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ANATOMY OF AN EPITHERMAL MINERALIZATION: MUMCU (BALIKESİR-SINDIRGI), INNER-WESTERN ANATOLIA, TURKEY

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ABSTRACT.- An epithermal mineralization at Mumcu has been developed on the "simple transfer faults" vertically cross-cutting the main breakaway of the Simav Graben, and between the metamorphics of Paleozoic (?) and Miocene andesitic volcanics. An argillic alteration composed of kaolinite, montmorillonite and cristobalite takes place around the mineralization, within both two types of the rocks. Silicification, brecciation, and opalisation are also observed along the fault which constitutes the boundary between the metamorphics and volcanics. Breccias partly have a matrix composed of black silica or limonite. Pervasive and intensive jasperoids occur at the west of the studied area. Epithermal mineralization which is situated in the opalite zone within the metamorphics is represented with cinnabar associated with arsenopyrite, electrum (?) and rare gold particles. The gold values determined both in the Hg-bearing opalite and pyrites are 500 and 340 ppb. respectively. Given these data, it is likely suggested that the Hg-bearing opalite represents the top of an epithermal gold mineralization which has not eroded yet. According to the genetic model designed for Mumcu epithermal mineralization, one could except a bonanza zone dominated by gold towards the deeper parts.

INTRODUCTION

The studied area is in the inner part of the Western Anatolia, between Sındırgı county of Balıkesir province and Simav county of Kütahya province (Fig. 1). The area is located in the northern bloc and at the western edge of the Simav Graben, next to the graben fault that is the most important tectonic feature of the region.

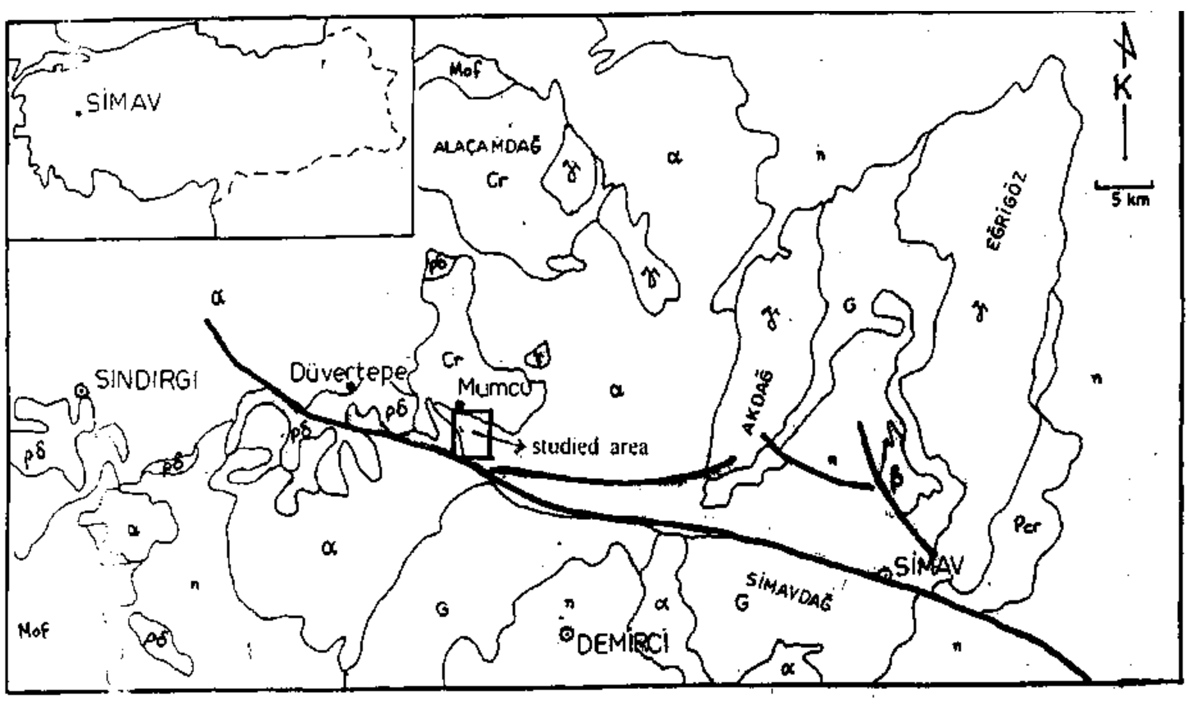

Figure -1 Location map of the studied area (simplified and revised from the Geological Map of Turkey in scale 1/500.00). G. gneisses: Cr. metamorphics: Pcr? Paleosoic metamorphics: Mof Mesosoic ophiolites: ρδ: peridotite, gabbro: γ granite: α andesite; β : basalt; n: Neogene.

Geological researches on the metamorphic rocks of the region were made by Akdeniz and Konak (1979 *a, b)* and Konak (1982). Öztunalı (1973). Eğrigöz and Uz (1978) studied the granitoid massif of Akdağ, from the petrogenetic point of view. Ercan. et al. (1981/1982) investigated the chemical composition and origin of the volcanic rocks of Cenosoic age in the Simav region.

In this study, an epithermal gold mineralization which is located in the rocks as related with the faults of the Simav Graben will be determined and a genetic model associated with the characteristics of the mineralization will be constructed.

GEOLOGY OF THE STUDIED AREA

Kalkan Formation

It is located at the base of the lithological units within the studied area (Fig. 2). Kalkan Formation consists of biotite-bearing gneisses, and some marble lenses occur in the lower levels of the formation. The unid age as pre-Paleozoic by Konak (1982) constitutes the "Gneiss core", in terms of Şengör et al. (1984), with the underlying migmatites eastwards of the studied area. Gneisses are likely to be formed from pelitic sediments and shales (Akdeniz and Konak, 1979a) that metamorphosed in almandine-amphibolite fades.

Simav Metamorphics

Simav Metamorphics consisting of various schists were metamorphosed in the greenschist facies constitute the "schist envelope" with the formations of Sarıcasu and Arıkayası overlying them. According to Akdeniz and Konak (1979a) and Şengör et al. (1984). The schist envelope is unconformable over the gneiss core. However, it is clearly seen that these two units are in a tectonic relationship near Simav. By the crushed zone between the schists and gneisses.

The Simav metamorphics begin with quartz-muscovite schists, and continue with quartz-muscovite-biotite schists. Metamafic-metaultramafic levels named as Kulat Member (Akdeniz and Konak, 1979 *a, b)* are seen in the middle part of the unit. They were folded and metamorphosed with the muscovite-biotite schists. But, their initial relations, have not been resolved yet. Marble levels are observed in the upper parts of the metamorphics. Since (Konak, 1982). According to Uz (1985), they were derived from a volcano-sedimentary sequence where rhyolitic and basaltic lavas tuffs alternated with the clayey and carbonatic sediments.

Sarıcasu Formation

Sarıcasu Formation consists of quartz-, albite-, chlorite-, muscovite- and sericite-bearing schists representing lower grade metamorphic facies than the Simav Metamorphics. The alternating levels of quartz and albite with muscovite and sericite form a banded structure. Recrystallized gray limestone lenses with calcschist structure occur in the upper levels of the formation.

Arıkayası Formation

It has both lateral and vertical gradation to the Sarıcasu Formation, the unit is composed of limestone with granoblastic texture consisting of the calcite crystals that have equigranular dimensions and irregular boundaries. The rock comprises also muscovite and opaque minerals.

Budagan Limestone

Budoğan limestone unconformably overlies the metamorphics, starting with a conglomerate level including abundant and well rounded quartz pebbles. The bedding of the Budağan limestone which is dolomitized in the lower levels is not distinct. It has micritic, biomicritic, pelmicritic, and locally sparitic or pseudo-oolitic textures. Akdeniz and Konak (1979b) and Konak (1982) reported fossils giving a range of age from Rhaetian-Norian (upper Liassic) to Cenomanian (upper Cretaceous) to the formation, however according to Kaya (1972) who defined the formation for the first time the age of the unit is Maastrichtian.

Dağardı Melange

This formation comprises the unorderly mixture of the great masses of mudstone, radiolarite, limestone, tuffite and peridotite. It overlies all of the older by a tectonic contact, and the slabs of the Budağan limestone are tectonically emplaced into

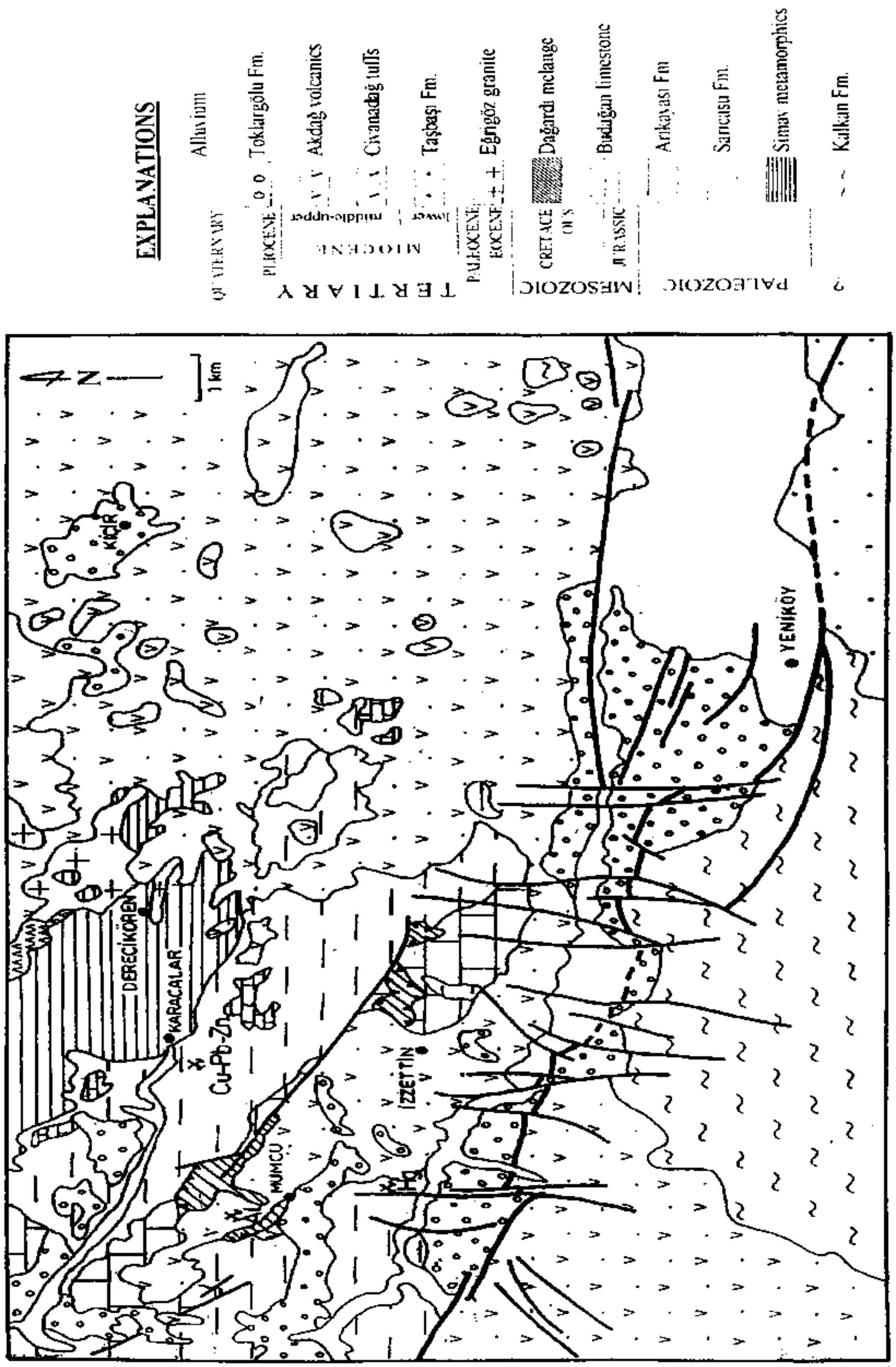

Fig. 2- Geological map of the studied area (revised from Akdeniz and Konak, 1979).

the melange (Konak, 1982). This formation includes Maastrichitan fossils near Dağardı where it is well described, and at the northern part of the Saphane Mountain (Akdeniz and Konak, 19796). Moreover, Dağardı Melange is unconformably overlain by the sediments of Eocene age around Duvertepe and Başlamış village of Akhisar county (Akdeniz, 1989; Akdeniz and Konak, 1979b).

Eğrigöz Granitoid

According to their modal compositions the pluton comprises monzogranite, tonalite and granodiorite, and is calc-alkaline in compositon. Bürküt (1966) suggested that the pluton reached it is composition by the differentiation and assimilation of the magmas a dioritic primary magma. However, Öztunalı (1973) defined the pluton as an anatexitic calc-alkaline granite, and suggested that the pluton started to form in the early Alpine phase (245 to 235 m.y.) and was emplaced in the principal Alpine phaset (78 to 58 m.y.). Uz (1973, 1978) suggested that the pluton consists of two different granite massifs. The first one surrounding the other is an older tectonised Hercynian granodiorite and formed by anatexis. The second cut post-tectonically the older one and is likely Jurassic in age. These young granites are magmatic in origin. According to Bingöl et al. (1982), the pluton that is syenomonzogranite in composition should be aged in late Oligocene-early Miocene (24,6 to 20,0 m.y.).

Simav granitoids intruded Budağan limestones and Dağardı melane, and are overlain by Taşbaşı Formation of the lower Miocene age (Akdeniz and Konak, 19796). Considering the field data, the emplacement age of the calc-alkaline granitoids should likely be Paleocene-Eocene.

Taşbaşı Formation

This unit is composed of loosely cemented conglomerate. The pebbles are angular, and the sorting of the unit is poor. The size of the grains get smaller towards the top, and locally, sandstone levels appear. Due to the pollens aged as middle-upper Miocene from the upper unit which is transitional to the Kızılbük Formation, Akdeniz and Konak (1979b) assigned lower Miocene age to the formation.

Civanadağ Tuffs

This unit consists of the tuffs which are rhyolitic, andesitic and dacitic in composition, and agglomerates in the upper levels. Marly, sand an clayey lenses occur locally. Agglomerate consists of volcanic fragments of various dimensions and the pebbles of metamorphics and ophiolitic melange. Civanadağ tuffs are laterally and vertically transitional to the Akdağ volcanics.

Akdağ Volcanics

The unit of the lavas of various compositions such as andesite, rhyolite, rhyodacite and dacite. According to Ercan et al. (1981/1982), Akdağ volcanics are subalkaline and have a calc-alkaline trend very close to the tholeitic series. According to their stratigraphical relations. Civanadağ Tuffs and Akdağ volcanics as middle to late Miocene in age (Akdeniz and Konak, 19796).

Toklargölü Formation

This unit is made up of unconsolidated coarse elastics. The grain size varies from sand to boulder. Alternations of silt, sand and pebble are observed in some places. Crossbedding is locally seen. Although no fossils are found. Gun et al. (1979) suggested that the formation is likely Plio-Quaternary in age.

SİMAV GRABEN

The most conspicuous tectonic feature of the region is the Simav Fault which trends nearly WNW-ESE for approximately 150 km. along the Simav river from Sındırgı at the west to Muratdağı at the east and which has a sinusoidal shape.

A depression plain bounded from south by the prominent escarpment of the Simav Mountain was occupied by Simav Lake which drained in 1950's. The fault is not a single fracture, instead in consists of several step faults parallel to the main fracture. The difference in altitude between the Civanadağ tuffs located in the northern and southern sides of the Simav Fault is 300 to 500 meters. Naşa basalts of Quaternary age and alkaline compositon (Ercan et al., 1981/1982) lie along the Simav Fault.

Konak (1982) depicted that the metamorphic zones in the northern block of the Simav Fault moved eastwards relative to the southern block. Therefore, the fault was a dextral strike-slip fault before the subsidence started the passive rifting. The lateral motion along a strike-slip fault before the subsidence started the passive rifting. The lateral motion of the fault surface (Crowell, 1974; Woodcock and Fischer, 1986; Sylvester, 1988). The planar normal fault at the surface transforms to a listric normal fault characterized by decreasing angle of dip with depth and a curved surface which is concave upward (Shelton, 1984). Therefore, Zeschke (1954), Akdeniz and Konak (1979b) and Koçyiğit (1984) defined the step faults on the surface of the footwall of Simav Graben as NE dipping gravity faults. Whereas, Dewey and Şengör (1979) pointed out that the bounding faults of the Simav Graben are listric faults that are rapidly flatten with depth.

A great number of faults trending N-S, perpendicular to the main fault at the western end of the graben, cut the Simav Fault. These cross-faults are referred by Gibbs (1984) as "transfer faults". According to Bosworth (1985), these structures are syn-rift features, although they may inherit a present zone of weakness. According to the Şengör's (1987) definition on the cross-faults observed in the western Anatolian graben, these cross faults cutting the Simav Graben are simple transfer faults. It means that the main breakaway fault of the graben is offset without rotation by strike-slip cross-faults.

Since the strike-slip movement of the Simav Fault caused shear fractures in- the Kızılbük Formation of the middle-upper Miocene age at the west of Simav, it is suggested that Simav strike-slip fault was still active during the late Miocene. Şengör et al. (1984) explained that the compressional tectonic regime, causing the movement of this fault, dominated the western Anatolia was transformed later to an extensional tectonic regime since the Cerravalian (upper Miocene). This new tectonic regime led to the formation of the grabens trending nearly east-west in the western Anatolia.

MUMCU EPITHERMAL MINERALIZATION

Mumcu epithermal mineralizations is situated on the Bağlar Hill, approximately 2 km south of the Mumcu village in the western end of the studied area and at the east of the well known Duvertepe kaolinite deposits (Fig. 2). The mineralization was emplaced in the fault zone formed by the transfer fault cross-cutting the Simav graben.

The schists of the Sarıcasu Formation of paleozoic age and the hyaloandesite tuffs of Civanadağ of middle-upper Miocene age are juxtaposed along these faults between Kızıl and Bağlar hills (Fig. 3). Both units are covered by the loosely cemented coarse detritics of the Toklargölü Formation of Plio-Quaternary age in the north.

The metamorphics of the Sarıcasu Formation consist of chlorite-quartz schists. The rocks has porphyroblastic texture and composed of quartz, calcite, and rare plagioclase, and has been subjected to the metamorpism in green-schist facies.

Hyaloandesitic tuffs with volcanic lava flows represent the Civanadağ tuffs in the studied area. Widespread zoned plagiociase (oligoclase-andesite) with polysynthetic lamella, corroded coarse quartz, partly opacitized biotite, and green amphibole phenocrysts that were transformed partly to biotite are seen in a devitrified matrix.

A little hyaloandesite blocks of the Akdağ volcanics crops out within the tuffs. It is composed of abundant zoned plagioclase with poylsynthetic lamellae, few biotite, and rare quartz phenocrysts within a glassy matrix. The cleavages of the biotite show local distortions.

Both tuffs and schists are strongly altered along the faults. Alteration is seen as a zone on 100 meters width in both rocks along the faults. The alteration products are determined as cristobalite, kaolinite, montmorillonite, tridimite and heulandite according to the XRD analysis. Döküş Hill kaolinite deposit that is located on the same faults at the northwest of the Mumcu village has alunite, dickite, cristobalite and quartz. An argillic alteration is discussed in the studied area on a account of the mineralogical assemblage. Due to the presence of montmorillonite, the alteration of the Kızıl hill is classified as intermediate argillic (Anderson and Eaton, 1990), and due to presence of alunite and dickite, the one of the Döküş hill as advanced argillic (Hemley and Jones, 1964).

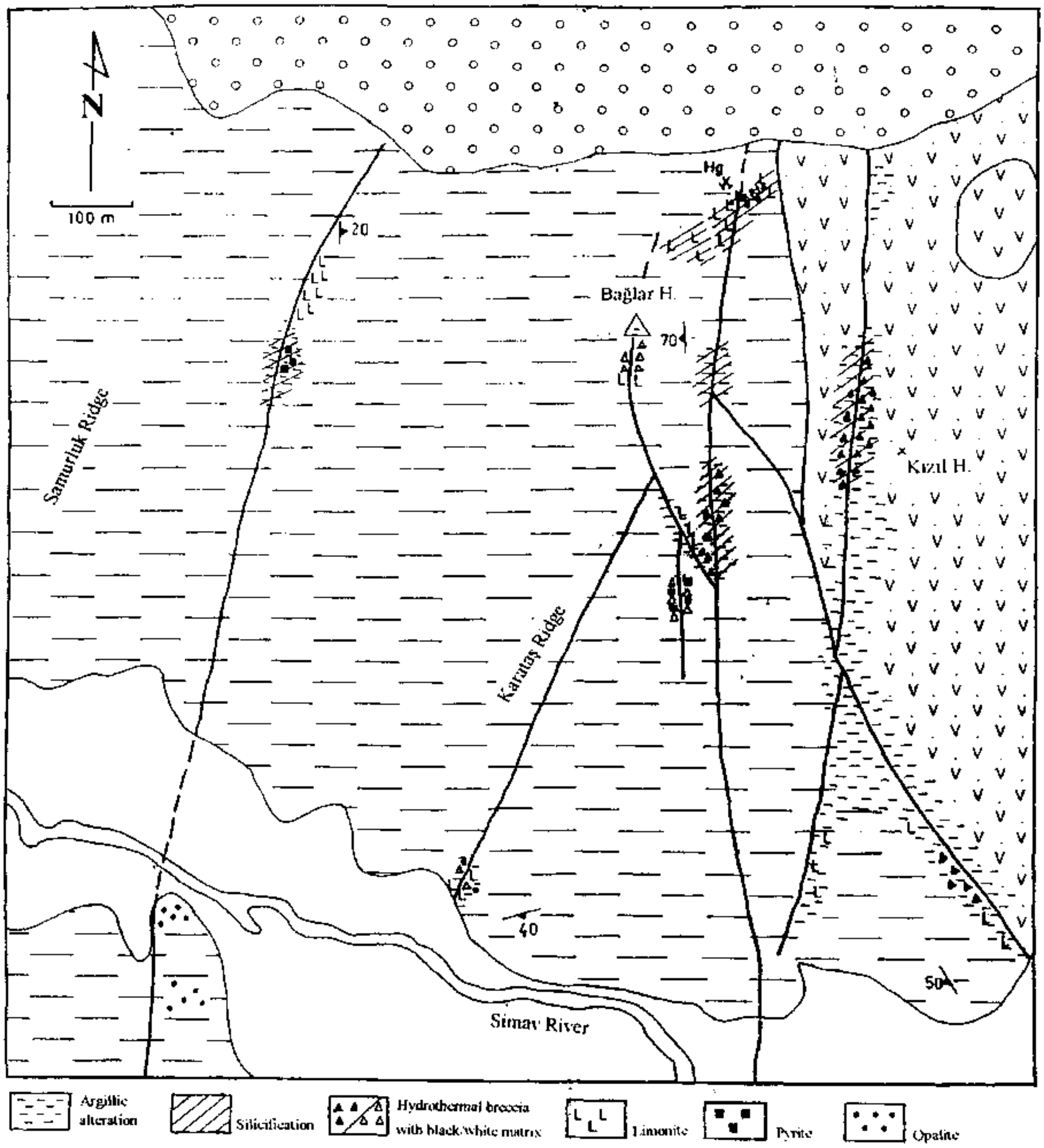

Fig. 3- Geological map of the Mumcu epithermal mineralisation. Explanations of the rocks in Figure 2.

White opaline coatings are observed on the fissure surfaces of the tuffs along the strongly argillized fault forming the boundary between the tuffs and metamorphics. In addition, the rocks in this part are also intensively silicified and brecciated. The breccia at the tuff side is formed by angular volcanic fragments in a silica matrix also some black silica veinlets. However, it is cemented by limonite and crossed by fine quartz veinlets at the schists side. The matrix of the breccia is white at Bağlar Hill and Karataş Ridge.

Pyrites are widespread, and quartz with drusy texture which is characteristics for an epithermal mineralization is observed along the faults at Samurluk and Karataş ridges. Idiomorphic honey-colored quartz crystals developed on the walls of the drusy cavities. Kaolinization and limonization are observed near the Simav river where these faults cut the Toklargölü Formation.

Strong limonization ad pyritization along the fault and bleaching in the host rock are observed at the west of the Bağlar Hill. Vuggy texture is developed in the limonitized parts. Intensive opalization is seen on the continuation of this fault at the south of the Simv river.

Intensive and pervasive jasperoid formation related to the marble levels in the schists of the Sarıcasu Formation is seen on the Kadiruçtu and Ballık hills, at the west of the mineralization area. Colored opal is partly observed in the rock and on the fissure surfaces. Colloform pyrite as black bands, and fine veinlets of limenite-hematite are dominant at the some parts of the rock.

Opalite occurs in an intensively limonitized part of the schists, on the northward continuation of the tectonic zone, at the northern slope of the Bağlar Hill. Opalite in various tones of black, green mineralization was formed in opalite, and spread along the fissures within the rock. Arsenopyrite and electrum (?) are associated with the cinnabar. A gold silver with the length of 5-7 micron and the width of 2-3 micron is seen in this part. The gold content of the Bağlar Hill opalite is 50 ppb. and of the pyrite zone, at the west. 340 ppb. The geochemical analyses of the mineralization is given in Table 1.

By considering all of these data, the mercury-bearing opalite represents the top most uneroded level of an epithermal gold mineralization (Clarke and Govett, 1990: Rytuba and Heropoulos. 1992). According to the mineralogical zoning seen in art epithermal system, it is quite possible that the bonanza zone dominated by gold is situated in the deeper levels.

DISCUSSION

A genetic model constructed to explain the Mumcu epithermal system is illustrated in Fig. 4, It was accepted that the mechanism of the system is comparable to the model proposed by Henley (1985).

The field evidence of the buried porphyry stock, which was the engine of the epithermal system to provide the heat to drive the hydrothermal circulation cell as stated by Henley and Ellis (1983) is the Derecikören granite at the north of the studied area. Skarns including base metals occur on the borders of this granitoid and a pophyry with pyrite, limonite and stockwork quartz veins crop outs at the north of the village. The presence of a hydrothermal quartz vein rich in Au (3.8 gr/t) and Ag (270 gr/t) within the schists, located Karacalar between the Derecikören granite and the Mumcu epithermal system may be evidence for an ore-bearing system. Some mineralized porphyry systems occur also along the Simav Graben fault at the east of the studied area and at the southeast of Gediz town.

The hot, acidic, low-density fluids rich in magmatic volatiles were produced related to the late phases during the cooling of a granitic stock (Sillitoe and Lorson, 1994). The ascended and condensed, and mixed with meteroic water at the shallower epithermal levels to generate the highly reactive and corrosive fluids involved in the generation of the gold-and silver-bearing and sulfide replacement bodies and the overlying quartz-alunite alteration (Henley, 1985). Chromite and magnetite observed within the opalite suggest that these solutions silicified metaultramafic/mafic bands within the schists.

These acidic fluids moved along the transfer faults to the parts suitable for the deposition and started to boil at the shallower levels where the pressure was between hydrostatic and lithostatic (Reed and Spycher, 1985). Thus, the decrease in the temperature of the fluid and the increase in pH resulted in the formation of the epithermal mineralization. On account of the low-contents of Sb.As.Ag and Au in cinnabar, it is suggested that the mercury can be transported in a vapor phase and deposited as cinnabar at the surface or near-surface environment, below the ground-water table (Rytuba and Heropoulos, 1992).

The water vapor and acidic gases (H_2S, SO_2, HCl) liberated during the boiling process con-

Table 1. Geochemical analyses of the Mumcu mineralization (values are in ppm: in % if bold).

LOCATION	Cu	Pb	Zn	As	Sb	Au	Hg	Mo	Ag
Bağlar Hill	49	23	10	20	>600	0.5	200	-	-
Samurluk Ridge	45	26	25	100	<4	0.34	0.2	20	-
Samurluk Ridge				<2	7	0.04	0.1	3	-
Karataş Ridge				<2	5	0.04	2.0	3	-
Bağlar Hill	68	44	84	275	<4	0.60		10	1.0
Karacalar vein	>1000	116	1000	>1000	>600	3			270
" "	%1.82	%8.58	%11.90	%0.16	%0.11	2.95			392

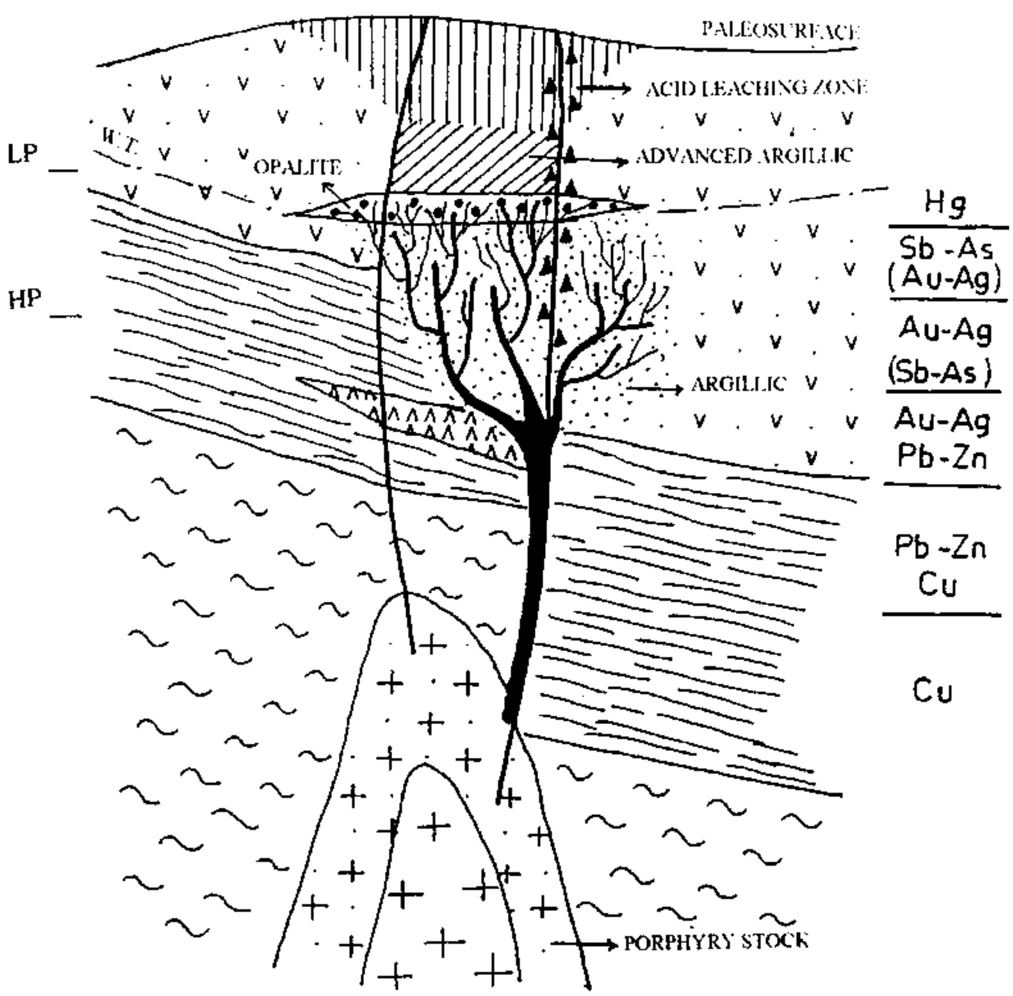

Figure 4- Genetic model of the Mumcu epithermal system.

densed into the cold water below the ground-water table, and formed argillic alteration (Henley, 1985). Alunite-, dickite- and cristobalite-bearing kaolins at the Döküş Hill represent the quartz-alunite and acid-leaching zones of advanced argillic alteration which have been eroded at the Bağlar. Cristobalite and opal indicate the surfical zone of such an alteration (Sillitoe and Lorson, 1994). The quartz-alunite zone was formed along the faults below the acid-leached cap.

The temperature of the hydrothermal solutions rapidly decreased by mixing with the cold meteoric water and opal precipitated instead of quartz (Fournier, 1985a). The lateral flow of the fluids due to the enhanced permeability of the host-rock, formed roughly stratabound opalite horizons. Hg-bearing opalite covers gold-bearing quartz sulfide veins.

The step-like, narrow, fault-localized, chalcedonic quartz ledges are supposed to be the feeders for the quartz sulfide bodies. The hydrothermal breccias with black silica veinlets at these parts are likely the upward projections of such feeders. It is suggested that the vuggy chalcedonic quartz was produced by hypogene leaching of all principal rock components, except for part of the silica, under highly acidic (pH<2) (Stoffregen, 1987).

Overpressure on the hydrothermal fluids, as a result of their accumulation beneath impermeable silicified tuff caused hydraulic fracturing and explosions forming the hydrothermal breccias (Hedenquist and Henley, 1985). The black matrix-should have been emplaced with or after the ore deposition (Sillitoe and Lorson, 1994). In contrast, white matrix breccia is believed to have been emplaced before most of the metals were deposited.

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