks and (111) cleavage surfaces i.e. weak zones of the magnetite. Pyrites associated with maghemitized and martitized magnetite contains goethite and lepidocrocite in cracks and are commonly characterized by needle or grain like marcasitization (Plate VII, fig. 4). Sometimes colloform (gellike) goethite is observed. Sulphide minerals are secondarily replaced by lepidocrocite and goethite appearing in boxwork textures in some places.

Fine-grained silicate inclusions occur in older magnetite while younger pure magnetite and pyrite are associated with coarse grained silicates.

A-Kafa granitic rocks

Although refered to as granitic rocks in literature, the igneous rocks of the Murmano pluton in contact to the Divriği A-Kafa iron ore deposit vary in composition from quartz syenite to monzonite even diorite. Dominant rock type of this complex pluton is characterized by monzonite (Zeck and Ünlü 1987; 1988a; 19886).

Tabular hematite and ilmenite grains and euhedral to subhedral magnetite occur among the silicates of the monzonite. The magnetite is martitized along cleavages. Sphene and rutile occur as well. The minerals are associated with coarse-grained ilmenite with fine hematite exsolutions. Magnetite is partly replaced by goethite and/or goethite occur occasionally after pyrite in magnetite. Some hydrogoethites contain pyrite relics.

Widespread martitization observed in most of the coarse-grained magnetite is developed both in cracks, and parallel to (111) surfaces, of the magnetite. Martitization is also seen at the border of euhedral ilmenite grains occurring in magnetite.

Sulphide minerals are generally replaced by limonites.

Two types of magnetite occur in diorites of the Murmano pluton located a little further from the A-Kafa iron ore The first type is represented by coarse-grained magnetite of primary origin and exhibits penetrating martitization and maghemitization. The second type of magnetite tends to form during reactions between the silicate minerals and is concentrated at the edges of the silicates as tiny magnetite crystals. Small amounts of ilmenite, rutile, sphene and hematite are also observed in diorites.

Soğucak (Güneş) region serpentInites

Serpentinite crops out between Divriği and Çetinkaya and is derived from peridotites. Pyroxenite is also serpentinized. Serpentinite contains olivine relics together with serpentine group minerals represented by lizardite, antigorite and chrysotile and uralites in addition to large amount of opaque minerals. Serpentinized peridotite and pyroxenite are the host rocks for disseminated mineralizations of Ni-, Co-, Cu-, and Fe- sulphides and magnetite and chromite. Magnetite-bearing veins in fractures and cracks of the Serpentinite vary from millimeter to several dm in thickness.

Disseminated, fine-grained euhedral to subhedral magnetite usually contains pyrite and silicate mineral inclusions and pyrite in veinlets. Pyrite is generally droplike. Euhedral to subhedral pyrrhotite is often associated with magnetite, including pentlandite exsolutions frequently replaced by violarite. Mackinawite exhibits wormlike figures in pentlandite. Cubanite lamellas in chalcopyrite occur together with disseminated pyrrhotite and pentlandite. Magnetite surrounds the chromite like a zone, a transition zone between magnetite and chromite is observed in almost every grain (Plate I, fig. 1-4).

Typical magmatic corrosion features are observed along the edges of some euhedral chromites (Plate III, fig. 4) but in others this feature is missing (Plate III, fig. 5-6). In the chromite, magnetite is preceded by a transition zone to pure magnetite surrounding the chromite like a haloe. Euhedral pyrite and silicate inclusions are observed in this magnetite (Plate III, fig. 3). Silicate inclusions also occur in the chromite. Magnetite separated out due to the serpentinization process postdates the chromites (Plate IV, fig. 5). Two kinds of textural relation appear at the contact between silicate and chromite surrounded by magnetite. One part of the chromite represents almost angular and regular contact relation, another part of the chromite shows irregular, dissolution-like contact relations with silicates (Plate IV. fig. 6). Serpentinization is common in the latter type of texture. Some chromite grains contairi both types of relationship (Plate V, fig. 1).

Magnetite formed by senpentinization is located as pseudomorphs after olivine and orthopyroxenes (Plate II, fig. 5). Common silicate inclusions and pyrite occurrences are observed in this kind of magnetite. Flowerlike growths of magnetite observed besides finegrained, irregularly distributed magnetite and euhedral and/or subhedral magnetite grains are thought to be related with serpentinization. Additionally, fine-grained secondary magnetite is often situated along the cleavage and cracks of silicate minerals (Plate II, fig. 6) (Plate IV, fig. 1-3). In the Serpentinite pyrrhotite is intensively altered to pyrite and magnetite (Plate VII, fig. 6) and rarely to marcasite with bird eye texture. Magnetite is maghemitized and martitized. The youngest magnetite occurs in veinlets and in the cracks and fractures of the serpentinites (see also Bozkurt, 1974; Bayhan, 1980; Bayhan and Baysal, 1981).

DISCUSSION

As a result of textural studies, three, main stages and one transition stage are recognized in the ore, host and country rocks of Divriği and Soğucak regions by ore microscopical investigations. In general, the first stage is characterized by primary minerals, second stage by serpentinization, the transition stage by intensive cataclasis and the third stage by intrusion of granitic rocks (Fig. 2).

Stage I: Primary minerals

Primary minerals formed during upper mantle conditions are illustrated in Plate I.

Stage II: Serpentinization

Sequential events of emplacement into continental crust by obduction of oceanic lithosphere and intrusion of granitic rocks are emphasized at this stage (Plate II-IV).

Transition Stage: Intensive CataclasIsm

Additional intensive deformation developed during serpentinization and at early stages of granitic intrusion is described at his stage (Plate V).

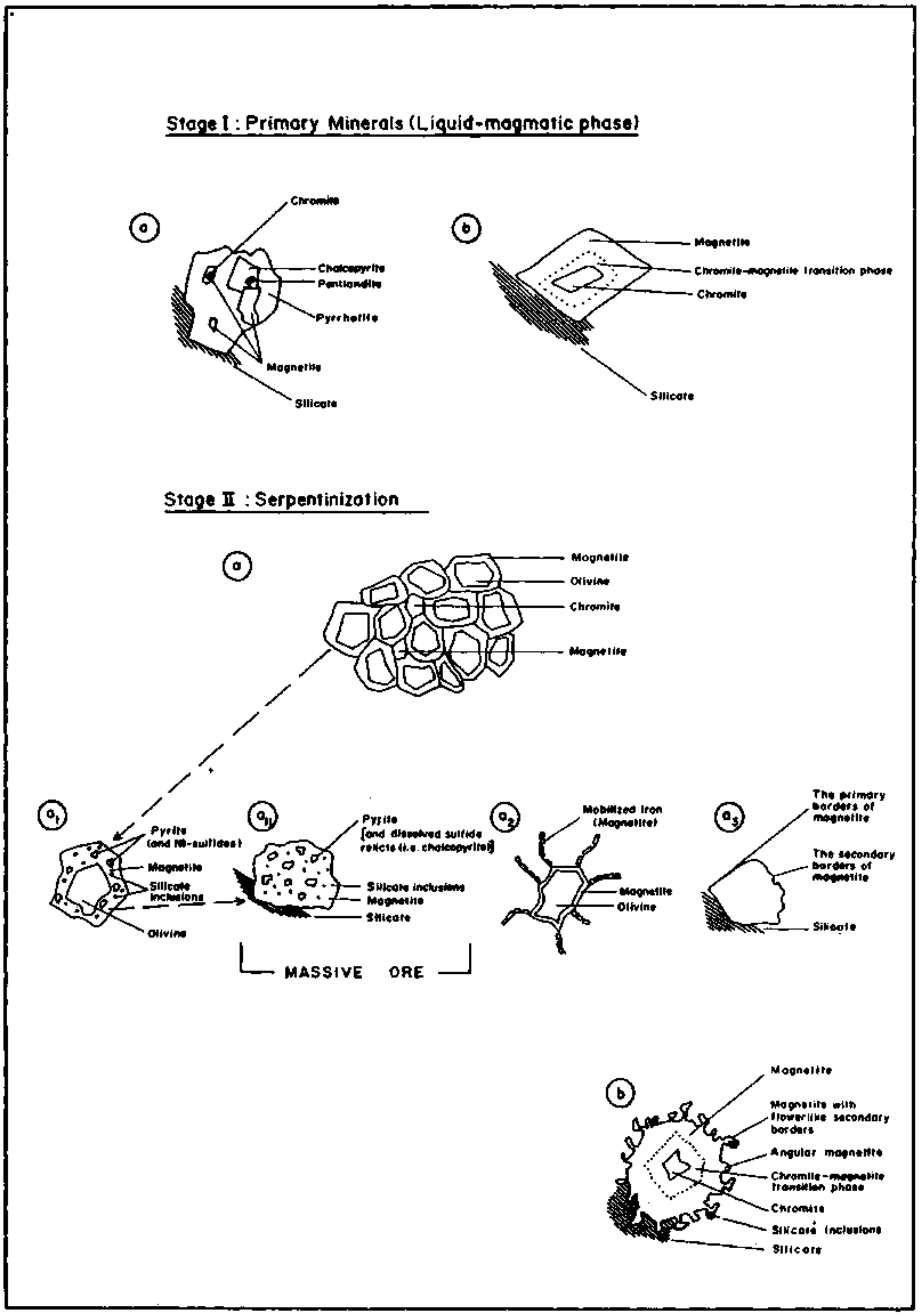
Stage I : Primary Minerals (Liquid-magmatic phase)
a
Chromite
Chalcopyrite
Pentlandite
Pyrrhotite
Magnetite
Silicate
b
Magnetite
Chromite-magnetite transition phase
Chromite
Silicate
Stage II : Serpentinization
a
Magnetite
Olivine
Chromite
Magnetite
a1
Pyrite
(and Ni-sulfides)
Magnetite
Silicate
inclusions
Olivine
a11
Pyrite
[and dissolved sulfide
relicts (i.e. chalcopyrite)]
Silicate inclusions
Magnetite
Silicate
MASSIVE ORE
a2
Mobilized Iron
(Magnetite)
Magnetite
Olivine
a3
The primary
borders of
magnetite
The secondary
borders of
magnetite
Silicate
b
Magnetite
Magnetite with
flowerlike secondary
borders
Angular magnetite
Chromite-magnetite
transition phase
Chromite
Silicate inclusions
Silicate

Fig. 2

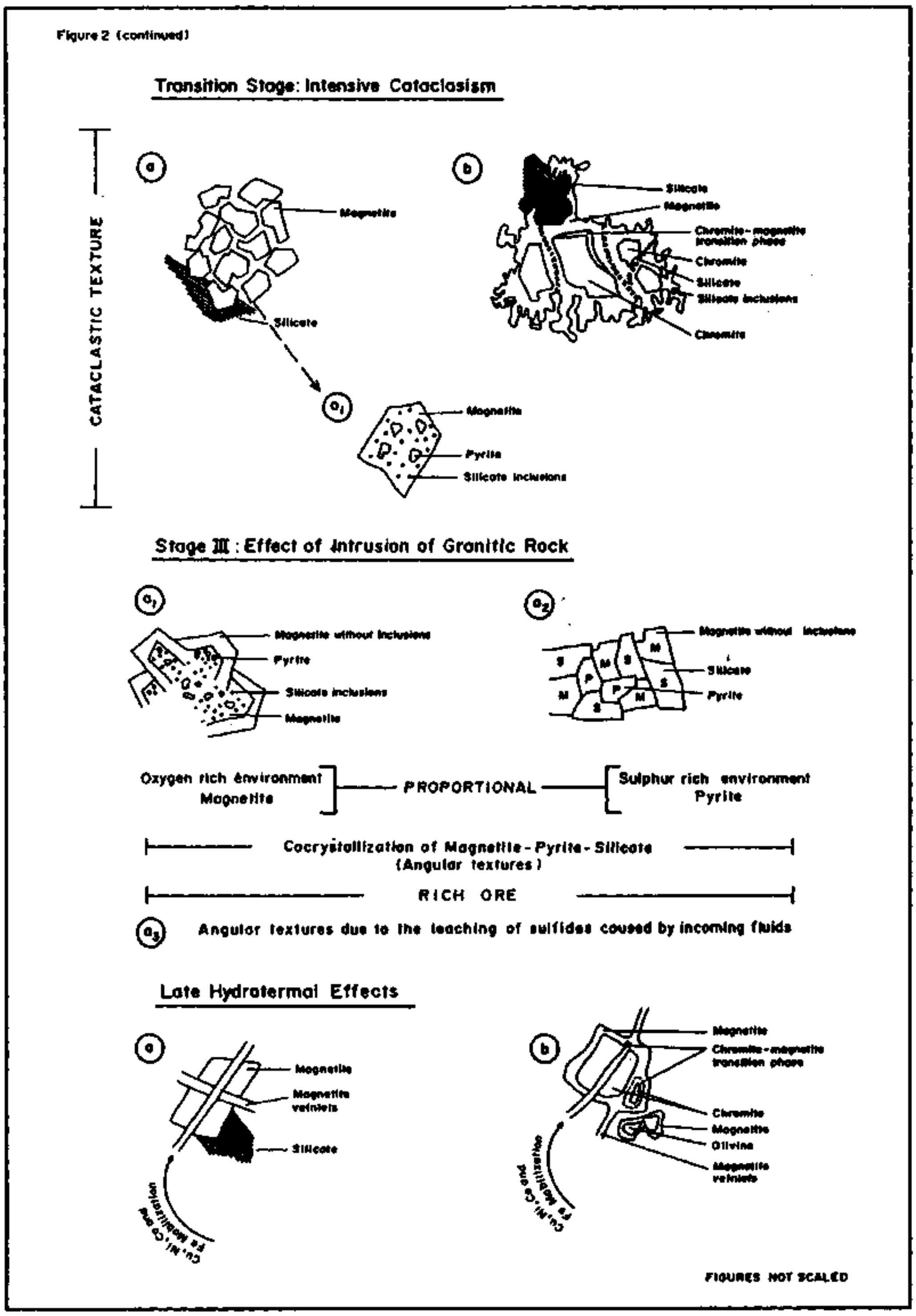

Fig. 2- Textural characteristics of different mineralization stages from older to younger (Stage II and Transition Stage silicate minerals are mainly serpentinite minerals like chrysotile, antigorite etc. Stage III silicate minerals are mainly chlorite, biotite, phlogopite and/or muscovite. No cataclasis have been observed on mica minerals. Very fine-grained, anisotropic silicate and/or carbonate minerals are also observed in the Transition Stage a).

Stage III: Granitic Rock Effects

The hydrothermal alteration events developed by hydrothermal convective cells in the serpentinite are the main process in this stage (Plate VI-VII).

It is possible to characterize the genetic interpretation of the Divriği iron ore deposit as a sequence of metamorphic + hydrothermal alteration processes begenning with metamorphosis under upper mantle conditions, continuing at various metamorphic conditions contemporaneous with the emplacement of the obducted oceanic crust upon the continental crust imposing hydrothermal alteration processes and finally weathering (Table 1).

Genetic Features

Genesis of the ore from the Divriği and Soğucak areas is outlined in Table 1. A very general synthesis is suggested for the Divriği and Soğucak ore deposits based on the comparison of textural features of ore minerals from the two areas.

The liquid magmatic phase with primary ore minerals (e.g. chromite) is more characteristic for Soğucak than Divriği. This reflects relative intensity of hydrothermal alteration in the two areas. The auto-hydration developed at early stages is similar for both Divriği and Soğucak areas.

Magnetite formed by serpentinization and associated with chromites is well known from Soğucak while the magnetite, pyrite and silicate association is more common at Divriği. The iron mobilization followed by formation of veinlet type magnetite is less pronounced in the Soğucak area than in Divriği area. The concentration of veinlets with magnetite is proportional with the abundance' of hydrothermal fluids.

Tectonic events such as deformation and cataclasis of chromite and magnetite are more pronounced from the Divriği than the Soğucak region. This also confirms the direct or indirect effect of the granitic intrusion. The intrusion of the "granitic" rock mobilized the iron and developed magnetite, pyrite and silicate to the Divriği iron ore type.

Alteration processes like maghemitization, martitization and marcasitization are more common at Divriği than at Soğucak, also due to processes generated by hydrothermal convection. The youngest veinlets cut all structures and this hydrothermal event is similar in both regions.

Table 1- Mineralization stages and genetic features determined after ore microscopical studies

GEOLOGIC PROCESSES	*PHOTOGRAPHIC PLATES*	*MINERALIZATION STAGES*	*EXPLANATIONS*
Primary Mineralization	PLATE I	Liquid-magmatic phase	Chromite. magnetite and sulfide association
Serpentinization	PLATE II	Serpentinization	Auto-hydration
	PLATE III		Magnetite. pyrite, silicate occurrences and chromite association as a product of serpentinization
	PLATE IV		Mobilization of iron
Effect of Intrusion of Granitic Rock	PLATE V	Tectonic deformation (Intensive cataclasism)	Mechanical deformation in chromite and magnetite
	PLATE VI	Early hydrothermal effects of granitic rocks	Cocrystallization of magnetite, pyrite and silicate (angular textures)
	PLATE VII	Late hydrothermal effects	The youngest veinlets intersecting the structure and maghemitization, martitization and marcasitization

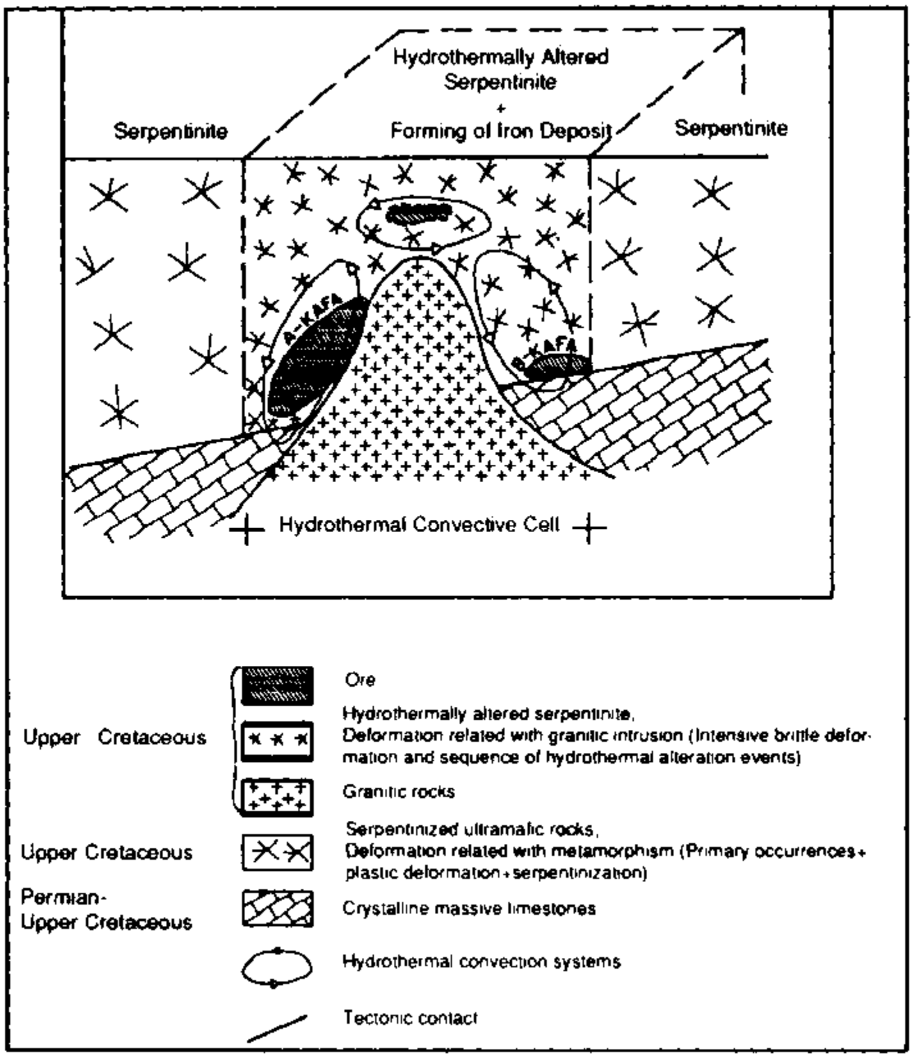

Fig. 3- Schematized formation model of Divriği A- and B- Kafa iron deposits (non scaled).

CONCLUSIONS

Mobilization and genesis

Most of the iron deposits in the Divriği region is found in serpertinized ultramafic rocks. Granitic rocks intrude these rocks. Thus, the serpentinite is hydrothermally altered.

The serpentinization stage is the most important stage at the formation of the studied iron deposits. It follows from the following model reactions: [Engin and Hirst, 1970; $7(Mg_{09}Fe_{01})_2SiO_4$ (forsteritic olivine) + $3(Mg_{09}Fe_{01})SiO_3$ (enstatitic pyroxene) + 10.57 H_2O - $5H_4Mg_3Si_2O_9$ (serpentine) + 0.57 Fe_3O_4 (magnetite) + 0.3 MgO + 0.57 H_2; Spooner and Fyfe, 1973; $11Fe_2SiO_4$ (fayalite) + 2SOv $4H^+$ $7Fe_3O_4$ (magnetite) + FeS_2 (pyrite) + 11 SiO_2 (quartz) + $2H_2O$, Pallister and Hopson, 1981]. The iron bearing silicates of primary origin are the basis for the formation of iron deposits and therefore yield a generally low grade iron ore.

Second stage is characterized by leaching. Hydrothermal fluids circulate in convective cells generated by the heat from the intrusion of granitic rocks and mobilize iron from the serpentinite, but the iron is quickly precipitated again in the serpentinite and in this way concentrated to a high grade iron ore deposit (Fig. 3). The high-grade iron ore is formed as a result of repeated mobilization and precipitation of iron.

Exploration

According to previous mining geological studies, Divriği iron ore deposit and the other iron ore deposits of the Divriği region were desented evaluated as skarn type related with granitic rocks (Gysin, 1938; Klemm, 1960; Koşal, 1973; Petrascheck and Pohl, 1982 and Gümüş, 1989). Gümüş, 1979 has interpreted the Divriği iron ore deposit as formed by processes of pyro-mobile metasomatism. High interest in skarn formation caused that exploration by drilling was undertaken on the contact of the granitic rocks.

Recent studies (Stendal and Ünlü, 1991) and the follow-up by magnetic anomalies over the hydrothermally altered serpentinites led to the discovery of 40 million tons of high grade iron ore in the serpentinites.

According to world standards (Bottke, 1981) Divriği iron deposit is a medium grade iron deposit with 100 million ton reserve with 55 % Fe grade. Since 1939 and with the discovery of new reserves the Divriği deposit new reaches 140 million tons. But with the ongoing exploration studies the size of the deposit can still increase in the future.

ACKNOWLEDGEMENTS

The authors thank Dr. Ahmet Çağatay, Prof. Dr. Ayhan Erler, Assoc. Prof. Dr. Okan Tekeli and Prof. Dr. Hasan Bayhan for the constructive criticism of the paper and also acknowledge the financial contributions of the University of Copenhagen to the laboratory studies. Polished sections of ores and rock samples referred in this paper are in the custody of the Geological Institute, University of Copenhagen. The authors acknowledge the financial support of the NATO FELLOWSHIP PROGRAMME of Denmark (Nos. 29/86 and 38/87) and of MTA and TDCI., Ankara for the field work.

Manuscript received April 18, 1995

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PLATES

PLATE-I

Fig.1- Deformed pyrrhotite (light grey) in serpentinite. Euhedral chromite (dark grey) surrounded by magnetite(grey)areatthecentral-andright-hard portions of the lower edge of the grain-Mackinawiteinclusions-bearingpentlandite grains (white) are at the center of the upper edge of pyrrhotite.At right chalcopyrite (white) withcubanitelameliae(SoğucakN-83,inair, parallel nicol=P.N.)

Fig. 2- Mackinawite indusiois in pentiande cleavages in the same sample as Figure 1 (Soğucak N-83, in air, P.N.).

Fig. 3- Euhedral chromite (dark grey in the centre) with magnetite envelopes (grey) and euhedral chalcopyrite with cubanite lameliae Tongue-like pentlandite (light grey) with tiny mackinawite incdusions lies at the contact of magnetite and chalcopyrite in chalcopyrite. This figure represents the right edge of Figure 1 (Soğucak N-83. in air. P.N.).

Fig. 4- Pyrrhotite (light grey) cracked along its cleavages in serpentinite. Euhedral magnetite (grey) and chromites (dark grey) at the core of pyrhotite. Mackinawite-bearing pentiandite (very light grey) between magnetite and pyrrhotrte (Soğucak N-83, In air, P.N.).

Fig. 5- Magnetite (white) crystals with chromite relics (light grey) in serpentinite. Chromite-magnetite transition phase in very light grey (Divriği CS 1-12, in air, P.N.).

Fig. 6- Chromite relic (in core, dark grey), surrounded by a chromite-magnetite transition phase grey) and magnetite (light grey). Euhedral magnetite crystal (white) in the centre of the figure (Divriği CS 1-12, in oil, P.N.).

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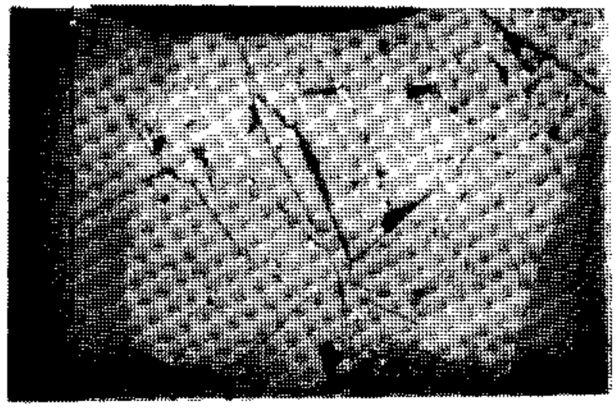

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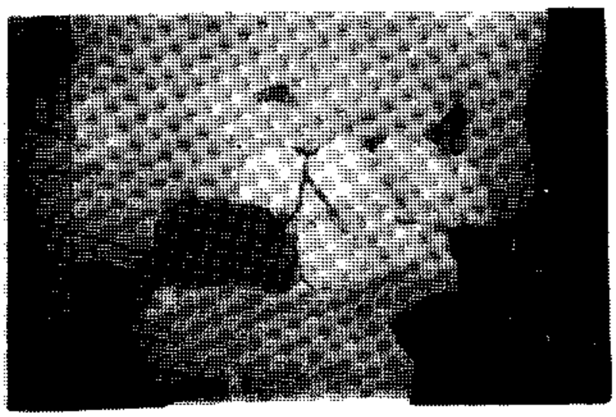

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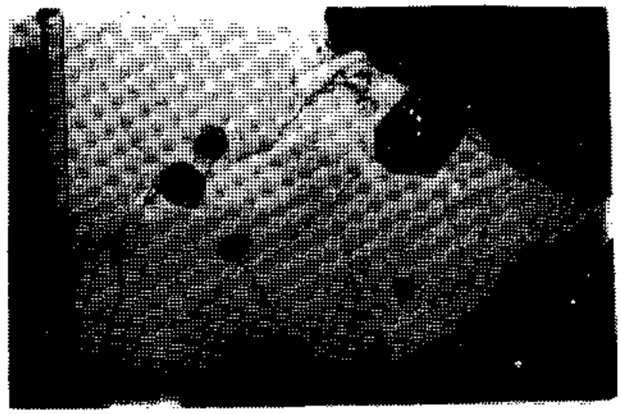

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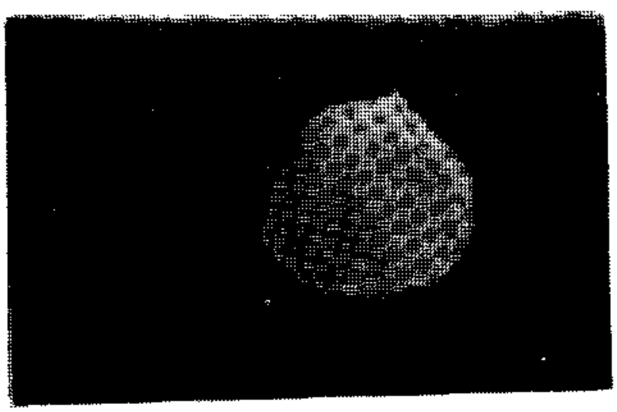

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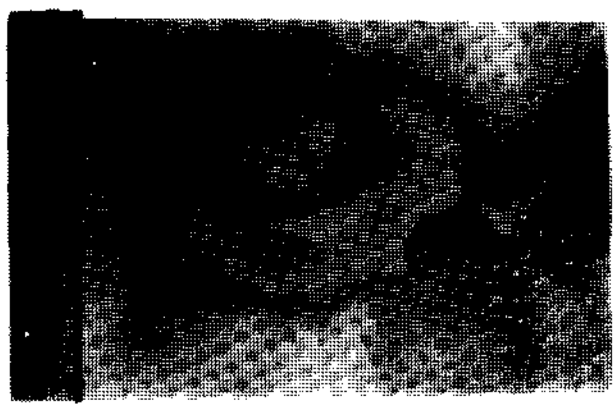

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PLATE-II

Fig. 1- Ringlike magnetite (white) around anhedral olivine relics and tiny veinlets of magnetite between divines in serpentinite (Divriği CS 1-12, in air, P.M.).

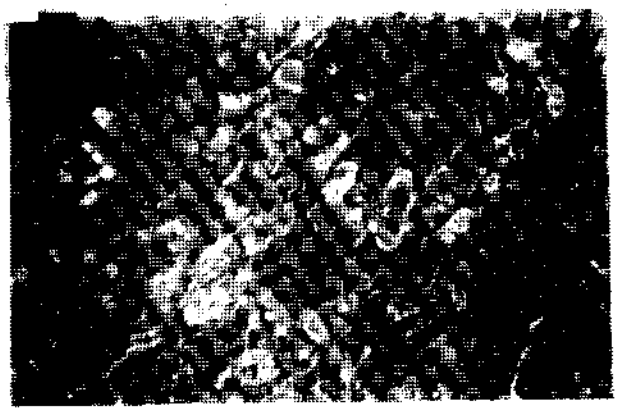
Fig. 2- Hydrogoethite (grey) and towards the core magnetite (white) in anhedral olivine relics (skeletiike, white at its edges) (Divriği CS 1-12, in oil, P.N.).

Fig. 3- Hydrogoethite (grey-light grey) in the centre and around it magnetites (white). Ringlike magnetite (light grey) at the outer part of oval shaped olivine relic in serpentinite (Divriği CS 1-12, in oil, P.N.).

Fig. 4- Magnetite aggregates (grey) with pyrite (white) inclusions formed around and over olivine relics (light grey) in serpentinite, in the right-hard and middle upper part of figure (Divriği CS 1-12, in oil, P.N.).

Fig. 5- Magnetite (white anhedral skeletal crystals) formed after serpentinization in serpentinite (Soğucak G-120, in air, P.M.).

Fig. 6- Mesh texture showing small magnetite grains (white) in serpentinite (Soğucak G-48, in air, P.N.).



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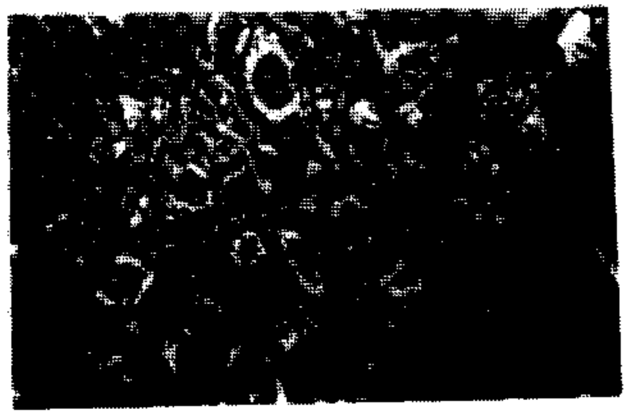

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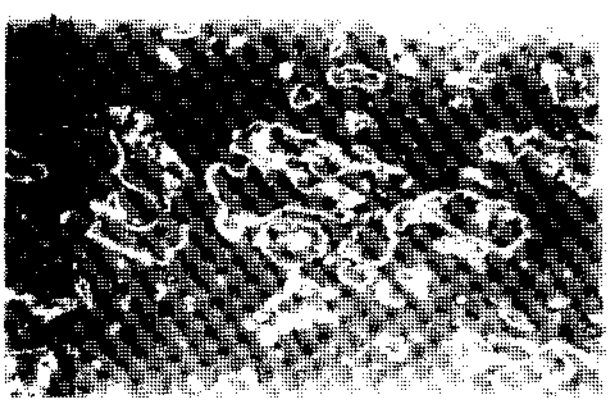

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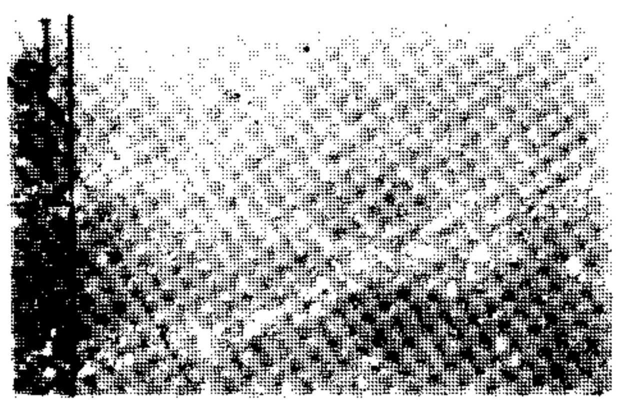

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PLATE -III

Fig. 1- Magnetite (light grey) with pyrite inclusions (white) and silicate inclusions (dark grey) in serpentinized olivines. Secondary magnetite crystals grow on euhedral magnetite in lower right-hand portions (Divriği CS 1-12, in air, P.N.).

Fig. *2*- Magnetite (white) crystals around chromite (light grey) core in serpentinite. Primary silicate inclusions (dark grey) in chromite (Divriği CS 1 - 12, in air, P.M.).

Fig. 3- Euhedral chromite (grey) surrounded by magnetite (white). Secondary magnetites (white) at the outer parts of the complex crystal in serpentinite. Partly dissolved small pyrite inclusions (light grey) and small silicate inclusions in chromite and magnetite (Soğucak G-48, in air, P.N.).

Fig. 4- Magnetite (white) around euhedral chromite core (light grey) in serpentinite. Pyrite (light white) at lower right parts and uppermost parts of the right-hand crystal. Magmatic corrosion suggested by lines of small black dots in the outermost parts of chromite cores and by silicate inclusions in magnetite zone (Soğucak G-119, in air, P.N.).

Fig. 5* Small magnetite grains (white) and magnetite zones (white) around euhedral chromite cores in serpentinite. Triangular magnetite grain in chromito at the left. Silicate inclusions (dark grey) in the magnetite zone of the right-hard crystal. The outermost shell is secondary magnetite with baylike outlines (Soğucak G-120, in air, P.N.).

Fig. 6- Chromite (grey) cores surrounded by a chromite-magnetite transition phase (light grey). A very small pyrite crystal (light white) occurs in transition ptiase at right lower part of figure; magnetite (white) surrounds the transition phase. At the outermost parts secondary magnetites break the primary outlines. Fine grained, angular silicate inclusions (dark grey) in the crystal (Soğucak G-162, in air, P.M.).

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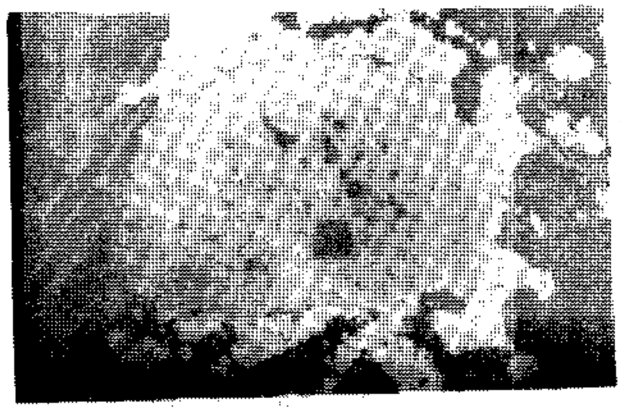

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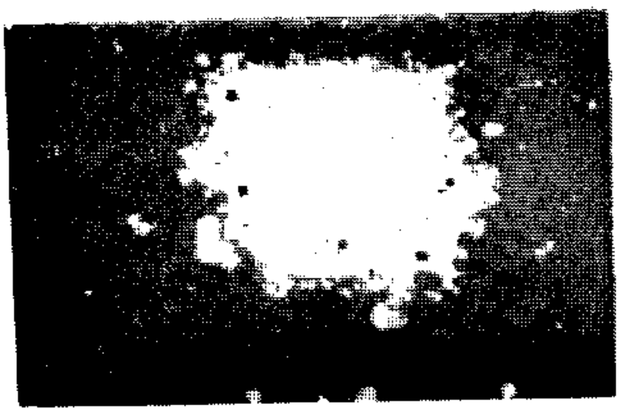

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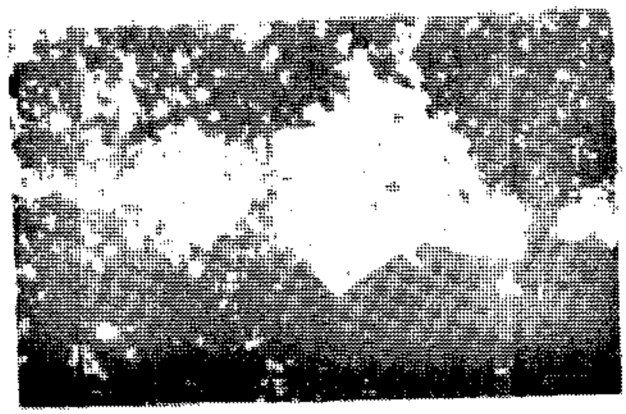

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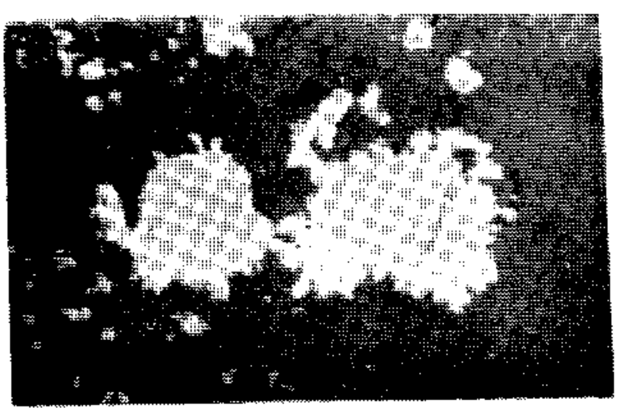

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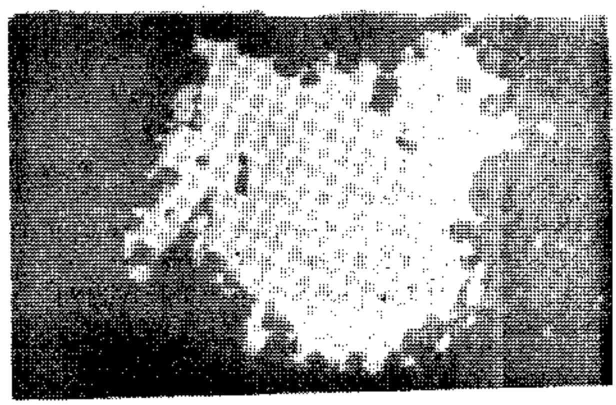

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PLATE -IV

Fig. 1- Magnetite (white) as a result of iron mobilization among anhedral olivine relics (dark grey) in serpentinite (grey) (Soğucak N-83, in air, P.N.).

Fig. 2- Coarse-grained, euhedral magnetite (white) with porous magnetite rims (light grey) and secondary magnetite (light grey) in the cracks in serpentinite (Soğucak N-83, in air, P.N.).

Fig. 3- Pyrrhotite (white) and pentlandite (white) intergrown at the center of the left-hand edge of the figure in serpentinite an magnetite (white) formed after mobilization in cracks (Soğucak N-83, in air, P.N.).

Fig. 4- Anhedral magnetites (white, oval skeletons) formed by serpentinization processes and veinletlike, mobilized magnetites (white) in serpentinite (Divriği CS 1-12, in air, P.N.).

Fig. 5- Magnetite (very light grey), anhedral chromite relics (grey) at its core and transition phases (light grey) between those minerals. Primary silicates (black) at the 'middle lower part of magnetite. Secondary magnetites (white) disturb the primary grain contacts at lower right-hard part of the same mineral (Soğucak G-162, in air, P.N.).

Fig. 6- Chromite (grey) core, the chromite-magnetite transition phase (light grey) around it and magnetite (white) in the outer parts of the otide aggregate. Secondary magnetites disturb and overprint the baylike primary outlines outermost parts of the crystal. Colloform magnetite at the right part (Soğucak G-119, in air, P.N.).

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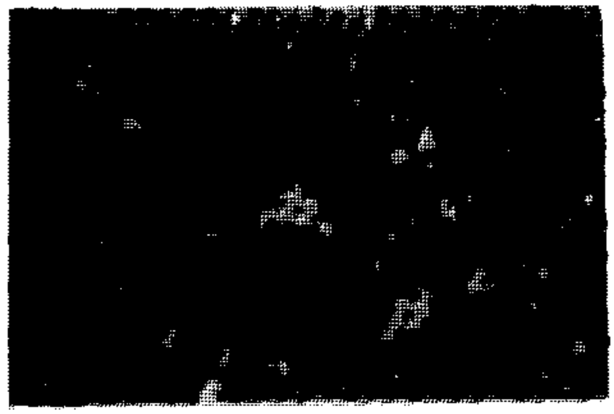

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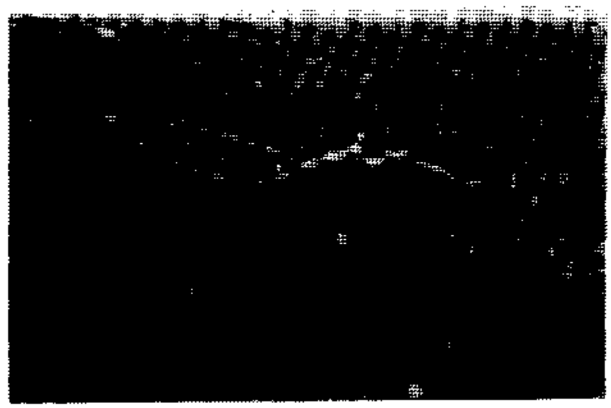

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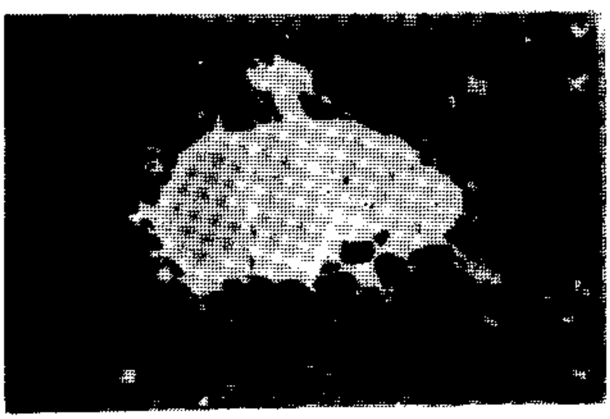

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PLATE -V

Fig. 1- Cataclastic chromite (grey) in the middle of the crystal aggregates surrounded by the magnetite transition phase (light grey) and magnetite (white). Silicate inclusions (dark grey) and secondary magnetite towards the outer zones of magnetite (Soğucak G-162, in air, P.N.).

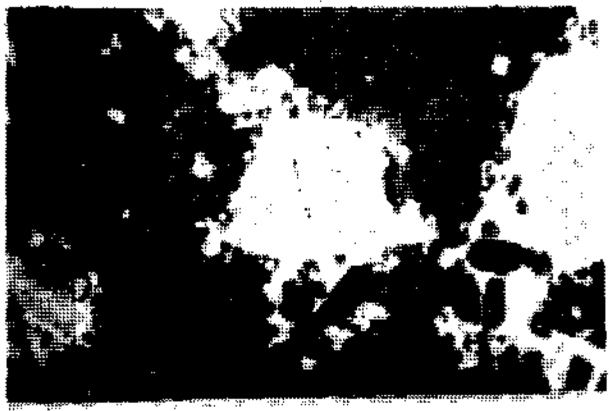
Fig. 2- Cataclastic chromite (grey) at the core and the surrounding chromite-magnetite transition phase (dark-light grey) in magnetites (light grey) in serpentinite. Silicate fillings (dark grey of the ofpen spaces (Divriği AS 1-12, in air, P.N.).

Fig. 3- Cataclastic chromite (grey) in magnetite (white), cros-cut by veinlike magnetite. Fine-grained magnetites (white) in serpentinite (Divriği AS 1-12, in oil, P.M.).

Fig. 4- Zoned replacement of chromite (grey, relics in the core), a narrow zone of chromite-magnetite transition phase (light grey) and around them a crystal aggregate of magnetite (white), Pointlike hydrogoethite at the lower left-hand pards (Divriği CS 1-12, in oil, P.M.).

Fig. 5- Cataclastic magnetite in serpentinite (Divriği AS 1-2, in air, P.M.).

Fig. 6- Cataclastic zoned magnetite (grey). Silicate inclusions (dark grey) are' in the centre, pure magnetite without inclusions on periphery (Divriği AC 1 -2, in air, crossed nicols = C.N.).



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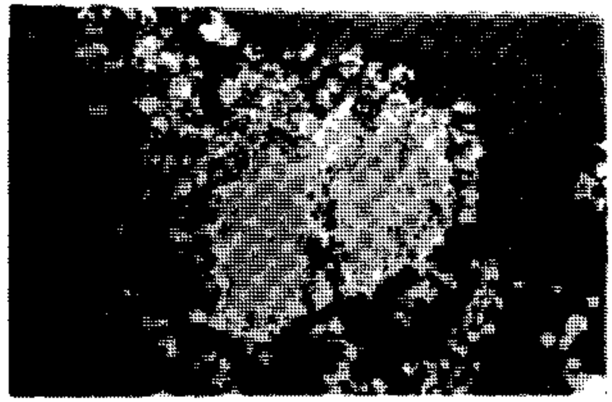

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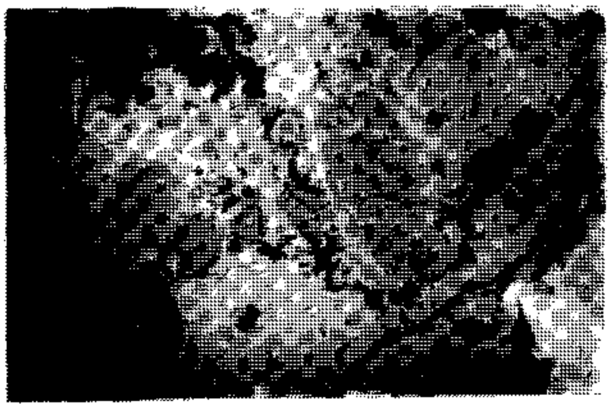

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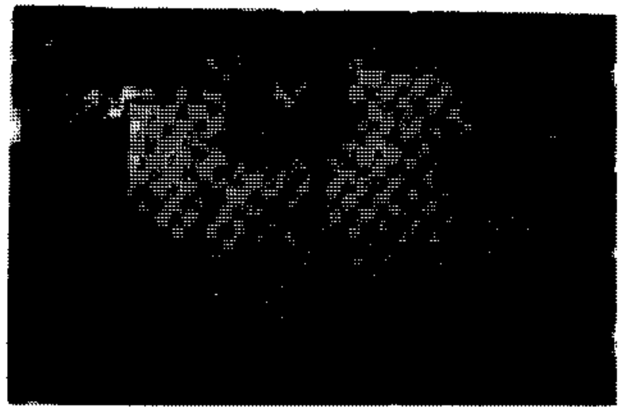

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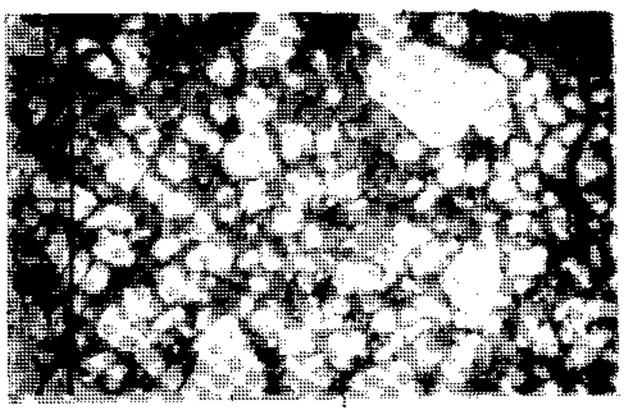

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PLATE -VI

Fig. 1- Magnetite (white) and silicate (grey) minerals with open spaces (black) left after dissolution of sulphide minerals. Angular silicate inclusions (grey) in magnetites (Divriği AC 2-6, in air, P.N.).

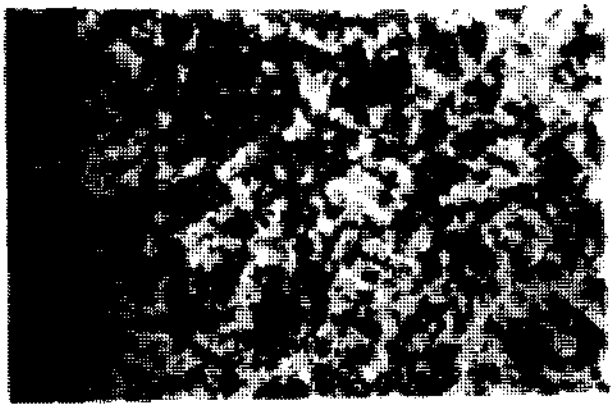
Fig. 2- Angular magnetite (white) intergrown with silicate minerals (grey) (Divriği AC 3-15, in air, P.N.).

Fig. 3- Dissolved sluphide areas (dark grey) among angular magnetite crystals (light grey). Silicate inclusions in magnetite. A very fine-grained pyrite (white) in the middle upper portions (Divriği AC 2-1, in air, P.N.).

Fig. 4- Euhedral pyrite (white) in angular, pure magnetites (grey) without inclusions. Small silicate inclusions (black) in the middle part of magnetites. Silicate minerals in the dark grey areas among magnetite (Divriği AC 3-2, in air, P.N.).

Fig. 5- Coarse-grained, angular magnetite (grey). Small but abundant silicate inclusions (black) in the magnetite cores. Subhedral pyrite (white) at left lower part. Silicate fillings (dark grey) between euhedral magnetite and pyrite (Divriği AC 1-6, in air, P.N.).

Fig. 6- Angular, pure magnetite crystals (grey) without inclusions and euhedral pyrite crystals (white) around silicate inclusions bearing magnetite. Silicate minerals (black) in open spaces (Divriği AC 3-15, in air, P.N.).



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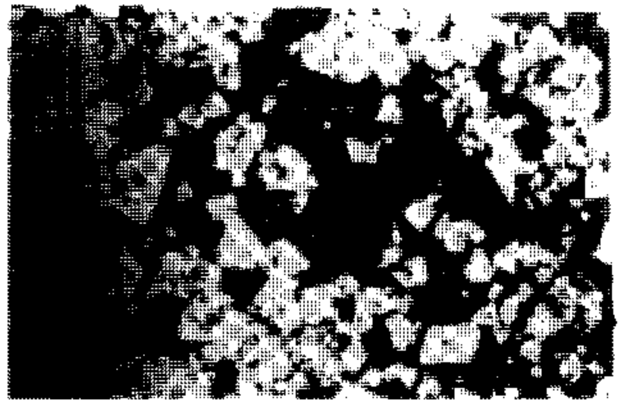

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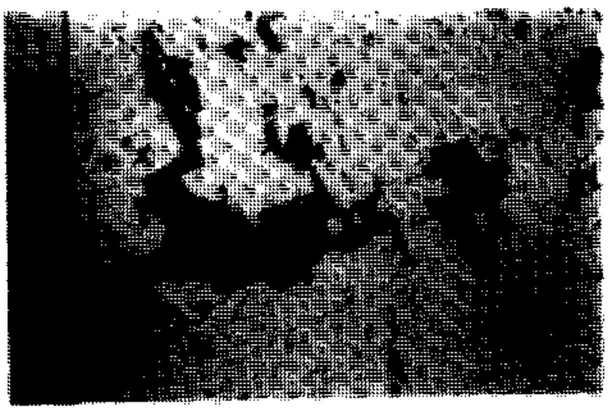

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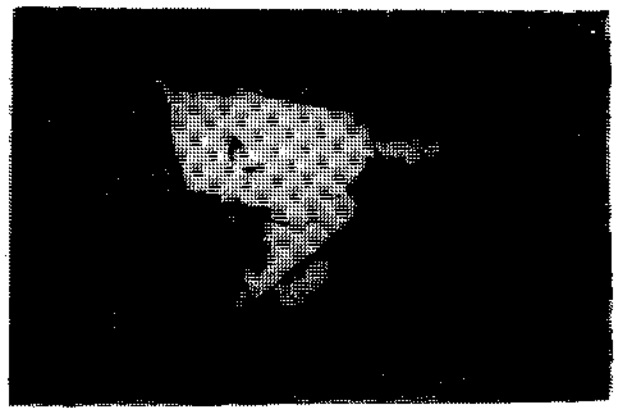

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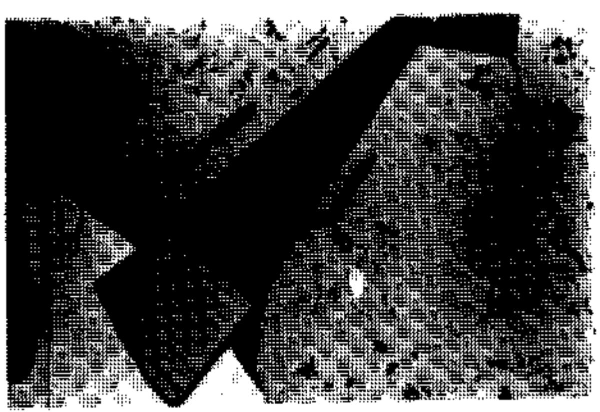

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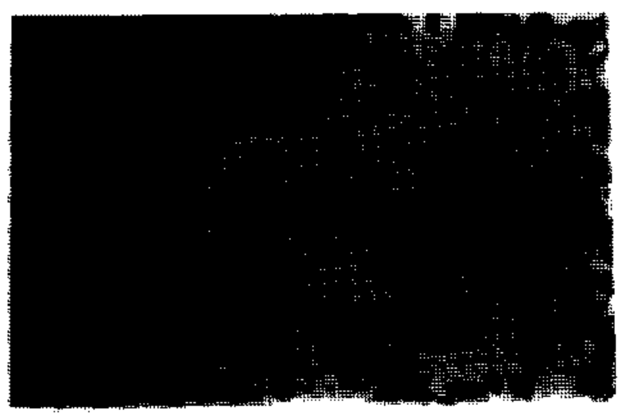

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PLATE -VII

Fig. 1- Silicate inclusions (black) bearing magnetite in pure magnetite without inclusions. Young magnetite (grey) with small pyrite crystals (white) developed at a crack in the upper part of figure (Divriği AC 2-16, in air, P.N.).

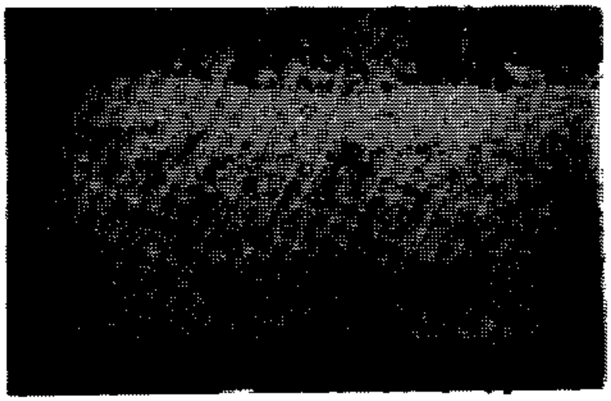
Fig. 2- Magnetite crystals (light grey and grey) showing sectonal zoning in a veinlet (Divriği AS 1-2, in air, P N.).

Fig. 3- Magnetite (grey) maghemitized (light grey) in the central parts and martitized in a needle-like form (white) at the outer parts (Divriği BC 2-24, in oil, P.M.).

Fig. 4- Veinletlike maghemitization (light grey) of magnetite (grey) at lower and right edges of figure. Marcasitization (light grey) at outer zones of pyrite crystal (white) at the left side. Silicate (black) at upper left corner and lowermost part (Divriği BC 2-3, in air, P.N.).

Fig. 5- Dirty white coloured, layered, needle-like marcasite (white) replacing pyrrhotite at the upper side of figure and coarse-grained pyrite crystals (white). Above pyrite hydrogoethite (grey) occurences in open spaces (Divriği AC 3-6, in oil, P.M.).

Fig. 6- Chromite in the core (dark grey), around the chromite-magnetite transition phase (grey) and surrounding them magnetite rim (light grey) in the centre of the figure. Most of the figure is covered by pyrite (white) and magnetite (light grey) obtained from pyrrhotite. Silicate mine-rals (black) at the left-hand side of the figure (Soğucak G-49, in air, P.N.).



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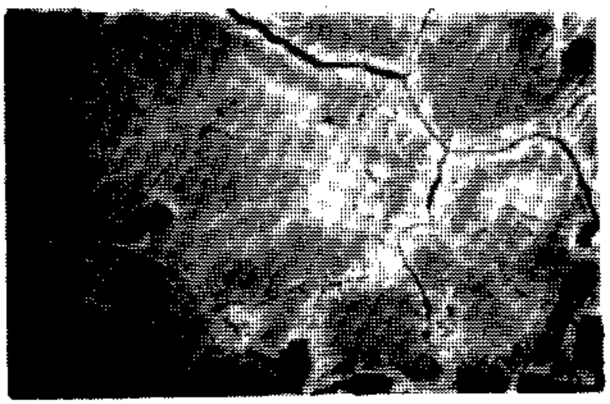

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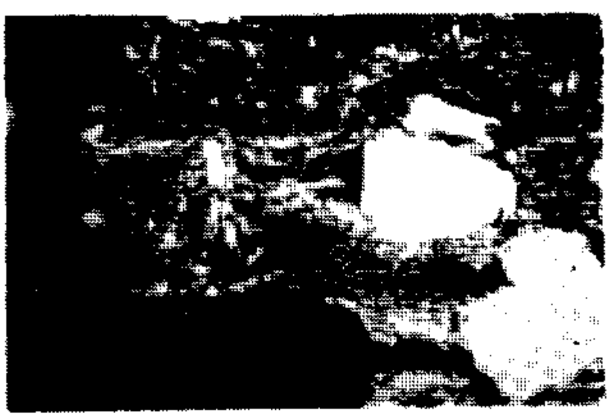

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