RELATIONSHIP BETWEEN MAGNESIAN SKARNS AND IRON ORE DEPOSITS AT DEREKÖY, NW TURKEY

DEREKÖY'DE DEMİR YATAKLARI VE MAGNEZYUMLU SKARNLAR ARASINDAKİ İLİŞKİ, K-B TÜRKİYE

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ÖZ: Bu çalışmada, granitoid sokulumları ile ilgili bir çok cevher zuhurlarının bulunduğu Istranca masifinin içinde yer alan demir zuhuru ile magnezyumlu skarn oluşumunun ilişkisi ortaya konulmaya çalışılmıştır. Seçilen epizonal Dereköy plütonu, orta-üst Jura karbonat serisi içine sokularak kontak metamorfik ve metasomatik olaylara neden olmuştur. Genelde monzonit-granodiorit olan bileşim kenar zonlarda daha mafik bir karakter kazanmış ve hatta dolotaşları özümlenmesi sonucu kentallenit gibi ender kayaçlar endoskarnda yer almıştır. Magnezyumlu eksoskarna bağlı olarak Çakmakbayır, Beyendik Tepe de önce magnetit sonrada kalkopirit cevherleşmesini görmekteyiz. Dereköy plütonunun syenitik bileşimli genç fasiyesi üst Jura Kapaklı dolotaşlarını omuzlamış kaldırmış, geçirimsiz yüksek CO_2 atmosferinde 800°C'ye varabilen ısılarda super ısıtılmış magmanın uzun süren etkisiylede Domuzbayır dokanağında fassait ve periklas gibi ender magnezyumlu yüksek ısı minerallerinin kristallenmesi sağlanmıştır.

ABSTRACT : In this study we examine relationships between granitoid intrusions magnesian skarn formations/iron ore deposits of the Istranca massif. Epizonal Dereköy pluton carried contact metamorphic and metasomatic events in middle-upper Jurassic formations. Mainly monzonitic-granodioritic rocks occur in the pluton but at the periphery more mafic apperance were recognized. Even in the endoskarn we determined rare rocks like kentallenite wich has his origin from the assimilation of dolomites. Magnetite and late chalcophyrite ore mineralization crop out in the Çakmakbayır-Beyendik Tepe exoskarn. Late syenitic facies of the pluton upwelded the upper Jurassic aged Kapaklı dolomite formation; in this unpermeable section, with high CO_2 partial activity and long dated high contact zone temperature as high as 800°C, we found rare magnesian minerals like fassait and periclase at Domuzbayır contact area.

INTRODUCTION

The most remarkable features in the formation of skarns are the association between magnesian skarns and the magmatic phase, and the development of the normal Ca-skarns under postmagmatic conditions (Zharikov, 1968; Einaudi et al., 1981). Theese assemblages typically contain combinations of Ca-Fe-Al garnet, pyroxene, wollastonite, vesuvianite in calcic (limestone) hosts; and forsterite, diopside, monticellite, magnetite, tremolite, chlorite in magnesian (dolostone) hosts. Where hydrous skarn and replacement assemblages are superimposed on anhydrous skarns, the high-temperature phases typically are replaced by lower temperature equivalents partly or completely.

Magnesian skarns occur at the contact aureole of magmas or cooling igneous bodies, because of silica-rich magma interactions with rocks that are undersaturated with respect to silica but rich in magnesia.

Common zonation can be shown as follows:

granitoid	clinopyroxene + bitownite	fassait + spinel + forsterite	forsterite + spinel	calcite + forsterite + spinel	dolostone

At high skarn temperature in postmagmatic environment, we belive that a poor alumina mobility and of alkali-rich minerals development were formed. Common mineral assemblage is fassaite, orthopyroxene, anorthite, spinel, forsterite, phlogopite, pargasite, humite, Mg-borates and scapolite.

At lower hydrothermal conditions, the post skarn alteration is represented by formation of serpentine, talc and tremolite. Main ore formation is magnetite. At shallow depth (1-3km), around epizonal intrusions, because of low CO_2 fugacity and elevated magma temperatures, a periclase marble is also observed in the contact metamorphic zone.

Our previous studies on contact metamorphism/metasomatism have focused generally calcic (limestone) skarns in NW-Anatolia (Öngen, 1981, 1983, 1992) where magnesian skarns are absent. Dolostones of Jurassic age vastly crop out near Dereköy, close to the Bulgarian frontier (Aydın, 1974; Üşümezsoy, 1982; Yurtsever et al., 1985). It is regarded to this type of skarn formation as the main reason of the relatinships between dolostone metasomatism and iron ore formation.

GEOLOGY

Istranca Group rocks crop out near Bulgarian frontier. Permo-triassic and Jurassic detritic and carbonate units of about 1200 in thickness expand in NW-SE direction (Fig.1). This group overly tectonically the polymetamorphic basement and the metagranite of Kırklareli Nappe of paleozoic age.

We distinguished the stratigraphy (Fig.2) as;

Kocabayır Formation (Ptrk) crops out south of Dereköy and forms a broad synclinal with its axe in the direction N75W. Mostly detritic sediments from conglomerates to quartzites constitues lower parts of the formation.

Mahya Formation (Trm) reposes normally on Elmacık Quartzite and is made of calcschists, graphitic slates and metapelites with well developed phyllitic foliation. Theese fine grained rocks were highly deformed at pluton contacts. Sometimes, limestone horizons appear in the upper section.

Dolapdere Formation (Jd) is made almost of carbonate rocks which overly normally the metapelites. Some crinoids, in black limestone unit of Çukurpınar, gave a Jurassic age. Under microscope, we observed calcite grains in an argillaceous cement. Upper levels of this formation is composed of white dolomitic marbles of Keltepe unit and pure yellowish dolostones of Kapaklı unit. Microscope studies show well developed polygonal calcite outlines in a mozaic texture whereas dolomite has serrated grain boundries. Dolostone outcrops occur in the southern pluton but the main dolostone body is situated to the north. Detailed mapping revealed small dolostone outcrops in the intrusion body and vice versa (Fig.1).

Age datations were carried out on plutonic rocks: during Upper Cretaceous-Paleocene Demirköy, Karacadağ, Dereköy plutons and some subvolcanic stocks were intruded in Istranca Group rock series (Tokel and Aykol, 1987). Aydın (1982) determined a K/Ar age for the Dereköy Pluton as 83.1 Ma.

DEREKÖY PLUTON

With its very irregular geometry; many golfs, enclave segregation, multiple dayk system and its different petrographic facies; gabbro, granodiorite, monzonite, syenite, porphyr; Dereköy Pluton gathers all aspects of epizonal emplacement of a felsic magma (Fig.1).

Main rock type is granodiorite (eastwards) and monzonite (westwards) but to the north late syenite intrusion has sharp contacts with all facies. At contacts with country rocks, locally, secondary facies like gabbro has been developed (Table.1).

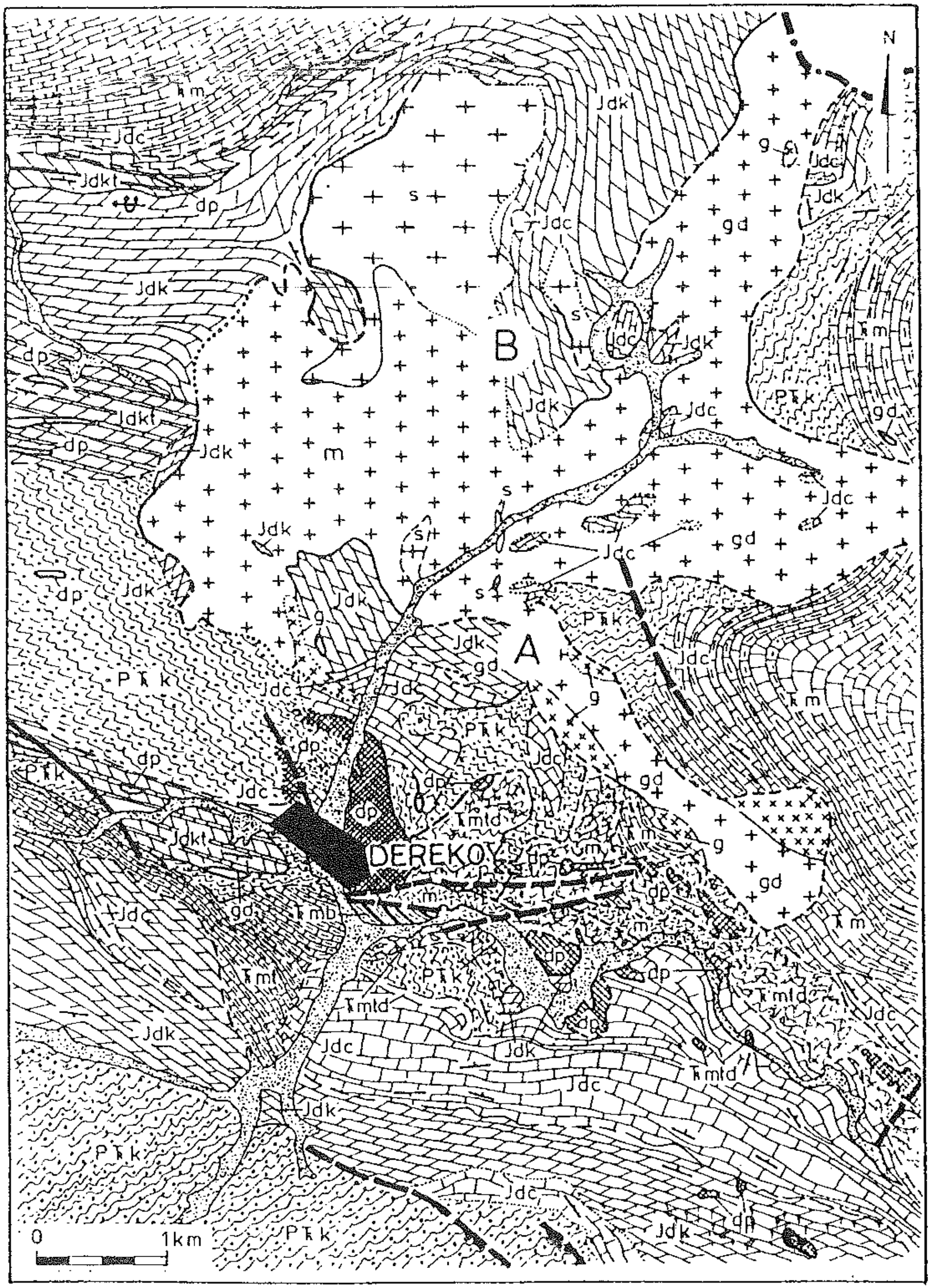
Granodiorite: Grey coloured coarse grained rock has a continuous contact zone with monzonite to the west; many outcrops may be observed along the road Dereköy-Bulgaria. Under microscope we observed xenomorphic orthoclase, idiomorphic plagioclase (andesine-oligoclase), green idiomorphic amphibole, biotite and quartz.

Magnesian hornblende has some pyroxene relicts at crystal center. Magnetite is the main opaque mineral phase. Near the contacts quartz dioritic composition dominates with diopside, bitownit and epidote.

Monzonite (BT-2) : This felsic rock has progressiv contact with granodiorite; but to the north of the pluton, all contacts with syenite are sharp. Main difference in the field is the alkali feldspar content and some abundance of amphibole. Under microscope, monzonite bears zonal arrangement of small plagioclase in orthoclase megacrysts, plagioclase with a normal zoning (An_{36}-An_{22}) but Or_{07} at rim, actinolitic hornblende, small crystals of clinopyroxene, red-brown biotites, epidote with allanite center.

Microdioritic enclaves are generally concentrated near the contacts. Quartz, plagioclase and amphibole are the main constituents. Some biotite enrichment at enclave border is evident. On the other side, monzonite contains pyroxene, plagioclase and poecilitic orthoclase.

Syenite (D-1): Northern section of Dereköy Pluton has a syenitic composition. Rose coloured rock contain centimeter sized megacrysts of alkali feldspar. We can cross the sharp contact between monzonite and syenite on the road (Fig.1). Syenite is evidently the youngest intrusive phase and its push-aside/lifting features on the Kapaklı dolostone is very clear. Syenite has a very heterogenous grain size. Megacrysts of alkali feldspar are around 3 cm. Amphibole and biotite form small gro-



Şekil 1. Dereköy plütonu çevresinin jeolojisi (Yurtsever ev diğ., 1985 basitleştirilmiş). A Çakmakbayır ve Beyendik Tepe, B Domuzbayırı.

Figure 1. Geological map around Dereköy pluton (simplified from Yurtsever et al., 1985). A. Çakmakbayır and Beyendik Tepe areas, B. Domuzbayırı area.

Upper Cretaceous-paleocene			**Dereköy Pluton** (g=gabbro, s=syeniye, gd=granodiorite, m=monzonite, dp=diorite porphry)
		//////////////	
		Jd	**Dolapdere Formation**
	upper	Jdk	Kapaklı Dolostone
Jurassic	middle	Jdkt	Keltepe dolomitic Marble
	lower	Jdc	Çukurpınar Calcschist

		Trm	**Mahya Formation**
Trias		Trmt	Taştepe impure limestone
		Trmb	Balaban graphitic Slate
		Trmtd	Terzidere Metapelite
		////////////	
Permo-			**Kocabayır Formation**
Trias		Ptrk	Elmacık Quartzite
		////////////	
Pre-permian		Pzk	**Kırklareli Metagranite**
		Pzf	**Fatmakaya Gneiss**

Şekil 2. Dereköy yöresinin genelleştirilmiş stratigrafik kesiti (Aydın, 1974; Yurtsever ve diğ., 1985).
Figure 2. Stratigraphic column concerning Dereköy area (Aydın, 1974; Yurtsever et al., 1985).

ups. Under microscope, orthoclase (zoning Or_{90}-Or_{67}) envelopes the other constituents of the rock. Plagioclase inclusions are seen in zonal arrangements. Very fine film perthite is a common feature. At the contact with orthoclase, quartz exhibits hexagonal outlines. Amphibole is a actinolitic hornblende altered to chlorite. Idiomorphic sphene crystals are disseminated.

CONTACT AUREOLE

Magnesian skarns and hornfels were developed at the contacts of Keltepe dolomitic marble unit and of Kapaklı dolostone. Three different profiles across the aureole will be studied (Fig.1 at A and at B; Table.2):

At **A**:

- monzonite / dolomitic marble (BT series)
- monzonite / dolostone (BT1 series)

At **B**:

- syenite / dolostone (D series)

Jurassic carbonate formations were cutted by monzonite resulting in many isochemical and metasomatic reactions, more importantly Fe/Cu mineralizations. On the other side, syenite intrusion, probably of laccolite form, lifts dolostone cover creating a high-temperature contact aureole.

BT profile at A: monzonite / dolomitic limestone

Monzonite (BT-2) : Sample from near contact is a felsic rock with orthoclase megacrysts (2 cm). X-ray and optical examinations reveal monoclinic structure. Chemical composition gives between albite and orthoclas ($Or_{60}Ab_{40}$). Other features are Carlsbad twin, apatite and opaque mineral inclusions and myrmekite rims. Idiomorphic plagioclase shows normal zoning but the Or value ($Or_{1.6-6.0}$) is very characteristic in terms of subvolcanic conditions. Red-brown biotite is partially altered in chlorite; its TiO_2 content (5%) is similar to contact metamorphic biotites. Other constituents are fine actinolite and minutious quartz grains. Many fissures are filled with dolomite.

Within 10 meters along dolomitic marble contact we observe ***mafic enclaves*** which also show metasomatic alteration.This is fine grained diorite or gabbro (absence of alkali feldspar). Plagioclase shows two habits: xenomorphic crystals with patchy core and labrador/bitownit composition, idiomorphic late crystals have an anorthite jump between core and rim (An_{52}---> An_{72}).

Tablo 2. Dereköy bölgesindeki magmatik ve metamorfik kayaçların kimyasal analizleri. Magmatik kayaçlara ait CIPW norm hesaplarıda eklenmiştir.

Table 2. Chemical analyses of magmatic and metamorphic rocks at Dereköy area. Also CIPW norm results from magmatic rocks are shown.

	BT-2	D-1	BT-3	BT1-A	BT-4	BT-5	BT-7	BT1-A*	BT1-G	BT-12	D-2	D-3
SiO_2	59.57	61.02	57.72	41.58	38.24	47.99	4.30	35.13	32.48	0.11	45.08	0.35
TiO_2	0.65	0.48	0.54	0.43	0.06	0.10	0.09	0.38			0.32	
Al_2O_3	18.73	17.62	16.18	8.23	4.79	4.37	2.13	5.95	1.44	0.04	9.63	0.22
Fe_2O_3	4.35	3.96	1.72	17.14	23.47	6.78	0.95	23.08	15.55	0.08	1.12	0.18
MnO	0.08	0.07	0.07	0.39	0.68	0.53	0.02	0.52		0.12	0.08	0.02
MgO	1.53	1.53	2.65	16.48	1.78	10.17	18.12	18.98	36.05	20.10	15.84	25.68
CaO	3.31	2.92	6.93	9.07	29.10	21.73	32.85	8.29	1.90	32.22	21.83	33.94
Na_2O	4.34	4.27	3.02			0.08		0.10			0.20	
K_2O	6.22	6.49	8.16	2.83	0.04	0.04	0.28	2.80			0.33	
H_2O^+	0.88	0.65	2.53	2.69	1.67	7.45	40.66	3.44		46.05	4.82	39.52
P_2O_5	0.52	0.30	0.32	0.14	0.35	0.06	0.05	0.33				0.02
Total	100.18	99.31	99.84	98.98	100.15	99.30	99.45	99.00	86.85	98.75	99.25	99.93
CO_2			0.79			6.01	41.11			47.50		30.75
Ba	716	714	819	175	10	10	20	42		10	64	10
Cr	9	12	15	94	20	72	22	70		8	10	13
Cu	58	49	38	30633	4995	34	27	5000		10	10	12
Ni	9	10	20	85	31	24	20	38		8	43	14
Rb	267	322	345	340	10	10	15	477		10	26	10
Sr	600	520	508	148	13	254	218	19		189	33	95
Zr	286	282	205		35	42	20	45		10		10
Cl			3730			56						

	BT-2	D-1	BT-3	BT1-A
Ap	1.14	0.66	0.69	0.28
Il	1.23	0.91	1.01	0.74
Mt	1.13	1.03	0.44	4.04
Or	36.65	38.24	47.35	15.06
Ab	36.63	36.04	16.52	
An	12.99	9.72	6.38	12.70
Di		2.34	18.16	23.26
Hy	8.27	6.94		
Ol				38.50
Ne			4.64	
C	0.17			
Q	0.65	2.38		
Wo			1.94	

Rock names

BT-2 : MONZONITE
D-1: SYENİTE
BT-3: SCAPOLİTE ENDOSKARN
BT-4: ANDRADİTE SKARN
BT-5: DİOPSİDE SKARN
BT-7: IMPURE MARBLE
BT1-A: OLİVİNE MONZONİTE - ENDOSKARN
BT1-A*: OLİVİNE EXOSKARN
BT-1G: OLİVİNE EXOSKARN + MAGNETİTE
BT-12: DOLOMİTİC MARBLE
D-2: MAGNESİAN HORNFELS
D-3: BRUCİTE MARBLE

This feature is the result of carbonate rock assimilation. Clinopyroxene is altered in actinolite + magnetite. But the crystallization of hyperstene ($En_{65}Fs_{30}Wo_{05}$) shows silica saturation before metasomatism. This enclave must have a quartz dioritic composition.

Scapolite bearing endoskarn (BT-3): this is a porphyric rock where all plagioclases are altered in scapolite (mei = 24%), calcite and epidote (Ps=24%). Fine grained matrix is made of orthoclase (Or_{90}) and diopside (Hd_{20-25}). This alteration is the result of gazeous and hydrous activities involving Cl, CO_2 and H_2O. Shay (1975) described similar mineral assemblage of endoskarn between monzonite and dolostone. Scapolite (marialite) formed after reactions involving Ca, Mg and Si. Chlorine analysed from Dereköy sample (3730ppm)and scapolite is comparable to observations of Shay. Scapolite is formed from the following reaction:

Tablo 1 . Dereköy plütonik fasiyeslerinin modal analizi.
Table 1. Modal compositions of Dereköy pluton facies.

sample	BT-1	BT-1A	BT-2	D-1
Quartz	11.9		6.4	12.6
Alk.feld	1.5	20.1	42.6	36.3
Plagioclase	68.5	38.2	38.6	35.8
Biotite	13.3	5.2	7.7	5.1
Hornblende	1.5		0.4	6.8
Pyroxene	0.6	25.9		
Olivine		7.0		
Chlorite	0.4		0.5	
Acces.min	2.3	3.6	3.7	3.3
Rock name	Diorite monzo	Olivine nitc	Monzo	Syenite

$$3\ CaAl_2Si_2O_3 + CaCO_3 \dashrightarrow Ca_4Al_6Si_6O_{24} + CO_3$$

Anorthite Calcite Scapolite

If marialite forms the temperature must be higher.

Prograde skarn reactions

The exoskarn is about 30 metres thick. We distinguished two skarn formations:

a. Garnet exoskarn (BT-4): This massiv skarn is made of garnet and thin layers of diopside (Fig. 3A). Garnet is izotropic at contact (Ad_{65}) with diopside inclusions. The rim is nearly andradite (Ad_{93}) and free of inclusions. At this stage of metasomatism we observe magnetite I crystallization within the pyroxene layers. It has a poecilitic appearence with very small diopsides. Late garnet II grows in geods with well developed dodecahedrons. Its composition is seems to be pure andradite (Ad_{100-95}) the rim is anizotropic (Ad_{75}). Clinopyroxene is pure diopside ($En_{49}Fs_{02}Wo_{49}$). This late garnet is accompanied by magnetite II and chalcopyrite (> 5000 ppm Cu in total rock analysis). Some alumina-serpentine minerals are the alteration products of the pyroxene.

b. Pyroxene exoskarn (BT-5): This exoskarn is developed near dolomitic marble exibiting a simple paragenesis. Coarse idioblastic crystals of pyroxene ($En_{47}Fs_{02}Wo_{51}$) are partially altered into actinolite. Late stage crystallization includes epidote (Ps=24%), quartz, calcite and stilbite. No metallic phase occurs in this skarn.

Dolomitic marble (BT-6, BT-7): We observe alternating layers of polygonal calcite with phlogopite + Mg-chlorite and dolomitic horizons with olivine(Fo_{98}), Mg-chlorite, clintonite and chalcopyrite (Fig.3B). Fine dyke systems cut the dolomite horizons, and they were filled by late stage postskarn solutions. Vein filling minerals are: Ti-clinohumite, Mg-spinel, diopside and chalcopyrite. Clinohumit is a late phase, developed by the action of H_2O:

$$4\ \text{Forsterite} + \text{Dolomite} + H_2O \dashrightarrow \text{Clinohumite} + \text{calcite} + CO_2$$

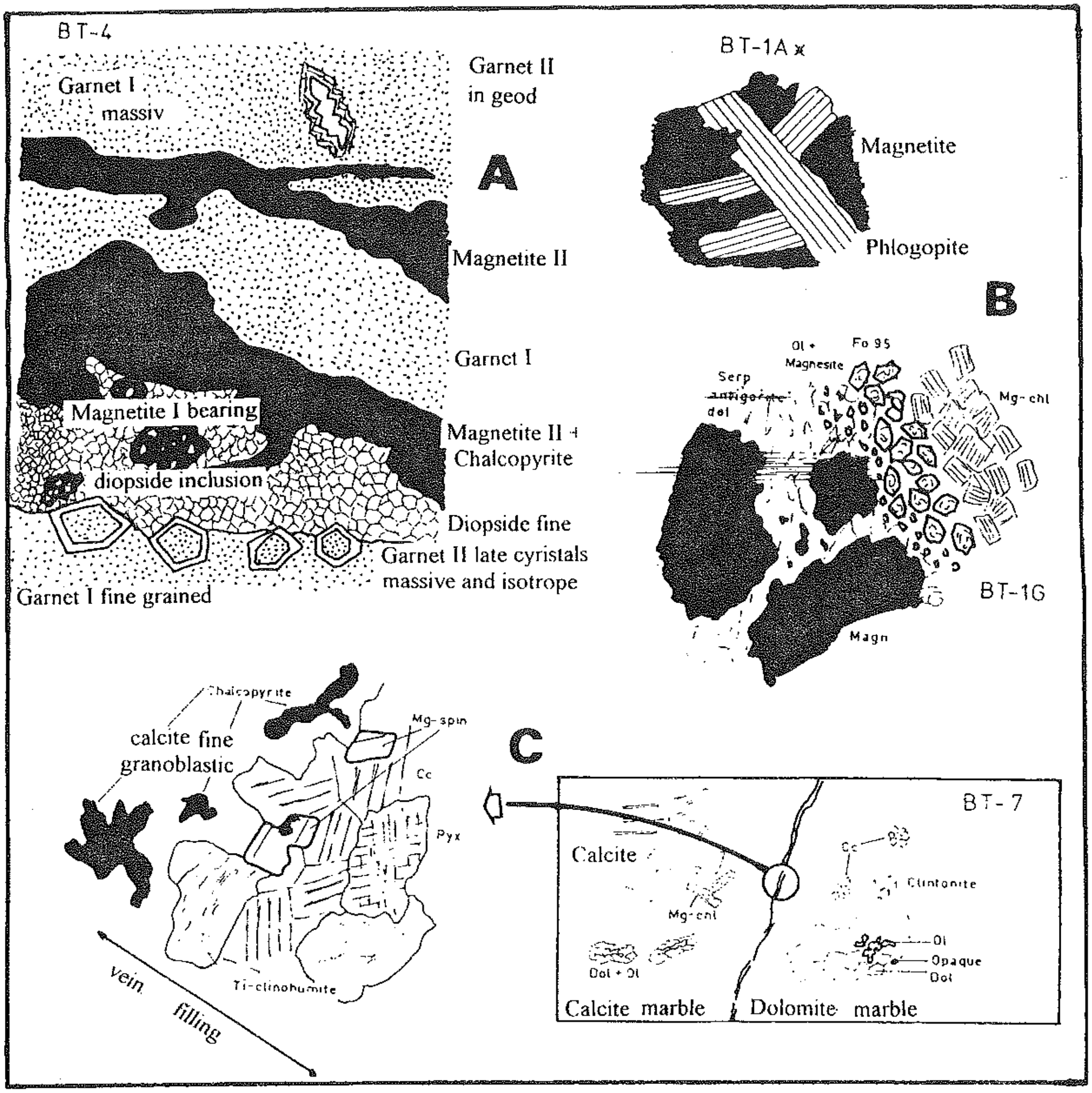
Olivine is formed at lower temperatures:

$$\text{Tremolite} + 11\ \text{Dolomite} \dashrightarrow 8\ \text{Forsterite} + 13\ \text{calcite} + 9\ CO_2 + H_2O$$

Phase relationships after Rice (1977a) and Hover-Granath et al. (1983) shown on the diagram (Fig.4) with lower fugacity of (OH, F) and important oxydation (chalcopyrite appears) may underline following conditions: 550-600°C, $XCO_2 < 0.2$. Calcite in dolomitic marble has a MgO content of 2.91-2.8%.

BT1 profile at A: monzonite / dolostone

Endoskarn (olivine monzonite=kentallenite; MacKenzie et al., 1982; BT1-A) : This rare and strongly silica undersaturated rock (SiO_2=39.61%) is rich in magnesia and alkali. Subidiomorphic olivine (Fo_{75}) is observed under microscope and calculated in the CIPW norm. It is partially altered in lizardite and bowlingite. The most spectacular aspect is a corona reaction rim around olivine crystals where orthopyroxene seperates it



Şekil 3. Dereköy skarnları silikat ve cevher mineral parajenezi.
A. Piroksen-granatlı eksoskarn (gar=granat, di=diopsid, mt=magnetit)
B. Dolomit mermeri ile dolomitik mermer arasındaki metasomatik damar dolgusu
C. Filogopit ile magnetit beraberliği. Magnezyumlu skarn bozulma zonunda magnetit oluşumu. Magnetit ile forsterit arasında doğrudan dokanak bulunmaz

Figure 3. Silicate and metallic mineral paragenesis of Dereköy skarns :
A. Pyroxene garnet exoskarn (gar=garnet, di=diopside, mt=magnetite)
B. Metasomatic dayk filling between dolomitic marble and dolomite marble.
C. Magnetite crystallization with phlogopite. Magnetite crystallization in the altered section of magnesian skarn. No direct contact between magnetite and forsterite.

Upper Cretaceous-paleocene		**Dereköy Pluton** (g=gabbro, s=syeniye, gd=granodiorite, m=monzonite, dp=diorite porphry)	
		///////////////	
		Jd	**Dolapdere Formation**
	upper	Jdk	Kapaklı Dolostone
Jurassic	middle	Jdkt	Keltepe dolomitic Marble
	lower	Jdc	Çukurpınar Calcschist

		Trm	**Mahya Formation**
Trias		Trmt	Taştepe impure limestone
		Trmb	Balaban graphitic Slate
		Trmtd	Terzidere Metapelite
		////////////	
Permo-Trias			**Kocabayır Formation**
		Ptrk	Elmacık Quartzite
		////////////	
Pre-permian		Pzk	**Kırklareli Metagranite**
		Pzf	**Fatmakaya Gneiss**

Şekil 4. CaO-MgO-SiO_2-H_2O-CO_2 (Bowman and Essene, 1982) sisteminde T-CO_2 diagramı faz ilişkileri. Periklin-‡brusit geriye reaksiyonu 0.1 XCO2 eğrisinin sol tarafındadır. (Bu=brusit, Cc=kalsit, Do=dolomit, Di=diopsid, Fo=forsterit, Pe=periklin, Qu=kuars, Tc=talk, Tr=tremolit).

Figure 4. T-CO2 diagram showing phase relationship in the system CaO-MgO-SiO_2-H_2O-CO_2 (Bowman and Essene, 1982). Retrograde reaction pericline--->brucite is on the left side where less than 0.1 XCO_2 is attained (Bu=brucite, Cc=calcite, Do=dolomite, Di=diopside, Fo=forsterite, Pe=pericline, Qu=quartz, Tc=talc, Tr=tremolite).

from plagioclase (Fig. 5). We analysed this zone as:

Chrysolite --- clinoenstatite --- diopside --- andesine.

Similar textures are known from magmatic crystallization but they have always a spinel reaction rim which signs excess of magnesia. Another explication is ferrous nature of olivine. Diopside is formed from Ca transport in the opposite direction.

Twinned rose, coarse augite is filled with many inclusions at center (olivine, biotite, magnetite). Al-rich crystal rim is free of inclusion. Plagioclase is andesine (An_{34}). Red Ti-rich biotites are growing around ilmenites which has 5% MgO and 1% MnO. Plagioclase laths are zoned and show complex twinning. Core composition is andesine (An_{46}) but there is a jump in the middle zone (An_{55}), the rim is also andesine (An_{38}). This common feature of all plagioclases reflects a magmatic assimilation. Megacrysts of alkali feldspar makes 20% volume of the rock. Its composition is also uncommon: probably a sanidine ($Or_{46}Ab_{43}An_{11}$) and curiously we analysed 1% MgO. The silica undersaturated nature is very evident in the norm calculation: nepheline, olivine and diopside were calculated instead of hypersthene in the normal monzonite.

Prograde skarn reactions

Magnesian exoskarn (BT1-A*, BT1-G): makes very homogenous zone about 10 meters thickness. This massive olivine skarn bears important magnetite + phlogopite crystallization where small olivines altered into Fe-magnezite and antigorite (Fig.3C). Phlogopite is altered into Mg-chlorite. Dolomite is also present. Serpentine is commonly observed alteration product of forsterite:

2 Forsterite + Calcite + 2 H_2O + CO_2 ---> Serpentine + Dolomite

In case fayalitic composition is present, magnetite is another product of this reaction ($Fo_{75}Fa_{25}$ analysed). But BT1-G olivines are nearly pure forsterite (Fo_{95}). It is very probably that iron is transported from the magmatic rock. Crystallization of antigorite show elevated H_2O activity during postskarn phase.

Şekil 5. Endoskarn dokusu.

A. Olivinli monzonit (kentallenit). Olivin ve piroksen fenokristalleri ikizli plajioklas, biotit ve ortoklastan oluşan daha ufak taneli bir ara madde içinde bulunmaktadır.

B. Olivin ile plajioklas arasında ortopiroksen zonu ile belirgin korona dokusu. İnce plajioklas+diopsid iğnecikleri ortopiroksen tanesi üzerinde büyümektedir. Ara madde içinde bol apatit. Biotit ile magnrtit ilişkisi

Figure 5. Endoskarn texture.

A. Olivine monzonite (kentallenite). Phenocrystals of olivine and pyroxene are in a finer matrix of plagioclase laths twinned, biotite and orthoclase.

B. Corona texture with reaction rim. orthopyroxene seperates olivine from plagioclase. Fine needles of plagioclase + diopside growing on fine orthopyroxene. Abundance of apatite in the matrix. Biotite-magnetite relationship.

Dolomite marble (BT-12): The rock is yellow on the field and it is cut by multiple calcite dayks. Under microscope dolomite is coarse grained with serrated grain boundaries. Calcite exhibits magnesian character in dolomite cutting veins (2.8% MgO).

D profile at B: syenite / dolostone

At Domuzbayır area (Fig.1) we observe high-temperature isochemical metamorphism at the contacts of syenite / Kapaklı dolostone. Probably a laccolite, during the late stage, syenite intrusion lifted the dolostone cover. The main difference is the absence of a skarn phase in this area. The contact metamorphic zone exceeds 5 meter thickness. Stratification of the dolostone is parallel to the intrusive contact. Field study revealed that pink coloured and very coarse grained syenite, white compact hornfels zone, grey-black contact dolomitic marble and white dolostone far from the contact area.

Syenite (D-1): Near the contacts of syenite show following textural differencies:

- segregation of mafic and accessory phases. We observe red-brown fine biotite, actinolitic hornblende, magnetite, allanite, zircon and enrichment of apatite-sphene. Generally late crystallization of pyroxene is mantling amphibole. The reaction:

$Ca_2(M0.g, Fe)_5Si_8O_{22}(OH)_2 + 3\ CaCO_3 + 2\ SiO_2$ --->
Ca-amphibole calcite Quartz

$5\ Ca(Mg, Fe)Si_2O_6 + H_2O + 3\ CO_2$
Diopsit

Some amphiboles have colorless cummingtonite at the center (pozitive optic sign). This is a relict association of former orthopyroxene phase.

- orthoclase megacrysts (Or_{91}) envelopes other minerals. Carlsbad twinning, zonal arrangement of plagioclase inclusions (Frasl structure of magmatic crystallization), film type perthites and myrmekites at mutual contacts of plagioclase are general features. Some orthoclase (Or_{68}) have a patchy aspect with antiperthitic growing.

Pyroxene hornfels (D-2): We observe the common paragenesis of fassaite + Mg-Al spinel. Forsterite is absent probably because of high temperature or of highly silica undersaturated environment. Under microscope very fine grained hornfels shows three different habits of pyroxene: coarser fassaite crystals and finer fassait + spinel matrix are seperated by a monomineralic elongated fassaite band. This mineral is determined by its high optical dispersion, high Al-content, CaO around 25%, $Fe_2O_3 > FeO$, elevated values of Al in tetraedric coordination. Ivanova-Panayotova (1972) mentioned fassaite with merwinite from the contact area in Bulgaria. Merwinite do not occur in Dereköy but the general description of the zone show some similarities with the Malko Tarnovo zone (=Dereköy Pluton) in Bulgaria. Very restricted form of metasomatism is the clintonite (Ca-mica) mantle around spinel. The crystallization of phlogopite instead of clinochlore explains the presence of potassium. Spinel may form according to the following reactions:

$Mg(OH)_2 + Al_2O_3$---> $MgAl_2O_4 + H_2O$
Brucite Spinel

$MgO + Al_2O_3$ ---> $MgAl_2O_3$
Periclase Spinel

The second reaction is probably due to the case of Domuzbayır hornfels. Silica undersaturated nature of the rock signifies more Al-mobility than Si. Absence of a tremolite zone and forsterite shows following diopside reaction under high CO_2 atmosphere:

Dolomite + 2 Quartz ---> Diopside + 2 CO_2

Absence of tremolite zone also indicate minimal temperature of 500°C, but coexistence of fassaite + Mg-Al spinel corresponds minimal temperature of 625°C (2kbar, XCO_2=0.1).

Magnesian marble (Predazzite; D-3): this name is given by Trommsdorf and Schwander (1969). Typical aspect of the sample is the presence of brucite pseudomorphs after periclase and serpentinization of olivine. The mineral assemblage of periclase + forsterite + calcite + dolomite is the characteristic of inner zone of contact metamorphism (Fig.6). Brucite may form by the progressive reaction:

Dolomite + H_2O---> Brucite + Calcite + CO_2

But careful observation under microscope reveals that brucite occupies hexagonal outlines of former periclase. Hence, decomposition reaction of dolomite:

Dolomite ---> Periclase + Calcite + CO_2

and hydrated retrograde reaction may also possible:

Periclase + H_2O ---> Brucite (1)

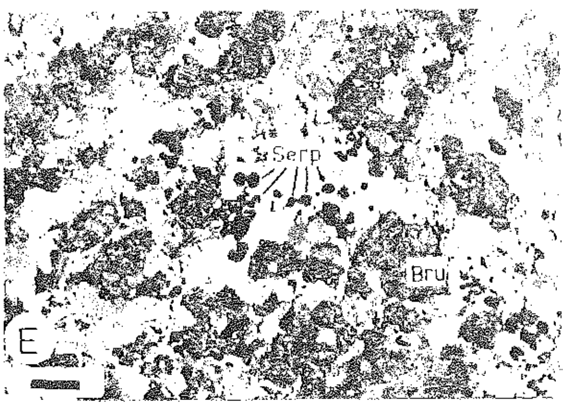
At Domuzbayır, certainly brucite is formed by the reaction (1). This reaction is also confirmed by the existence of Al-serpentine. Absence of magnetite explains the high forsterite composition of olivine. Calcite near serpentine is magnesian (3% $MgCO_3$) and finely dolomite crystals show the retrograde reaction (Turner, 1965):

Calcite + Periclase + CO_2 ---> Dolomite + H_2O

Calcite-dolomite geothermometry gives 460°C.

TEMPERATURE ESTIMATION - FLUID COMPOSITION

At Elkhorn contact in Montana, periclase isograde was calculated to be 590-600°C (Bowman and Esse-



Şekil 6. Brusit mermeri. Periklas psödomorfü geniş içi brusit dolgulu heksagonal alanla temsil edilir. Olivin tanelerinin serpantinleşmesi.

Fig 6. Brucite marble. Large hexagonal areas of former periclase filled with fibrous brucite. Serpantine after olivine.

ne, 1982). Formation of periclase + calcite is shown on the diagram (Fig. 4). Temperature varies with pressure: 600°C/2kbar. Univariant point of 600°C shows dolomite decomposition and/or retrograde apparition of brucite at hydrated conditions (XCO_2=0.07). The highly CO_2-rich nature of the fluid phase in the early metamorphism, must probably related to the presence of impermeable carbonate rock cover. Periclase + calcite at high XCO_2 conditions forms at 800°C/1 kbar (Pertsev, 1977). Thus, under such atmosphere, magma crystallization temperature was high and maintained at that level for a long period. Syenite magma was highly fluid and superheated. No chilled zones were found.

MAGNETITE PRECIPITATION AND MAGNESIAN SKARN

Triangular Ca-Mg-Fe diagram explained clearly that in magnesian skarn (dolomite host) the crysyallization is favourized threefold in comparison with calcic skarn (limestone host) environment (Einaudi, 1982a; Fig.7). Most magnesian minerals do not substitute iron in their atomic structure. Hence, the iron in solutions are concentrated during postskarn phase. Microprobe analysis reveal that all silicate minerals near magnetite are iron-free. On the other side, at limestone contacts near Fe-rich garnet-pyroxene skarn, Cu mineralization is more significant.

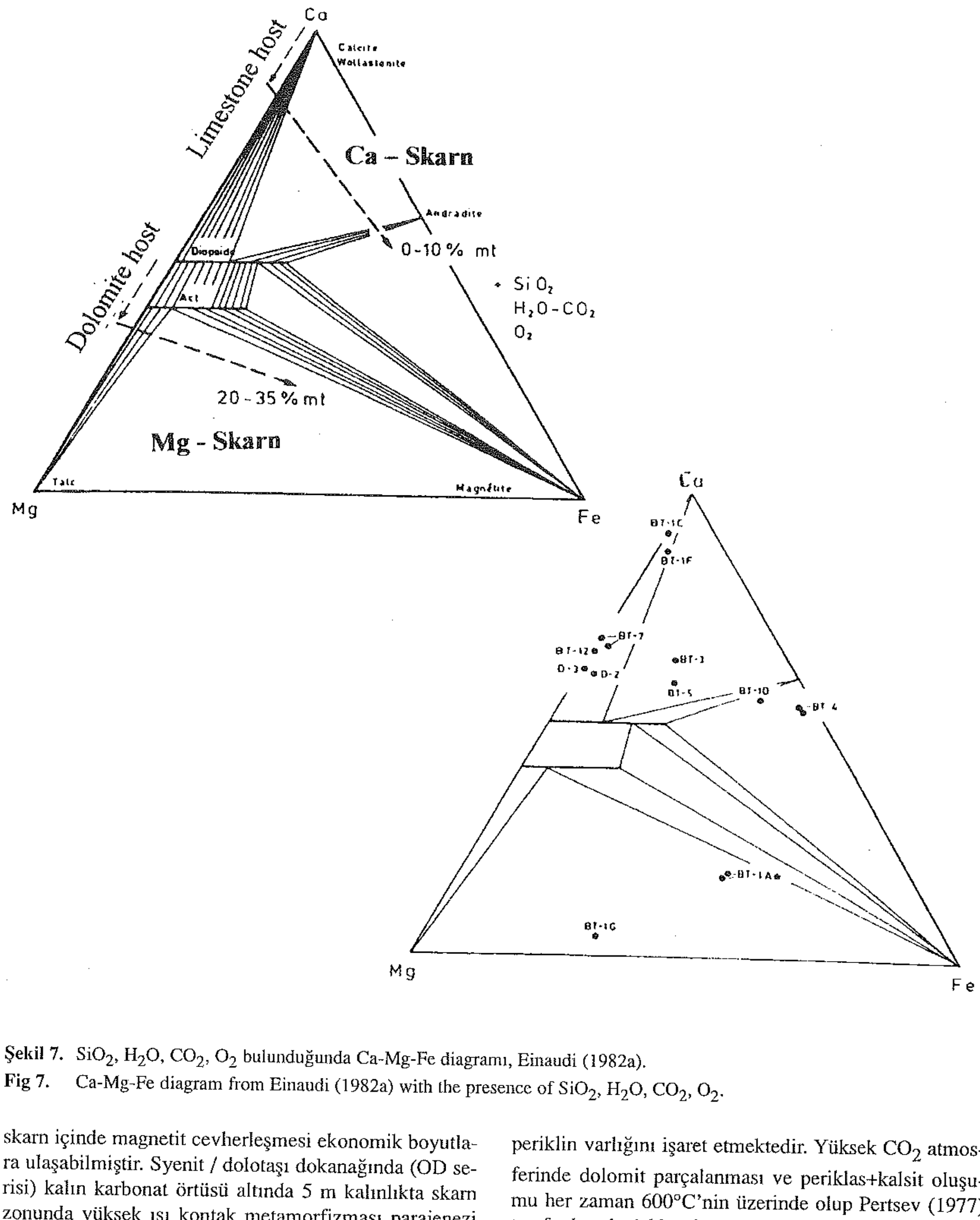
Some metallic and silicate phase were observed on the extension of Dereköy Pluton in Bulgaria, Malko Tarnovo Pluton. Vassileff (1978) and Jovchev et al. (1974) mentioned pure magnetite; and Milev and Bogdanov (1974) described copper mineralizations in calcic skarn near Burdsé and Gradishté. Only difference in Dereköy is the absence of merwinite and late ludwigite. We concluded that some contact metasomatic iron deposits in Turkey (for.ex. Divriği) should be compared in terms of their skarn mineralogy and of host rock composition with this study.

ÖZET

Zharikov (1968) ve Einaudi ve diğ. (1981) göre skarn oluşumunun en ilginç yanı magma kristalizasyon sürecine paralel magnezyumlu skarnların ve postmagmasal evredeki kalsiyumlu skarnların beraber bulunuşudur. Böylece bol sayıda skarn mineral topluluğu hem yüksek ısıda hemde düşük ısı metasomatik süreçte gelişir. Silis oranı az magnezyumlu yan kayaçlara sokulan magma kayacının etrafındaki genel fasiyes sıralaması aşağıdaki gibidir:

granitoid	klinopiroksen + bitovnit	fassait + spinel + forsterit	forsterit + spinel	kalcite + forsterit + spinel	dolotaşı

Sığ derinliklere sokulan (1-3 km) magma kütlelerinin etrafında periklas mermerleride gözlenir. Kuzey Batı Türkiye'de Dereköy yöresinde Jura yaşlı Mahya Formasyonu karbonatlı kayaçları Üst Kretase - Paleosen yaşlı granitoid kütleleri (K/ar yaşı 81.3 My) kesmektedir. Bunlardan biri olan Dereköy Plütonu saha görünüşü ve fasiyes dağılımına göre oldukça sığ bir sokulum (epizon) olduğu anlaşılmaktadır. Granodiorit, monzonit, syenit bileşimindeki fasiyesler yanında azda olsa gabrolara rastlanır. Kontak metamorfizma monzonit/dolomitli mermer (BT serisi), monzonit/dolotaşı (BT1 serisi) ve syenit/dolotaşı (D serisi) arasında araştırılmıştır. BT serisinde monzoniti oluşturan mineral özelliklerine göre subvolkanik bir karakterde olduğu gözlenmekte ve dokanakta skapolitli bir endoskarna dönüşmektedir. Eksoskarn zonunda magnetit + kalkopiritli granat skarn yanında steril piroksen skarn ve olivin + klinoklor + filogopit + klintonitten oluşan dolomitli mermer gözlenmektedir. Bu seviyenin oluşum koşulları: 550-600°C, XCO_2 < 0.2. Ayni monzonitin dolotaşı dokanağında (BT1 serisi) magma kayaca olivinli monzonit (kentallenit) bileşimli bir endoskarn mineralojisi göstermektedir. Eksoskarn zonunda tipik bir olivin skarn içinde endoskran mineralojisi göstermektedir. Eksoskarn zonunda tipik bir olivin



Şekil 7. SiO_2, H_2O, CO_2, O_2 bulunduğunda Ca-Mg-Fe diagramı, Einaudi (1982a).
Fig 7. Ca-Mg-Fe diagram from Einaudi (1982a) with the presence of SiO_2, H_2O, CO_2, O_2.

skarn içinde magnetit cevherleşmesi ekonomik boyutlara ulaşabilmiştir. Syenit / dolotaşı dokanağında (OD serisi) kalın karbonat örtüsü altında 5 m kalınlıkta skarn zonunda yüksek ısı kontak metamorfizması parajenezi saptanmıştır. Fassait+Mg-Al spinelli parajenez en azından 625°C, XCO_2 = 0.1, 2 kbar düzeyine erişildiğini göstermektedir. Ayrıca mermer içinde gözlenen brusitler periklin varlığını işaret etmektedir. Yüksek CO_2 atmosferinde dolomit parçalanması ve periklas+kalsit oluşumu her zaman 600°C'nin üzerinde olup Pertsev (1977) tarafından da 1 kbar basınç altında 800°C değeri verilmektedir. Magnezyumlu skarnların en önemli özelliği, Ca-Mg-Fe diagramında da görüldü gibi, bunlarda magnetit cevherleşmesinin kalsiyumlu skarnlara göre üç kat fazla olmasıdır. Burada demirsiz magnezyumlu mineral fazlarının bolca gelişmesi rol oynamaktadır. Dereköy Plütonunn Bulgaristan'da kalan kesiminde, Malko Tarnovo'da demir cevheri işletilmektedir.

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