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Genesis of the auriferous quartz veins and sulphide lodes in Kızıldağ massif (Hatay-Turkey): constraints from geochemical data, fluid inclusions and sulphur isotope studies

Kızıldağ masifindeki (Hatay-Türkiye) altınlı kuvars damarlarının kökeni: jeokimya, sıvı kapanım ve kükürt izotop çalışmaları

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ABSTRACT

The aim of this study is to present the results and meaning of the homogenization temperatures and salinity of the fluid inclusions, sulphur isotope, mineralogical and geochemical studies on gold bearing quartz veins and sulphide lodes, which are mainly hosted by sheeted diabasic dykes and to a lesser extend by gabbro in the Kızıldağ massif. The homogenization temperatures of the quartz veins and the sulphide lodes range between 160 °C - 280 °C and 270 °C - 392 °C, respectively. The freezing points of the fluid inclusions vary between -33.6 °C and - 46.6 °C, while the melting points were found ranging from -1.7 °C to – 8.2 °C. As a result, the salinity of the studied fluid inclusions were found to be ranging from 2.5 to 11.7 with a mean of 6.2 % wt NaCl. The δS^{34} values were determined to be changing from 0.8 to 4.6, which may indicate granitic rocks as the source of the auriferous vein-lodes. K and Na values in the veins do not show any anomalous increase or decrease. Due to this, it can be speculated that, there is no Na or K metasomatism or enrichment especialy related with the sea originated descending hydrothermal circulation. The main ore mineral in the veins and lodes is arsenopyrite. The mean As content of the diabasic dykes are very low, therefore the studied auriferous veins and sulphide lodes could not have been enriched in “As” by descending hydrothermal circulation through diabasic dykes. Pb depletion is very obvious in Hatay diabasic dykes, but the studied veins or sulphide lodes are not rich in Pb, on the contrary, veins and sulphide lodes are almost free from Pb-minerals with the exception of Ayvaz pit. The results of the study were compared and discussed with the results of previous studies carried out in different areas by different investigators. According to the results, the veins and lodes studied are determined to be a product of hydrothermal fluids and most probably originated from granitic to dioritic differentiates-ascendant enrichment- of the Kızıldağ ophiolites, rather than seawater leaching - descendant enrichment-of the ophiolithic rocks.

Key words: Gold, Hatay-Kızıldağ massif, hydrothermal, quartz-sulphide vein.

ÖZ

Bu çalışmanın amacı, özellikle diyabaz daykları ve daha az oranda da gabronun yan kayaçlık yaptığı, altın içeren kuvars ve sülfit minerallerince zengin damarlarda yapılan sıvı kapanım, kükürt izotop ,mineralojik ve jeokimyasal çalışmaların sonuçlarını ve yorumlarını sunmaktır. Kuvars damarlarındaki sıvı kapanımlarında belirlenen homojenleşme sıcaklığı 160 °C ile 280 °C arasında değişirken, bu değerlerin sülfit minerallerince zengin damarlarda 270 °C ile 392 °C arasında değiştiği belirlenmiştir. Ayrıca sıvı kapanımlarındaki donma değerleri -33.6 °C ile - 46.6 °C arasında değişirken, erime değerlerinin (Tm) ise, -1.7 °C ile –8.2 °C arasında değişmektedir. Bu bilgilerin kullanılmasıyla elde edilen tuzluluk değerlerinin ise % 2.5 ile % 11.7 NaCl arasında değiştiği ve ortalama değerin % 6.2 NaCl olduğu görülmüştür. Kükürt izotop çalışmaları sonucunda elde edilen δS^{34} değerinin 0.8 ile 4.6 arasında değiştiği ve bu değerin granitik bir kaynağa işaret ettiği sonucuna varılmıştır. Damarlardaki Na ve K değerleri herhangi önemli bir artış veya eksilme göstermemektedir. Bu verilere dayanarak, bölgede deniz suyu kökenli yüzeysel sulardan kaynaklanan bir Na veya K metasomatizmasının oluşmadığı söylenebilir. Çalışılan damarlarda ana cevher minerali arsenopirittir. Diyabaz dayklarının ortalama As değeri ise çok düşüktür. Bu nedenle, altın içeren kuvars damarları veya sülfit lodlarının, diyabaz dayklarının desendant(yüzeyden derine hareket eden) akışkanlarla yıkanmasıyla süzülen arsenikçe zenginleşmesi mümkün görülmemektedir. Hatay'daki diyabaz dayklarında Pb'nin de tüketildiği çok belirgindir. Ancak Ayvaz ocağı hariç, hiçbir damar veya sülfit lodunda Pb artışı görülmemiştir. Elde edilen tüm bilgiler birlikte değerlendirildiğinde, altınlı kuvars ve sülfit minerallerince zengin damarların hidrotermal bir *akışkanın ürünü olduğu ve bu zenginleşmenin, deniz sularının ofiyolitik kayaçları süzerek, desendant olarak oluşmasından ziyade, ofiyolitik bir mağmanın granitik-diyoritik karakterli son ürünlerine bağlı olarak gelişen assendant (aşağıdan yukarıya doğru yükselen- primer) akışkanların yerleşimi ile oluştuğu sonucuna varılmıştır.*

Anahtar kelimeler: *Altın, Hatay-Kızıldağ masifi, hidrotermal, kuvars –sülfit damarı.*

INTRODUCTION

The Kızıldağ Ophiolitic complex in southern Turkey (Figure 1) has received considerable attention. Erickson (1940), Wijkerslooth (1942), Romieux (1942), Dubertret (1953), Molly (1955), Vuagnat and Çoğulu (1967), Aslaner (1973), Çoğulu (1974 and 1975), Delaloye et al. (1977 and 1980), Selçuk (1981), Erendil (1984), Alpan (1985), Tekeli and Erendil (1986), Pişkin et al. (1984, 1987 and 1990) and Aydal (1989) are some to be mentioned. The study area is located 11 km NW of the Hatay city centre and covers an area of about 25 km^2 in Kisecik village and surroundings. Most of the quartz veins and sulphide lodes were found at Kızıltepe and Deliktepe, which are located just to the northwest of Kisecik Village (Figure 1). The general mineralogical and geochemical properties and differences of the quartz veins and sulphide lodes were presented by Aydal (1989). The main aim of this paper is to present mineralogical, geochemical, fluid inclusion and sulphur isotope studies on auriferous hydrothermal veins and lodes to provide information about ore formation processes.

GEOLOGICAL SETTING

The Hatay –Kızıldağ ophiolitic massif was formed between late Jurassic and early Cretaceous time (Delaloye et al.,1977) and was emplaced on the Arabian plate during the Campanian to early Maastrihtian (Aslaner,1973; Delaloye et al.,1980 ; Selçuk,1981).The allocthonus ophiolitic massif of the Kızıldağ was formed in a back arc environment (Delaloye et al.,1984). The geological setting of the area was described by Dubertret (1953), Vuagnat and Çoğulu (1967), Aslaner (1973), Çoğulu (1974 and 1975), Selçuk (1981),Tekeli and Erendil (1986) and (Pişkin et al.,1984, 1987 and 1990). These investigators identified six different rock units within the ophiolitic complex, such as tectonites, poikilitic zone, cumulates (ultramafic and mafic types), diabase dykes (as sheeted complex), pillow lavas and volcano- sedimentary rocks. A brief description of these units is presented below.

Tectonic peridotites of the Kızıldağ ophiolite occur in the middle parts of the massif and are overthrust onto the Barremian and Albian sediments, while reasonably large limestone blocks were incorporated in the ultramafic rocks. Peridote is the dominant rock exposed in the Kızıldağ ophiolite. It mainly consists of harzburgite and dunite. The poikilitic zone of the uppermost part of the tectonic peridotite forms a transition to the overlying cumulate suite.

The mafic rocks comprise two mappable units, layered and isotropic gabbro. Most of the layered gabbros are intensely altered and the isotropic gabbros are seen in association with the auriferous brecciated quartz veins in Barbarlı Dere region. The isotropic gabbro shows an extreme grain size variation from microcrystalline to pegmatitic.

The sheeted dike complex comprises multiple subparallel diabase dikes and mostly exhibits assymetric margins. Except along the upper and lower contacts of diabase dikes, no wall rock is present among individual dikes.The predominant trends of the almost verticaly sheeted dikes are NNE-SSW. Both, auriferous quartz veins and sulphide lodes are associated with these dikes.

The volcanic complex is composed of pillow and massive lava flows with interflow and interpillow sediments,including conglomerates.

MINERALIZATION

The Hatay gold deposit consists of a series of parallel, tabular and vertically oriented auriferous zones. These veins exhibit numerous fracturing and filling episodes. Mineralization is of two types; quartz veins and sulphide lodes. The dominant trends of the auriferous quartz veins are N50W and N85W with vertical, subvertical to

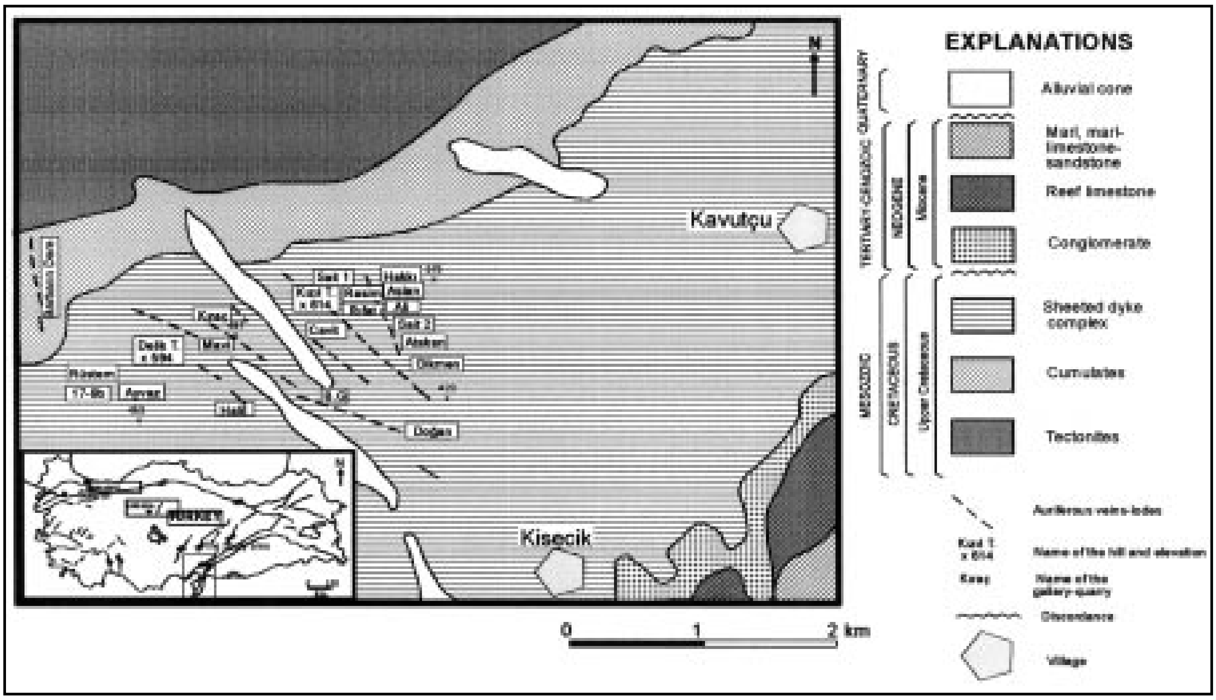

Figure 1: Geology and location map of study area.
Şekil 1: Çalışma alanının jeoloji ve yer bulduru haritası.

northerly, and southerly dips. These veins are almost entirely hosted by diabase dikes with the exception of the Barbarın Dere, where the brecciated quartz vein is hosted by gabbro. Therefore, auriferous quartz veins may be classified into two subgroups according to their hostrock. The thickness of the veins ranges from 1-2 cm to over 5 m, and their length extends to 500 m at the Doğan pit .

The sulphide lodes are controlled by N60W and N70W directed fault systems. But, unlike the auriferous quartz veins, some of them have no preferred orientation, as particularly seen at the Kıraç pit. The thickness of the sulphide lodes ranges from 5 cm to 140 cm, with lengths reaching up to 150 m at the Kızıltepe-Hakkı pit.

Reflected light microscope, scanning electron microscope (SEM) and microprobe analysis revealed the existence of the following ore minerals such as, arsenopyrite, sphalerite, chalcopyrite, pyrite, pyrrhotite, galena, native copper, gold, silver, and platinum group minerals. Chalcocite, cuprite, neodigenite, covellite, fahlore and scorodite occur as alteration minerals. Native copper and lead only were detected as solid inclusions in chalcopyrite and arsenopyrite, respectively (Table 1), (Aydal,1989).

Based on to the data collected from the polished section, SEM and microprobe analysis, the following paragenetic sequence of ore minerals can be stated; pyrrhotite 1, platinum group minerals, gold 1, silver, chalcopyrite, sphalerite, lead 1, arsenopyrite 1, arsenopyrite 2, chalcopyrite 2, pyrrhotite 2, pyrite 1, marcasite, gold 2, pyrite 2 and lead 2 (Aydal,1989).

Quartz is the most abundant gangue mineral in the auriferous veins and sulphide lodes. Two textural type of quartz were seen. Type 1 is an early formed grayish-white, medium- to -coarse grained, deformed quartz, which exhibits undulose extinction in thin section. It forms splintery, highly fractured textures and exhibits complex boundaries with neighbouring grains. Gold and sulfide minerals are associated with Type 1 quartz. Type 2 quartz, is milky to off- white, and typically less deformed. It contains minor amounts of sulfide and insignificant gold. In thin section, type 2 quartz is generally coarse grained, averaging 1-4 mm in size, although considerably larger grains were observed. In some areas, particularly along veins, the quartz has been

Table 1. The mineral content of the quartz veins and sulphide lodes.
Çizelge 1. Kuvars damar ve sülfit lodlarına ait mineral içerikleri.

Auriferous sulphide lodes	Auriferous quartz veins
Ore minerals	
Gold	Gold
Silver	Silver
Chalocopyrite	Chalcopyrite
Sphalerite	Sphalerite
Arsenopyrite	Arsenopyrite
Pyrite	Pyrite
Native copper	
Native lead	
Pyrrhotite	
PGE	
Gangue and secondary minerals	
Quartz	Quartz
Chalcedony	
Calcite	Calcite
Limonite	Limonite
Montmorillonite	Montmorilonite
Illite	Illite
	Erionite
	Leumontite
	Smectite
Cuprite	
Neodigenite	
Fahlore	
Marcasite	
Scorodite	
Chalcocite	
Covellite	
Sericite	

strained and recrystallized to form mosaics of fine (0.01 mm) interlocking grains.

Calcite is the most common and widespread minor constituent of the veins and is commonly seen along the margins of the veins as euhedral to subhedral grains associated with quartz and minor sulphide minerals. Staining with alizarin red indicates that the carbonate mineral is calcite rather than dolomite. Most of the calcite show stress twinning. Sericite is very rarely seen as intergrown with carbonate. In many places veining is accompanied by weathering, alteration and cataclasis of the vein and wall rock.

The auriferous veins contain some zeolites such as laumontite and erionite. Zeolites are widespread, particularly accompanying sulphide mineralization in the Doğan pit (Aydal, 1989). Argillic alteration are commonly seen in many places, but typical occurrences are observed at the Kıraç, Halil and Doğan pits. The clay minerals were shown by XRD,DTA and SEM studies to be smectite, particularly montmorillonite. Hematites and limonites occur in the study area as the products of weathering (Aydal,1989).

EXPERIMENTAL TECHNIQUE AND ANALYTICAL METHODS

All major, trace and REE geochemical analysis of the auriferous quartz veins, sulphide lodes, alteration zones and hostrocks were made by ACME – Canada Analytical Laboratories Ltd. During the analysis, 0.2 g samples were reportedly fused with 1.5 gr of $LiBO_2$ and dissolved in 100 ml 5 % HNO_3 and for REE, finished with ICP-ES and ICP/MS. Total C and S measurements were made by LECO. For Cu, Pb, Zn, Ni, As, Cd and Sb analysis 0.5 g sample is digested with 3 ml 2-2-2, HCl-HNO_3-H_2O at 95 degree C for one hour and diluted to 10 ml with water and finished with ICP. During the analysis SO-15/CSB, SO-15, C3 and G2 were used as standards.

The fluid inclusions were examined in thin section of the quartz veins-sulphide lodes a few millimeters in size which were polished on both sides down to thickness of about 0.5-1 mm using 1-0.3 µm sized alumina particles on a vibratory polishing machine. The slivers were prepared from these slices of veins (or lodes) containing minerals with fluid inclusions which were mounted on glass slides using cold Entelton resin. The thin sections were floated off by soaking in xylene for 1 to 3 days, and pre- selected areas of inclusions were cut out. Microthermometric measurements were then conducted on a“Fluid Inco.” heating-freezing (-180° C to + 600° C) stage mounted on a Olympus BX 60 microscope.

Two phased (liquid and vapour) primary inclusions were chosen and used during the study. Six samples were prepared for fluid inclusion studies in MTA (General Directorate of Mineral Research and Exploration of Turkey) laboratories. During the study, measurements were carried out on about 22 inclusions for each sample, so altogether 132 fluid inclusions were investigated for homogenization temperatures and 3 samples were used for 31 trial for salinity investigation in wt % NaCl. The temperature at which the vapour bubble disappears during controlled heating may then be determined in order to obtain a homogenization temperatures (Th), which gives a temperatures of formation of the fluid inclusion.

Pure nitrogene gas, which was passed through a heat exchanger in liquid nitrogen, was used to control cooling. Most inclusions froze at – 40 °C. The samples were taken down to – 50 ° C to ensure freezing of the inclusions since the fluid in the inclusions shows pronounced supercooling effects. The samples were allowed to warm up again and the temperature of ice disappearance (melting temperature -Tm) was then measured.

The selected 5 samples for S isotope determination were initially crushed and grinded to get 150 –200 mesh specimen in MTA laboratories. These samples were enriched using Tetra-brom-etan ($Br_4C_2H_2$) and washed with carbon –tetra- clor (CCl_4) before dried in the oven for half an hour at least. The enriched samples were then sent to Canada in separate bags. Sulphur isotope studies were performed by the academic staff in the University of Western Ontario, Department of Earth Sciences Laboratories in Canada.

GEOCHEMISTRY

The result of major oxide, trace element and REE analysis of the auriferous quartz veins and sulphide lodes, as well as those of the represantative samples from their host rocks and alteration zones,are presented in Tables 2, 3 and 4. A comparison between Table 2 and Table 3 reveals a decrease in almost all the major oxides in the mineralized zones, compared to the host rocks, with the exception of Fe_2O_3, which as expected from the occurrence of Fe-sulphide minerals, reaches values as high as 37% in the veins.

The trace element contents of the veins and their host rocks are depicted, in Figure 2, in terms of MORB-normalization patterns. The patterns yielded by the host rocks and the veins show similarities in that they have slightly elevated LILE (Large Ion Lithophile Elements) relative to HFSE (High Field Strength Elements). The elemental levels indicate a magma source depleted relative to MORB. The veins display the lowest elemental levels especially with the regard to HFSE.

The REE contents are shown, in Figure 3, as CHONDRITE-normalized patterns. Both the host rocks and the veins are characterized by low REE contents and reasonably flat REE patterns. As in the case of MORB-normalized trace element patterns in Figure 2, veins display the lowest elemental levels in Figure 3, a feature in conformity with the expectations since it is well known that most of the sulphide minerals are not good host for the elements concerned.

Regarding the mineralization, it is important to not that K and Na values in the veins do not

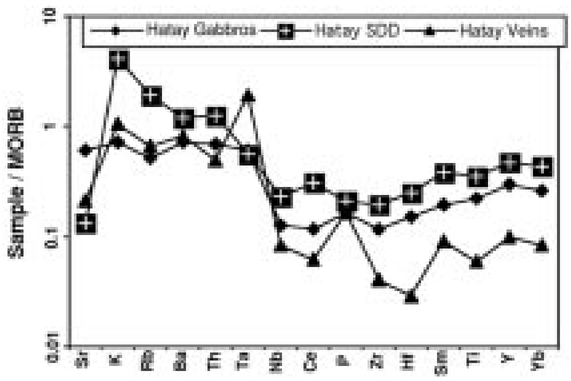

Figure 2: MORB normalization values are from vins and their host rocks (as mean values) (MORB normalization values are taken from Pearce, 1983).

Şekil 2: Çalışılan örneklere ait ortalama değerlerinin MORB normalizasyonu ile elde edilen profiller (MORB normalizasyon değerleri Pearce, 1983'den alınmıştır).

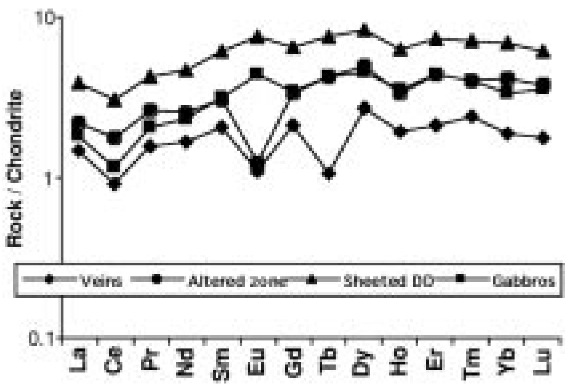

Figure 3: The REE patterns of the studied veins and their comparison with their hostrocks. Condrite normalization values are from Wakita et al., 1971).

Şekil 3: Çalışılan örneklere ait REE profilleri ve yan kayaç profilleri ile karşılaştırması. (Kondrit normalizasyonların değerleri Wakita ve diğ., 1971'den alınmıştır).

Table 2. The results of major, trace and REE analysis of the quartz veins and sulphide lodes.
Çizelge 2. Kuvars damar ve sülfit lodlarına ait ana oksit, iz ve REE analiz sonuçları.

	SiO_2	AL_2CO_2	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3
Veins	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
3 HAKKI	39.45	0.49	33.23	0.07	0.05	0.02	0.04	0.01	0.01	0.11	0.00
2 RASİM	59.68	0.73	17.93	0.09	0.10	0.05	0.05	0.01	0.02	0.06	0.02
4 ASLAN	79.93	0.80	8.02	0.32	0.15	0.10	0.07	0.03	0.01	0.08	0.01
5 RIFAT	11.19	2.38	28.81	2.56	19.26	0.04	0.04	0.10	0.01	0.30	0.00
6 ATAKAN	62.38	1.68	14.76	0.87	9.13	0.08	0.05	0.09	0.01	0.14	0.01
1 KIRAÇ	10.65	3.03	37.84	1.32	1.17	0.04	0.12	0.14	0.01	0.19	0.00
10 AYVAZ	85.57	6.15	1.68	0.29	1.52	0.21	0.84	0.16	0.09	0.01	0.04
8 BG	83.23	1.87	7.38	0.91	0.24	0.07	0.04	0.14	0.03	0.11	0.01
17-9b	48.73	14.39	15.37	10.72	0.26	0.22	0.06	0.53	0.04	0.23	0.02

	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Veins	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
3 HAKKI	0.10	0.10	0.05	0.20	0.10	0.05	0.12	0.05	0.13	0.05	0.08	0.05	0.15	0.02
2 RASİM	0.10	0.10	0.05	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
4 ASLAN	0.20	0.10	0.07	0.20	0.10	0.05	0.11	0.05	0.08	0.05	0.05	0.05	0.07	0.02
5 RIFAT	1.50	3.00	0.57	3.70	1.10	0.15	1.11	0.20	1.18	0.18	0.47	0.07	0.44	0.06
6 ATAKAN	0.60	0.90	0.19	0.90	0.30	0.07	0.38	0.08	0.38	0.06	0.24	0.05	0.21	0.03
1 KIRAÇ	0.10	0.10	0.07	0.20	0.10	0.05	0.20	0.05	0.19	0.05	0.17	0.05	0.19	0.04
10 AYVAZ	0.50	0.40	0.18	0.80	0.30	0.07	0.79	0.23	1.42	0.32	0.78	0.12	0.80	0.11
8 BG	0.30	0.20	0.12	0.50	0.30	0.05	0.28	0.08	0.45	0.09	0.24	0.05	0.34	0.04
17-9b	1.10	2.70	0.53	2.90	1.20	0.16	1.81	0.37	2.82	0.50	1.77	0.22	1.56	0.23

	Ba	Sc	Bi	Co	Cs	Ga	Hf	Nb	Rb	Sn	Sr	Ta	Th	Tl
Veins	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
3 HAKKI	10.00	1.00	0.10	52.20	0.10	2.00	0.10	0.21	0.43	1.70	1.40	0.40	0.20	0.10
2 RASİM	5.00	1.00	0.20	10.90	0.10	1.90	0.10	0.28	0.69	2.00	15.00	0.60	0.30	0.10
4 ASLAN	28.00	1.00	0.10	5.20	0.10	5.40	0.10	0.27	0.64	3.60	4.30	0.50	0.20	0.10
5 RIFAT	31.00	2.00	0.10	10.30	0.10	11.90	0.10	0.23	0.19	1.90	15.90	0.30	0.20	0.10
6 ATAKAN	16.00	1.00	0.10	3.70	0.10	2.70	0.10	0.31	1.04	2.00	10.50	0.20	0.20	0.10
1 KIRAÇ	12.00	2.00	0.20	16.00	0.10	9.80	0.20	0.52	0.83	1.90	2.60	0.50	0.50	0.10
10 AYVAZ	23.00	5.00	0.30	11.90	0.10	6.40	0.10	0.20	6.20	2.60	149.60	0.10	0.10	0.10
8 BG	8.00	2.00	0.20	5.90	0.10	3.10	0.10	0.28	0.41	1.60	4.40	0.20	0.10	0.10
17-9b	21.00	13.00	0.10	36.60	0.10	13.00	0.70	0.70	0.60	1.30	30.80	0.10	0.20	0.10

	Mo	Cu	Po	Zn	Ni	As	Cd	Sb	U	V	W	Zr	Y
Alt. Zone	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
3 HAKKI	1.00	17958.00	31.00	167.00	13.00	99999.00	21.10	142.00	0.10	9.00	0.50	0.80	0.80
2 RASİM	1.00	16895.00	151.00	255.00	9.00	84390.00	10.00	82.00	0.10	9.00	0.50	0.80	0.10
4 ASLAN	1.00	17830.00	17.00	42398.00	9.00	21790.00	93.00	1.30	0.10	5.00	2.00	1.80	0.60
5 RIFAT	1.00	2699.00	7.00	583.00	19.00	2213.00	19.70	1.00	0.10	5.00	0.50	6.80	7.10
6 ATAKAN	1.00	2412.00	333.00	20.00	10.00	8460.00	6.70	1.00	0.10	5.00	1.40	5.40	2.70
1 KIRAÇ	1.00	7239.00	17.00	37.233.00	39.00	99999.00	90.70	319.00	0.10	50.00	1.00	3.90	1.30
10 AYVAZ	1.00	134.00	2045.00	1047.00	41.00	1462.00	1.90	8.70	0.10	39.00	0.70	4.50	8.50
8 BG	1.00	1730.00	87.00	1211.00	9.00	24020.00	6.50	1.00	0.10	6.00	1.00	4.80	2.40
17-9b	1.00	68.00	9.00	343.00	72.00	112.00	8.10	0.50	0.10	205.00	3.20	18.70	16.10

show any anomalous increase or decrease. Due to this, it can be speculated that, there is no Na or K metasomatism or enrichment especialy related to the sea originated descending hydrothermal circulation. The As content of the diabasic dykes are very low and the mean value is pointed out by Delaloye as 2.2 ppm (Delaloye,1993). As previously pointed out, one of the main ore mineral in the veins and lodes is arsenopyrite, therefore, these auriferous veins and sulphide lodes could not have been enriched in "As" by descending hydrothermal circulation

Table 3. The represantative analysis of the altered zone, sheeted diabasic dykes and gabbros.
(SDD = Sheeted Diabasic Dyke, DT = Deliktepe, KT = Kızıltepe)

Çizelge 3. Alterasyon zonu, diyabaz daykları ve gabrolara ait temsili analiz sonuçları.
(SDD = Diyabaz Dayk topluluğu, DT = Deliktepe, KT = Kızıltepe)

	SiO_2	AL_2CO_2	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3
Alt. Zone	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
7 DOĞAN	75.95	6.95	5.33	0.15	1.83	0.21	0.57	0.11	0.01	0.01	0.018
9 MAVİ	68.01	10.82	6.96	0.37	0.09	0.35	0.81	0.69	0.12	0.01	0.007
SDD											
19 DT	47.52	14.63	15.36	8.25	4.21	0.47	1.19	0.6	0.03	0.15	0.018
20 KT	46	12.31	9.29	14.94	5.53	0.07	0.04	0.47	0.02	0.2	0.066
Gabbros											
11-43	46.19	14.36	6.72	10.21	10.29	1.65	0.08	0.43	0.02	0.17	0.065
12-68	50.3	17.22	7.32	9.38	8.37	2.14	0.13	0.38	0.02	0.14	0.031

	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Alt. Zone	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
7 DOĞAN	0.1	0.1	0.05	0.3	0.1	0.06	0.17	0.05	0.23	0.05	0.08	0.05	0.16	0.03
9 MAVİ	1.4	3.1	0.58	3	1.1	0.12	1.57	0.34	2.49	0.47	1.66	0.21	1.65	0.22
SDD														
19 DT	1.9	4.1	0.68	3.6	1.5	0.76	2.11	0.43	3.23	0.6	1.73	0.28	1.77	0.23
20 KT	0.8	2	0.42	2.2	1	0.35	1.44	0.3	1.82	0.34	1.01	0.16	1.15	0.15
Gabbros														
11-43	0.7	1.5	0.35	1.8	0.9	0.39	0.97	0.24	1.67	0.32	0.96	0.14	1.01	0.15
12-68	0.8	1.7	0.35	2.2	0.7	0.42	1.26	0.27	1.68	0.36	1.02	0.17	0.98	0.16

	Ba	Sc	Bi	Co	Cs	Ga	Hf	Nb	Rb	Sn	Sr	Ta	Th	Tl
Alt. Zone	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
7 DOĞAN	13	5	0.1	10	0.1	7	0.1	0.18	4.2	2.2	16.0	0.1	0.1	0.1
9 MAVİ	9	9	0.4	38.6	0.1	13.1	1	1.05	8.66	1.1	20.4	0.2	0.3	0.1
SDD														
19 DT	30	14	0.1	41.7	0.1	15.9	0.7	1.07	7.55	2	19.6	0.1	0.3	0.1
20 KT	19	14	0.1	34.5	0.1	12.7	0.5	0.58	0.23	4	12.6	0.1	0.2	0.1
Gabbros														
11-43	14	16	0.1	28.1	0.1	9.6	0.4	0.49	1.75	1.9	74.8	0.2	0.2	0.1
12-68	32	13	0.1	30.3	0.1	13.9	0.5	0.5	1.19	2.1	88.7	0.1	0.2	0.1

	Mo	Cu	Po	Zn	??	As	Cd	Sb	U	V	W	Zr	Y
Alt. Zone	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
7 DOĞAN	1	3005	87	2667	31	37140	11.1	1	0.1	45	0.5	2.8	1.1
9 MAVİ	1	1124	27	1064	24	3960	5.5	1	0.1	157	10.7	30	14.5
SDD													
19 DT	1	37	5	40	74	21	7.4	0.5	0.1	277	0.6	22.3	17.1
20 KT	1	70	7	55	174	38	4.8	1.3	0.1	179	0.5	13.4	11.1
Gabbros													
11-43	1	9	2162	347	52	93	2.4	0.5	9	0.1	179	0.5	10.1
12-68	1	74	8	114	77	107	2.1	1.3	9.7	0.1	196	0.5	13.3

through diabasic dykes. Furthermore, Pb depletion is very obvious in diabasic dykes, but the studied veins or sulphide lodes are not rich in Pb, on the contrary, veins and sulphide lodes are almost free from Pb-minerals with the exception of Ayvaz pit .

Ba, Cu, Ti, Pb, and Cr content of the studied gabbros are found higher than the average values reported in the literature as typical of these type of rocks. Especially Cu and Ti content are found 3 times, Ba content is 7 times higher than normal level. On the contrary, Sr, Co, Ni, V, and Zr values are determined lower than the average values. Especially Ni content is found 1/ 10, Co is 1/3 and Sr is found 1/2 of the average values. The K levels of the studied gabbros are found almost the same with the average value of

Table 4. The total REE, LREE, HREE contents and LREE/HREE, Eu/Sm ratios of the samples (samples from veins or lodes 1 to 9, from altered zones 10 to 12, from sheeted diabasic dykes 13 and 14, from gabbros 15 to 27).

Çizelge 4. Çalışılan örneklere ait toplam REE, LREE,.HREE miktarları ve LREE/HREE, Eu/Sm Oranları (örneklerden 1'den 9'a kadar olanlar cevherli damarlara, 10'dan 12'ye kadar olanlar altere zonlara, 13 ve 14 diyabaz dayklarına, 15'den 27'ye kadar olanlar ise gabrolara aittir).

Sample	TOTAL REE (ppm)	TOTAL LREE (ppm)	TOTAL HREE	LREE/HREE	Eu/Sm
Hakkı	1.25	0.45	0.30	1.50	0.40
Aslan	1.20	0.57	0.19	3.00	0.40
Rasim	0.95	0.35	0.25	1.40	0.40
Rıfat	13.73	8.77	1.04	8.43	0.14
Atakan	4.39	2.59	0.53	4.88	0.23
BG	2.94	1.12	0.67	1.67	0.13
Kıraç	1.54	0.47	0.45	1.04	0.40
Ayvaz	6.82	1.88	1.81	1.03	0.23
17-9b	17.87	7.23	3.78	1.91	0.13
Doğan	1.53	0.55	0.32	1.72	0.60
Mavi	17.91	8.08	3.74	2.16	0.11
HL	6.93	4.22	0.79	5.13	0.22
DT	23.02	10.28	4.01	2.56	0.51
KT	13.14	5.42	2.47	2.19	0.35
8-1	17.66	7.26	3.83	1.89	0.50
8-3	9.46	3.56	2.15	1.66	0.60
8-5	9.45	3.64	2.05	1.77	0.63
8-9	9.06	3.43	2.01	1.70	0.55
8-10	8.03	2.79	1.82	1.53	0.47
8-12	6.07	2.05	1.46	1.40	0.60
8-14	7.45	2.58	1.79	1.44	0.58
9	12.89	5.74	2.44	2.35	0.41
43	11.10	4.35	2.26	1.92	0.43
68	12.07	5.05	2.33	2.17	0.60
69	5.47	1.52	1.27	1.20	0.50
71	3.97	1.31	0.96	1.36	0.60
72	14.37	5.48	2.93	1.87	0.48

the gabbros (Mason,1966; Köksoy,1991; Delaloye,1993).

Sr, Zr, Co, Ni and V values of the studied diabasic dykes are found higher, whilst the Ba, Pb and Ti values are found lower than the average values typical for diabases in general.
The Cu and Cr content of the Deliktepe diabases are found very low, while the Rb value is very high than the average values. The K value show variation between the Deliktepe and Kızıltepe diabases.
The K content of the Deliktepe diabases are higher than the average value and the Kızıltepe diabasic rocks. Part of the reason for chemical differences among the Kızıldağ dikes (SDD) is that they have been chemically altered. K_2O and Rb are higher in altered zones and V is higher in gabbros.

Ti, Ba, Ni, Sr, Zr, Sr, Co, Pb, V and Cr values in the auriferous quartz veins and sulphide lodes are found to be much lower than theirhostrocks. K and Na values in the veins do not show any abnormal increase or decrease.

As known that most sulphide and oxide minerals are not good host for REE, REE analysis are usually restricted to non sulphide gang minerals. Therefore, the studied veins, sulphide lodes and their hostrocks are characterized by very low REE contents and reasonably flat REE patterns. The MORB normalized trace content of the gabbro, SDD and veins are plotted altogether with some known areas, in order to show element depletion of the source magma (Figures 2 and 3). The limited amount of REE suggest that REE contents and distribution vary widely depending upon the minerals analysed in the samples.

The total REE content of the veins range 0.95 to 17.87 ppm, while the total REE content range 3.97 to 17.66 ppm and 13.14 to 23.02 in gabbros and in sheeted diabasic dykes, respectively. On the other hand, the LREE/HREE ratio changes 1.04 to 8.43 in veins, while the ratio changes 1.20 to 2.35 and in gabbroic rocks and in diabasic dikes, respectively (Table 4).

In general, the investigated rock/chondrite normalization diagrams show that the LREE content of all samples are gradually increases towards to MREE, then show slight decreases towards to HREE. Almost the same pattern are seen in MORB normalization diagrams.

FLUID INCLUSION STUDIES

The freezing points and homogenization temperatures, most of which were determined on the same inclusions, are given in Table 5 and all homogenization data are presented as a frequency poligon in Figure 4. Quartz minerals were used for fluid inclusion studies as used by different investigators in many other studies (Table 6).

The inclusions were pre-selected to obtain an approximately random sample. The auriferous quartz veins are intimately intergrown with sulphides, which contain high densities of inclusions.The inclusions are of variable shape, some being very irregular, whereas others show well defined morphologies and are in general between 4-10 micron in size.

The inclusions are clearly of hydrothermal origin since their homogenization temperatures are reasonably high (Figure 4). The data for 6 samples vary from 160-392 °C, while the homogenization temperatures in sulphide lodes range from 270 °C to 392 °C in particular. When crystals grow or recrystallize in a fluid medium of any kind, growth irregularities result in the trapping of small portions of the fluid in the solid crystal. Such irregularities may be sealed off during the growth of the surrounding part of the host crystal,yielding primary fluid inclusion.Healing of fractures formed during crystal growth yields pseudosecondary inclusions, and healing of fractures formed at some later time yields secondary inclusions. Most inclusions in the studied samples are randomly distributed and do not show obvious geometric relationship (Figure 5).

Table 5. The freezing and melting points of the fluid inclusions.
Çizelge 5. Sıvı kapanımların donma ve erime noktaları.

Location	Sample No.	Freezing Point (-C)	Melting Point (-C)	% wt Nacl
	99-73	46,4	3	5
		46	4,5	7,1
		46	4,5	7,1
		46,6	4,6	7,4
		42	4,8	7,7
Kızıltepe		43	5,2	7,9
		38,7	6	9,2
		41	6,4	9,5
		43	7,9	10,2
		48	8	11,2
		42,6	8,2	11,7
	99-74	36	2,8	4,5
		36	2,9	4,8
		33,7	3	5
		36	3,1	5,3
		35	3,5	5,8
		35	3,5	5,8
		36	3,6	6
		35,5	3,8	6,3
	99-77	39,7	1,7	2,5
		36	1,9	3,2
		36	2,5	3,8
		36	2,5	3,8
		40	2,5	3,8
		40	2,7	4,2
		35	2,7	4,2
		38	2,8	4,5
		35	2,8	4,5
		34	2,9	4,8
		33,9	2,9	4,8
		33,6	3	5

Therefore, it can be considered that they are primary. It could be argued, but they seem to be representative of the fluid which actually precipitated the ore minerals. Since the quartz veins are intergrown with the sulphides, the fluid inclusion data from these samples, apply to the process of sulphide ore deposition itself.

All inclusions are frozen between -33.6 and -46.6 °C and their melting points vary from - 8.2 °C to – 1.7 °C, whilst their salinity changing from

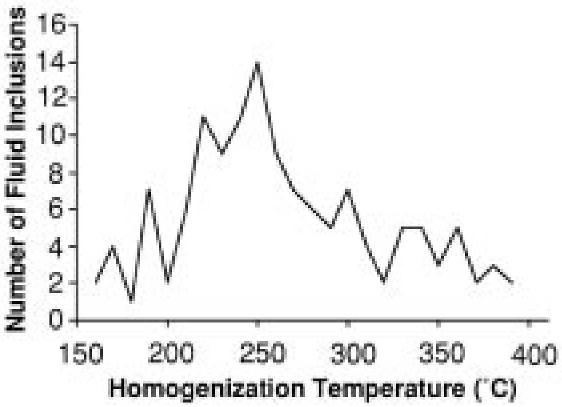

Figure 4. The histogram of the homogenization temperatures of the studied samples.
Şekil 4. Örneklerden elde edilen homojienleşme sıcaklıklarına ait histogram.

2.5 to 11.7 % NaCl, with an average of 6.2 % NaCl. The freezing point is statistically distinguishable from that of sea water.The salinity of sea water in the open oceans varies from 3.2 to 3.75 % NaCl (Riley and Chester,1971). In small ocean basins such as Mediterranean and the Red Sea, it rises to 4.1 % (Riley and Chester,1971). This produces a freezing point from –1.7 °C to –2.2 °C. Average sea water with a salinity of 3.5 % has a freezing point of –1.9 °C. Hence, it is clear that a hydrothermal fluid identical to seawater in its salinity did not form these auriferous quartz veins and sulphide lodes.

The freezing points of the Hatay vein - lodes may be compared to the freezing point of the Cyprus ore deposit fluid inclusions and may also be compared to data from the Kuroko polymetallic sulphide deposits of Japan. These are also of submarine origin, but formed in association with rhyolite domes rather than basic igneous rocks. The range of freezing point of Yunosawa deposit, Furutobe mine-Japan has been reported by Tokunaga and Honma (1974) as –1.8 °C to – 3.7 °C. This is very similar to the total range of fluid inclusion freezing points from Cyprus ore deposits (–1.2 °C to –3.2 °C) (Spooner and Bray,1977).

CONCLUSIONS

Based on the mineralogical, geochemical, fluid inclusion and $\delta^{34}S$ results, the veins and lodes studied are determined to be a product of hydrothermal fluids and most probably originated from granitic to dioritic differentiates-ascendant enrichment- of the Kızıldağ ophiolites, rather than seawater leaching -descendant enrichment-of the ophiolithic rocks.

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Table 6. The homogenization temperature and salinity values for the samples as compared to those from various deposits in world.
Çizelge 6. Örneklere ait homojenleşme sıcaklıkları ile tuzluluk değerlerinin dünyadaki çeşitli yataklarla karşılaştırılması.

Deposit	Minerals	Th (˚C)	Salinity (wt % Nacl)	References
Hatay-Kilisecik (Turkey)	Quartz	160-392	2.5-11.7	Present study
Emperor (Fiji)	Quartz	170-317	5.5	Ahmad (1979)
Neveda-Carlin (USA)	Quartz, barite, calcite	152-350	2.0-5	Radtke el al (1980)
Nevada-Tanopah (USA)	Quartz	140-290	1.0-3	Farley (1979)
Toyaltita (Mexico)	Quartz	250-310	1.9-13.8	Smith et al (1982)
Las Cuevas (Mexico)	Flourite	60-130	0-3	Ruiz et al (1980)
Colorado-Lake City (USA)	Quartz, sphalerite, flourite	183-272	0.1-6.6	Slack (1980)
Colqui (Peru)	Quartz, sphalerite	140-270	0-13	Kamilli and Ohmoto (1977)
Colorado-Sunnyside (USA)	Quartz, flourite, rhodochorosite	170-320	0-3.6	Cazadevall and Ohmoto (1977)
Colorado-Creede (USA)	Quartz	190-270	5.0-12	Barton and Roedder (1977)
Pachuca (Mexico)	Quartz, calcite	180-260	0-7.5	Drier (1976)

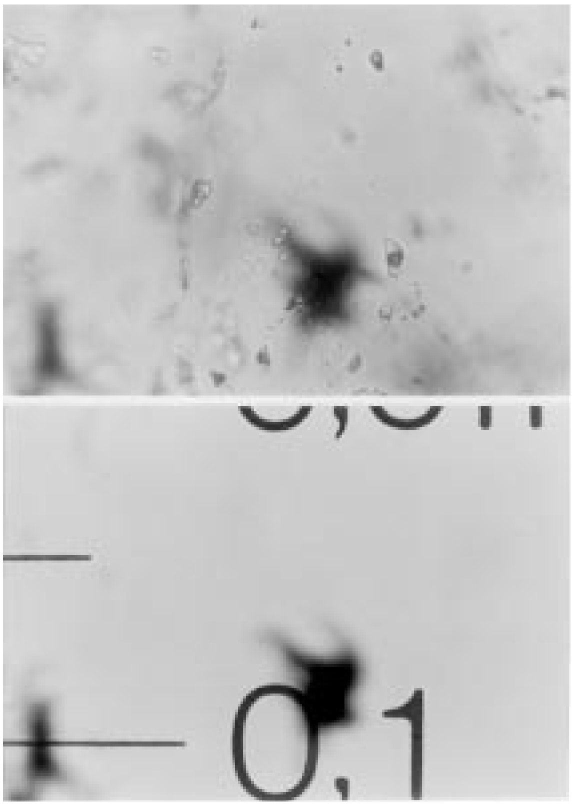

Figure 5: The microphoto (63 x 10) of the randomly distrubuted primary fluid inclusions in the samples.

Şekil 5: Örnekler içinde rastgele dağılım gösteren birincil sıvı kapanımların mikrofotosu.

microphoto taking from the fluid inclusions and to Hacı Doğan (MTA) for his help during the enrichments of the sulphide minerals for sulphur isotope determination. Finally my sincere thanks to research assistant Koray Sözeri for his help in various ways.

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