



## Using Various Tree's Leaves in Prospection of the Auriferous Quartz Veins and Sulphide Lodes (Hatay-Southern Turkey)

### Çeşitli Bitki Yapraklarının Altın İçeren Kuvars ve Sülfür Damarlarının Prospeksiyonunda Kullanılması

Doğan AYDAL University of Ankara, Faculty of Sciences, Department of Geology, 06100 Beşevler, Ankara  
(e-mail: aydal@science.ankara.edu.tr)

#### Abstract

This investigation is concerned with the effect of mineral content of soil to the tree leaves in Kisecek village and its surroundings located 11 km NW of the city of Hatay.

The leaves of *Platanus orientalis*, *Albizia andersonii*, *Alnus glutinosa*, *Salix alba*, *Cistus creticus*, *Phillyrea latifolia*, *Pistacia lentissima*, *Quercus infectoria* and *Quercus coccinea* were chosen for the study and 50 elements were analysed for 23 samples in the study area.

The average values of the As, Zn, S, Au, Ag, Cd, Co, P, Na, K, Sb, Se, Y, Mn, Cl and Ni were determined to be higher in the leaves of the trees having direct contact with the auriferous quartz veins and sulphide lodes.

On the other hand, the mentioned trees in the vitreous area away from the auriferous quartz veins and sulphide lodes were found to be enriched in Mg, Ni, Fe, Mn, Co, Ba, Sr, Ca, Ba, Al, U, Pr and Cr.

The mean value of the Te, U, Sm and Dy were detected almost the same in the trees in the both areas.

Finally, U, Th, V, La, Y, W, Ti, Ua, Th, Hb, Ho, Tm, Yb and Lu values of the leaves could not have been determined due to the low level of these elements.

As a result, some of the trees such as *Cistus creticus* and *Salix alba* were noticed to be the most sensitive trees affected by the soil. Pb, Ni, Co, Mn, Fe, Cd, Bi, P, Cr, Al, Zn, Ga, V, Ce, Pr, Nd, Sm, Gd and Dy content of *Cistus creticus* is higher than the rest. On the other hand *Salix alba* is higher in Mo, Zn, Ca, Mg, Se, S (in mining area) and Co, Mn and Cd (in non mining area).

This result suggests that leaves can be used as indicator for the auriferous quartz veins and sulphide lodes.

**Key Words:** Geobotanic, gold, silver, leaves

#### Öz

*Hatay ili merkezine 11 km uzaklıktaki bulunan Kisecek köyü ve çevresinde, alıver ve çınarlı alanlar ile altın damarlarının bulunduğu bölgede, Çınar, Samsun, Keşan, Sığirci, Pınar, Sakızlı, Çiftlik, Karapınar ve Faltı gibi 9 bitki türünden 23 yaprak örneği alınarak 50 element üzerine yapılan çalışmada, bitkilerin, bulunduğu bölgedeki minerallerle doğrudan temas eden ağaç türleri arasında (Şekil 1).*

*Altın içeren sülfür ve kuvars damarları ile doğrudan temas halinde ağaç yapraklarındaki ortamlara As, Zn, S, Au, Ag, Cd, Co, P, Na, K, Sb, Se, Y, Mn, Cl ve Ni değerlerinin, sülfür olduğu belirlenmiştir. Diğer taraftan, bu damarlar ile uzakta ve vitreöz alan bölgelerdeki bitki türleri ise aynı bitkilerin yapraklarında Mg, Ni, Fe, Mn, Co, Cr, Ba, Sr, Ca, Ba, Al, Bi ve Ce bulunmadığı tespit edilmiştir. Yapraklarında Te, Ga, Sm ve Dy değerlerinde ise her iki bölgede aynı değerlerde olduğu ve U, Th, V, La, Y, W, Ti, Ua, Th, Hb, Ho, Tm, Yb ve Lu değerlerinde ise vitreöz alanlar çok düşük seviyelerde belirlenmiştir.*

*Çınar, alıver ve Sığirci bitkilerinde atarsından en çok yüksek miktarla olduğu belirlenmiştir. Pb, Co, Mn, Fe, Cd, Bi, P, Cr, Al, Ni, Ga, V, Ce, Pr, Nd, Sm, Gd ve Dy miktarları Çınar bitkilerinde diğerlerine oranla daha fazla olduğu, bunun yanında Mn, Zn, Ca, Mg ve Se ise damarların bulunduğu bölgede, Co, Mn, ve Cd'in bulunduğu bölgedeki Sığirci ağaçlarında tespit edilmiştir.*

*Çınar olarak, yaprakları, alıver alanlar kuvars damarları ile altın damarlarına yerleşen bitkilerden biri olarak diğer bitki türlerinden farklı olarak belirlenmiştir.*

**Anahtar Kelimeler:** Jeobotanik, altın, çınar, ağaç yaprakları

#### INTRODUCTION

As it has been pointed out earlier, plants can be used either as geobotanical indicators which reveal mineral anomalies by their presence or absence "Cannon (1960), Viktorov and others (1964), Malyyuga (1964), Bronka (1972), Gieling and others (1979)" in prospecting for economically important minerals.

This paper reports the results of a biochemical investigation for gold bearing sulphide mineralization in an area of 25 sq. km around Kisecek village, city of Hatay, Turkey.

Plant gold concentration usually occur in the ppb range on a dry weight basis, even in anomalous areas (Jones, 1970). This makes analysis of a plant material for gold difficult and explains why the use of plants as indicators of gold mineralization has

Whole rock and REE analysis of the rocks, auriferous quartz veins and sulphide veins was made by ACME. For the analysis 0.2 g of the samples were fused with 1.5 g of  $\text{LiBO}_2$  and then dissolved in 100 ml 5%  $\text{HNO}_3$ . ICP/MS was used for the determination of Mo, Cu, Pb, Zn, Ni, As, Cd and Sb. For analysis, 0.5 gr sample is digested with 3 ml 2-2-2 HCl- $\text{HNO}_3$ - $\text{H}_2\text{O}$  at 95 degree and then diluted to 10 ml with water. Gold and Ag analysis were made by ICP/ES & MS in ACME-Canada, Meda Steel- Belgium and M.T.A. (Mineral Research and Exploration General Directorate of Turkey) in order to examine the reproducibility or accuracy of the results in the samples.

Chemical analyses of the leaf samples are given as "Table 1".

The geochemical analysis of diabasic dykes, gabbros are given in "Table 2", while the geochemical analysis of gold bearing quartz veins and sulphide lodes are summarized in "Table 3".

Some selected cross-examination graphics were prepared and shown as element versus element graphics in order to show the differences and/or similarities of the chemistry of the leaves in the mineralised and non-mineralised areas "Figure 1".

## RESULTS AND DISCUSSION

The mean value of As was 3.57 ppm in the mining area, whereas the mean value of As was 0.656 ppm in the trees having no direct contact with any of the auriferous quartz veins or sulphide lodes. The average value of Zn in both areas were determined (33.6-22.4) respectively, whilst for S (0.160-0.121%), Au (1.86-1.63 ppb), Ag (9.8-7.42 ppb), Cd (0.128-0.066 ppm), Cu (0.386-0.271 ppm), P (0.088-0.074 %), Na (0.018-0.0093 %), K (0.60-0.57%), Se (0.206-0.128 ppm), Y (0.087-0.060 ppm), Mn (118-106 ppm), Ba (3.26-3.15 ppm), Cd (0.026-0.013 ppm), Nd (0.069-0.038 ppm) and Sb (0.05-0.038 ppm).

The mean value of Mg in the leaves of the trees in the non-mineralised and mineralised areas were found 0.422 %, and 0.342 % respectively. The average value of Ni in the non-mining and mining areas were determined to be (15.21-4.31 ppm), Fe (0.057-0.027 %), Mo (0.031-0.027 ppm), Cr (1.36-0.85 ppm), B (33.0-25.9 ppm), Sr (21.63-21.02 ppm), Ba (3.47-3.26 ppm), Ca (1.01-0.93%), Al (0.033-0.021 %), Bi (0.036-0.032 ppm) and Co (0.134 -0.116 ppm).

Pahlsson (1989) and Steffens (1990) showed that Cu, Pb, Cd and Hg enrichments in trees are

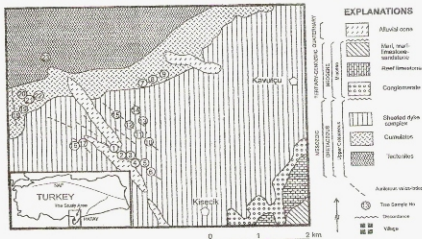


Figure 1: Simplified geological map and sample location in the study area  
Şekil 1: Çalışma alanının basitleştirilmiş jeolojik haritası ve numune lokasyonları

not been commonly considered.

The geochemical relationship between gold and arsenic in epithermal deposits has been established by various workers "Boyle and Jonasson (1973), Girding and others (1978), Warren and others (1964), Friedman and Olson (1985)".

In this study the potential use of arsenic and 48 other elements as a pathfinder for gold in this area were examined. Furthermore, the geochemical analyses of the host rocks were examined also to study the effect of chemical composition of the rocks-soil to the studied trees.

#### LOCATION AND GEOLOGY OF THE STUDY AREA

The study area is located 11 km NW of the city Hatay in Southern Turkey.

The general geology has been described by various authors and as well as by the present author. One area that has received considerable attention is the Kizilirmak Ophiolitic complex in the Southern Turkey. Erickson (1940), Wijkerslooth (1942), Romieux (1942), Dubertret (1953), Molly (1955), Vuagnat and Coğulu (1967), Aslaner (1973), Coğulu (1973), (1974), Delaloye and others (1980), Selçuk (1981), Alpan (1985), Tekeli and Erendil (1986), Aydal (1989), Piskin and others (1990) and Çağatay and others (1991) are some to be mentioned.

These workers identified six different rock units within the ophiolitic complex; tectonites, poikilitic zone, cumulates (ultramafic and mafic types), diabase dykes (as a sheeted complex), pillow lavas and volcano sedimentary rocks.

At the present study area the predominant rocks are mainly sheeted diabasic dykes, tectonites, gabbros and pillow lavas are in lesser amount.

Especially diabasic dykes and gabbros are cut by numerous auriferous sulphide lodes and quartz veins, most of which have considerable amount of microdimensional gold and silver. The mineralised zone lies between 450 and 650 meters elevation. Arsenopyrite, sphalerite, chalcopyrite and pyrite are the most abundant sulphide minerals in quartz veins and lodes.

#### PLANTS SPECIES AND SAMPLING

##### PROCEDURE

Nine species were chosen and 15 samples were collected from the study area. Besides, 8 additional samples were collected from an adjacent area in order to examine the variation of especially As, Zn, Cu, Fe and as well as Au and Ag concentrations in the study area. The last 8 samples were collected from a comparable topographic area nearby, where earlier geochemical studies indicated absence of gold anomalies.

The species collected from the lower area were *Planatus orientalis*, *Arbutus andrachne*, *Alnus glutinosa* and *Salix alba*, in the deep rooted perennials. On the other hand, relatively shallow rooted *Philyrea latifolia*, *Pistacia lentiscus*, *Quercus infectoria*, *Quercus coccifera* and *Cistus creticus* were collected from the relatively higher elevation at the study area.

All of the species are reasonable widespread not only in the study area but also in Southern and Western part of Turkey. In the mineralised area plant samplings were carried out especially over areas of silicified argillite and sulphide veins and from the plants on the diabase dykes, gabbros and tectonites in non-mineralised area.

Because of the soil contamination root samples were not preferred and approximately 100 gr of leaf samples were collected from each species. The samples were washed and dead material were removed prior of oven drying at 80°-100°C for 12-24 hours depending up on the leaf thicknesses.

#### ANALYTICAL PROCEDURE AND GEOCHEMISTRY

All dried leaf samples were packed in double nylon bags and send to Canada- ACME Laboratories, which has ISO 9002 certificate for chemical analysis.

The samples were pulverized and prepared for the analysis by the ACME staff. According to the given report, 30 g of sample were dissolved for each determination in 180 ml 2-2-2 HCl-HNO<sub>3</sub>-H<sub>2</sub>O at 95 degree C for one hour and is diluted to 600 ml. Analysis made by ICP/ES and MS. for 50 elements.



Ag Various Tree's Leaves in Prospection of the Auriferous Quartz Veins

Table 2: The geochemical analyses of the diabasic dykes and gabbros.

Çizelge 2: Diyabaz daylakları ile gabbroların kimyasal analizleri.

Diabasic Dykes (Have a direct contact with auriferous lodes-veins)		Diabasic Dykes (Have no direct contact with auriferous lodes-veins)		Gabbros (Have contact with auriferous lodes-veins)		Gabbros (Have no contact with any auriferous lodes-veins)	
X (n=6) range		X (n=6) range		X (n=6) range		X (n=5) range	
SiO <sub>2</sub>	50.02 (43.6-54.68)	52.49 (48.70-54.0)	47.05 (41.41-49.47)	48.08 (46.73-49.03)			
MgO	19.0 (17.07-17.21)	8.84 (8.02-12.80)	9.85 (8.002-10.629)	9.62 (8.66-11.05)			
CaO	2.40 (0.09-4.70)	7.42 (5.50-8.50)	11.205 (8.04-11.205)	11.06 (8.03-12.07)			
Fe <sub>2</sub> O <sub>3</sub>	9.98 (6.69-11.15)	8.81 (8.20-10.0)	5.75 (5.2-6.43)	7.34 (4.43-8.36)			
K <sub>2</sub> O	0.257 (0.18-0.299)	0.358 (n.d.-0.84)	0.249 (0.206-0.302)	0.25 (0.17-0.315)			
Na <sub>2</sub> O	1.45 (1.29-1.46)	2.83 (1.78-3.85)	1.105 (1.12-1.21)	1.50 (1.03-2.09)			
TiO <sub>2</sub>	0.61 (0.36-0.887)	0.55 (0.24-0.99)	0.313 (0.293-0.333)	0.30 (0.28-0.323)			
Al <sub>2</sub> O <sub>3</sub>	14.38 (13.30-15.58)	15.916 (13.0-15.50)	12.91 (14.50-17.95)	17.16 (16.91-18.33)			
MnO	0.154 (0.054-0.235)	0.11 (0.05-0.18)	0.087 (0.05)-0.1)	0.11 (0.09-0.14)			
As	0.836 (0.239-0.105)	0.092 (0.07-0.105)	0.250 (0.184-0.305)	0.008 (n.d.-0.01)			
Zn	0.123 (0.080-0.212)	0.089 (0.070-0.11)	0.066 (0.031-0.082)	n.d.			
Co	0.11 (0.070-0.223)	0.078 (0.04-0.098)	0.006 (0.001-0.010)	n.d.			
Pb	0.272 (n.d.-1.707)	0.226 (0.117-0.332)	0.002 (0.001-0.008)	0.013 (0.006-0.018)			
Ni	0.132 (0.033-0.253)	0.04 (0.00-0.016)	0.024 (0.013-0.032)	0.05 (0.04-0.065)			
Cr	0.295 (0.078-0.803)	0.10 (0.07-0.12)	0.85 (0.042-0.12)	0.15 (0.062-0.167)			
Cu	8.89 (6.77-11.02)	3.91 (2.82-4.37)	8.63 (4.12-12.31)	7.42 (1.66-10.18)			
Total:	99.47	101.601	100.436	99.591			

closely related with the flora metabolism system and might cause poisoning. Nevertheless, it was noticed that copper was especially preferred by small sized trees such as *C. creticus*, *P. latifolia* and *Q. infectoria*, whereas lead especially was preferred by *Q. infectoria* and *C. creticus*. Furthermore, Cu and Pb were determined to be preferred by relatively higher trees such as *P. orientalis*, *S. alba* and *A. andrachne*. Their contents are particularly more in the non-mineralised area.

Relatively higher values of Pb, Ni, Co, Mn, Fe, Au, Bi, P, Cr, Al, Na, Ga, Y, Ce, Pr, Nd, Sm, Gd and Dy were determined in mineralised areas especially in the *C. creticus*, which is the smallest plant among the studied plants. The highest values of Mo, Zn, Co, Mn, Cd, Ca, Mg, Se and S were determined in *S. alba*.

According to these results it can be easily said that accumulation of gold and other elements in the leaves has no positive correlation with the size of the trees and the depth of the roots.

According to Pahlsson's (1989) study in Sweden, Cu and Pb appear to be accumulated in the roots and the contents in the leaves remain at the normal level until the roots are saturated.

Most probably because of this reason, the deep rooted tree's leaves in the mineralised area such as *P. orientalis* (Cu, Ag, K, Cd, Ca, Sr), *A. andrachne* (Cu, Mo, Mn, Ca, Na, Sr, Se, B), *A. glutinosa* (Au, Cu, Ag, S, Mo, Cd) and *S. alba* (Au, Cu, Ag, Mo,

Mn, Y, B) were found to be poorer in some elements, which are shown in brackets.

Some selected element's normal levels of the leaves and their comparison with the studied leaves in the mineralised and non-mineralised areas are shown in "Table 4".

According to these values, it can be easily stated that the leaves were enriched in Zn, As, Cu, Mn, Ca, Mg, S, Al, Cr, Co, Ni and Se, whereas the level of the Fe, K, P, Na values were found to be decreased if they are compared with the mean values of the relevant elements given by Finck (1969).

Significant positive correlation was detected between As-Mn, Fe-Co, Mn-Co, Mn-Pb, As-Pb, Zn-Co and Mn-Fe. Correlation coefficients of some selected elements are shown in "Table 5". Furthermore, reasonably high positive correlation especially between the concentration of gold and arsenic was detected. Plants containing high "As" concentrations were found generally to have relatively higher levels of gold. In other words, "As" can probably be used in some circumstances in biogeochemical prospecting to locate the area of gold anomaly in the study area.

The concentration and interrelation of As, Zn, Cu, Fe, Pb, Mn in relation with Au in mineralised and non-mineralised areas are given in "Figure 2".

Some peculiarities were detected during the

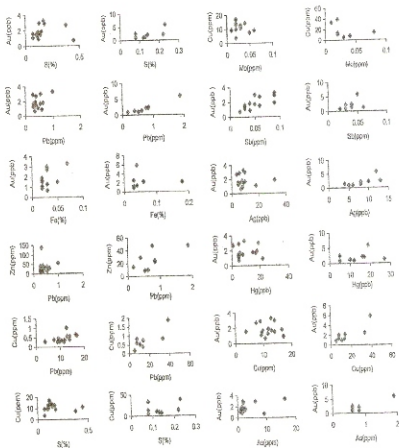


Figure 2: Graphical illustration of the concentration and interrelation of As, Zn, Cu, Fe, Pb, Mn and their relation with Au. The first graphic always represents mineralized zone, whilst the second always represents non-mineralized area as used same couple-elements for graphics.

Şekil 2: As, Zn, Cu, Fe, Pb, Mn konsantrasyonlarının birbirleri ile ve altın konsantrasyonu ile ilişkilerini gösteren grafikler. Aynı elementler ile oluşturulan grafiklerin ilki mineralleşmiş zonu, ikinci mineralleşmemiş zonu temsil etmektedir.

## Using Various Tree's Leaves In Prospection of the Auriferous Quartz Veins

Table 3: The geochemical analyses of the auriferous quartz veins and sulphide lodes.

*Çizelge 3: Altın içeren kuvarz damarları ile sülfid damarlarının kimyasal analizleri.*

	Gold bearing quartz veins (Au) Range	Sulphide veins in Tailings Range	Gold bearing quartz veins in pit Range
SiO <sub>2</sub>	75.08 (81.84-81.02)	61.62 (58.17-66.06)	85.38 (71.52-89.61)
FeO	0.20 (0.4-0.20)	0.71 (0.1-1.01)	0.51 (0.4-0.51)
CaO	0.80 (0.4-0.80)	0.21 (0.4-0.40)	0.26 (0.4-0.90)
MgO	4.45 (1.15-5.75)	20.20 (15.3-25.2)	4.42 (2.2-5.97)
PbO	0.22 (0.10-0.30)	0.10 (0.10-0.10)	0.38 (0.10-0.70)
ZnO	0.38 (0.4-0.51)	0.22 (0.4-0.70)	0.09 (0.4-0.20)
Al <sub>2</sub> O <sub>3</sub>	0.88 (0.4-0.88)	0.83 (0.96-0.96)	0.05 (0.8-0.96)
Na <sub>2</sub> O	1.75 (0.80-1.62)	4.54 (3.2-7.2)	1.21 (0.3-1.80)
K <sub>2</sub> O	1.00 (0.10-1.10)	11.62 (0.1-10.0)	0.71 (0.1-1.11)
Cl	0.14 (0.09-0.10)	0.20 (0.20-0.30)	0.11 (0.09-0.20)
Cr	0.28 (0.19-0.30)	2.00 (0.2-0.30)	0.16 (0.07-0.20)
Co	0.20 (0.4-0.20)	0.1 (0.4-0.20)	0.10 (0.09-1.00)
Ni	0.42 (0.4-0.30)	0.1 (0.4-0.20)	0.05 (0.1-0.10)
Mn	0.00 (0.00-0.20)	0.07 (0.04-0.2)	0.03 (0.00-0.00)
Sr	0.00 (0.4-0.01)	0.06 (0.00-0.05)	0.00 (0.00-0.00)
Li	0.01 (0.1-0.01)	0.06 (0.1-0.01)	0.01 (0.0-0.01)
Ag	0.00 (0.0-0.00)	0.04 (0.1-0.01)	0.00 (0.0-0.00)
As	0.00 (0.0-0.00)	0.00 (0.0-0.00)	0.00 (0.0-0.00)
Bi	0.00 (0.0-0.00)	0.00 (0.0-0.00)	0.00 (0.0-0.00)
Te	0.00 (0.0-0.00)	0.00 (0.0-0.00)	0.00 (0.0-0.00)
Se	0.00 (0.0-0.00)	0.00 (0.0-0.00)	0.00 (0.0-0.00)
Mo	0.00 (0.0-0.00)	0.00 (0.0-0.00)	0.00 (0.0-0.00)
U	0.00 (0.0-0.00)	0.00 (0.0-0.00)	0.00 (0.0-0.00)
Th	0.00 (0.0-0.00)	0.00 (0.0-0.00)	0.00 (0.0-0.00)
Sum	100.00	100.00	100.00
Average	6.50	6.40	6.77

comparison of the chemistry of the leaves in gold bearing veins and rock analyses. Some elements, such as Mn, Co, Pb, Ni and Sr were found in small concentrations in the studied veins and rocks, but somehow the analysis of the leaves showed that these elements appeared to be comparatively and unexpectedly high in concentration in the studied leaves. For instance the Mn levels in gold bearing sulphide veins and quartz veins are very low and range between 100-3000 ppm, whereas the Mn values in the leaves vary between 23-516 ppm.

In the same sense, the Co values in the veins and rocks vary between (3.7-52.2 ppm), Pb (7-2162 ppm), Ni (9-290 ppm), Sr (1.4-150 ppm), whereas the values changes in the leaves (0.2-6.5 ppm), (0.28-1.88 ppm), (0.9- 51.5 ppm) and (4.3-67.6) respectively.

Petelman (1967) and Rose and others (1979) pointed out that Mn, Ni, Pb and Co are slightly mobile ( $K$ =Mobility coefficient=0.1-1) elements in water under oxidising condition (pH=5-8). But these elements become moderately mobile and naturally the uptake by some plants will be much stronger, if the oxidising condition becomes more acidic (pH < 4). Because of this reason, it can be stated, that the condition should have been strongly acidic during the uptake process of the relevant plants in the study area.

On the contrary, some elements such as Fe and Al, which are normally in high concentration in

the rocks and veins found to be very low in concentrations in the studied leaves.

The reason for these peculiarities have not been well understood yet, but most probably it is related with the low solubility of the phytochelates, thus plants simply uptake some elements easier than the others. According to Rose and others (1979), these elements considered to be immobile ( $K < 0.1$ ).

The function of the elements are not always clearly defined by the authors and there are many controversies between the relevant statements, but generally it is said that, Cd, Pb, Zn, Sb, Ag, Ni, Hg, Cu, Sn, Au, Bi, Fe and W all induce phytochelates. According to Grill and others (Grill and others, 1987), among the common metals, Cd is the strongest inducer, whereas Zn appears to be weak requiring very high level for induction. On the other hand, Pahlsson (1989) stated that Zn and Cu are essential elements for higher plants and are involved in several metabolic processes, whereas Pb and Cd are not known to have any function in plants. Heavy metals such as Zn and Cu are required by biological systems as structural and catalytic components of proteins and enzymes, and as co-factors essential to normal growth and development. In excess, these micronutrients and related heavy metals such as Cd, Hg, Ni and Pb became extremely toxic to cells (Steffens, 1990). These heavy metal-binding polypeptides are known as phytochelates. The role of phytochelates in plant metal tolerance has been the subject of several recent review (Rausser (1990), Robinson and Jackson (1986), Robinson (1990), Tomsett and Thurman (1988)).

Rennenberg (1987) pointed out that phytochelates play a central role in the detoxification of excess metals.

Many more studies can be given as references but so far no study was found to solve all problems related with the metallic element uptake regime of the studied plants.

According to Pahlsson (1989), present knowledge is not enough to propose a limit for normal and toxic concentration of Zn, Cu, Cd, Pb and other elements in the plants.

- Most tree species have mycorrhiza which at

**Table 4:** Some selected element's normal level in the leaves and their comparison with the studied leaves in mineralised and non-mineralised areas. The capital letters in brackets represent the species, which have the highest and the lowest concentrations. For instance Po stands for *P. orientalis*. Normal level of the elements were taken from Finck (1969).

*Çizelge 4:* Bazı seçilmiş elementlerin yapraklardaki normal değerleri ve bu değerlerin belirli ve belirsiz, bölgeledeki örnek değerleri ile karşılaştırılması. Parvanes içindeki lilyük baklar en yüksek ve en düşük konsantrasyona sahip türü temsil etmektedir. Örneğin Po, *P. Orientalis* anlamındadır. Elementlere ait normal değerler Finck (1969)' dan alınmıştır.

	In Leaves (Finck, 1969) (mean values in brackets)	Mineralised Area			Non-mineralised Area		
		Min	Max	$\bar{x}$	Min	Max	$\bar{x}$
Zn	10-100 (30) ppm	12.5 (Po)	134 (Gd)	33.36	9.1 (Po)	41.1 (Ba)	25.54
As	0.1-0.5 ppm	0.9 (Aa)	16.4 (Ca)	3.57	0.6 (Aa)	1.9 (Aa)	0.656
Cu	2-40 (9) ppm	3.8 (Aa)	17.23 (Dd)	11.437	3.2 (Aa)	53.36 (Aa)	13.154
Fe	50-1500 (50) ppm	23 (Aa)	59 (Aa)	27.5	30 (Aa)	180 (Aa)	55
Mn	20-200 (40) ppm	32 (Aa)	516 (Ca)	318	17 (Po)	450 (Ca)	302.6
K	0.5-5 (2.5) %	0.37 (Po)	1.09 (Po)	0.5	0.42 (Po)	0.86 (Po)	0.57
Ca	0.05-5 (1) %	0.67 (Ca)	1.57 (Ca)	0.95	0.54 (Ca)	1.21 (Ca)	0.95
Mg	0.1-1 (0.2) %	0.24 (Po)	0.51 (Ba, Ag)	0.363	0.12 (Po)	0.75 (Ba)	0.432
S	0.05-0.5 (0.2) %	0.07 (Po)	0.45 (Ca)	0.16	0.09 (Po)	0.23 (Aa)	0.121
P	0.1-0.5 (0.1) %	0.06 (Dd)	0.129 (Ca)	0.08	0.057 (Ca)	0.094 (Aa)	0.076
Na	500-3000 ppm	40 (Dd)	1540 (Ca)	317	40 (Ba)	260 (Ca)	90
Al	20-50 ppm	100	500 (Ca)	206	100 (Gd)	600 (Ca)	323
Cr	0.1-1 ppm	<0.1	3.4 (Ca)	0.655	<0.5	37 (Ca)	1.597
Co	0.03-0.5 ppm	0.1 (Aa)	2.1 (Ca)	0.366	0.2 (Ca)	6.3 (Ca)	0.375
Ni	0.1-3 ppm	0.9 (Aa)	15.3 (Po)	4.31	1.5 (Ca)	51.5 (Ca)	14.16
Se	0.1 ppm	<0.1	0.6 (Ba)	0.266	<0.1	0.2 (Ba)	0.137
Sr	10-100 ppm	4.3 (Po)	51.3 (Po)	21.62	6.7 (Ca)	67.6 (Aa)	21.62

least at lower concentration can protect the root from taking up heavy metals.

- Some elements appeared to be accumulated in the roots and the contents in the leaves at a normal level until the roots are saturated.

- Absence of mycorrhiza may increase the metal uptake and thus the risks of the root injury.

- External condition such as drought and parasitic attacks may effect the mineral uptake regime of the trees.

Furthermore the water content of the soil is found to be very important for the "uptake" of heavy metal elements. As known, plants will uptake copper as  $\text{Cu}^{+2}$ , Mn as  $\text{Mn}^{+2}$  and Fe, as  $\text{Fe}^{+2}$ . Wherever water occupies all of the porosities in the soil (stream environment and heavy rain areas), the amount of oxygen in the soil decreases and under this reduced condition plants may uptake more heavy metals. Probably because of this reason, the leaves of the *S. alba* have the highest amount of Mo, Zn, Co, Mn, Cd, Mg and Se in non-

mineralised areas "Kaçar and Kafkat (1999); and personal communication with Prof. Dr. Rifat Yalçın".

The analyses of the RLL in the leaves were not found to be useful for comparison, just because one has no chance to normalize these determined values with anything. Nevertheless, the highest values of Y, Ce, Pr, Nd, Sm and Dy were determined in the *C. creticus*, which is the smallest and shallow rooted plant among the studied plants.

## CONCLUSIONS

Biochemical and Geochemical data have shown that plant metallic element concentration correlate strongly with the soil element concentrations with some exceptions. As a matter of fact, besides total metallic element content, many factors concerning plant and soil, such as injury of roots, draft, pollution may influence the total metallic element content of plant's leaf.

As it was pointed out earlier that, some of the

Table 5: The correlation coefficient of some selected elements from the studied leaf samples.

Çizelge 5: Çalışılan yapraklardaki bazı seçilmiş elementlerin korelasyon katsayıları.

	Au (ppb)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ni (ppm)	Co (ppm)	Mn (ppm)	Fe (%)	As (ppm)	Sr (ppm)	Sb (ppm)
Au (ppb)	1										
Cu (ppm)	-0,0673	1									
Pb (ppm)	0,39594	0,54283	1								
Zn (ppm)	-0,4491	0,0739	0,06168	1							
Ni (ppm)	0,03421	0,08804	-0,1793	-0,0326	1						
Co (ppm)	0,41202	0,2571	0,73379	0,2971	0,2223	1					
Mn (ppm)	0,24915	0,51428	0,64532	0,28371	-0,0307	0,79914	1				
Fe (%)	0,48454	0,15974	0,55197	0,26098	0,2217	0,92842	0,62068	1			
As (ppm)	0,39725	0,02617	0,53236	0,052157	-0,027	0,8411	0,69285	0,79092	1		
Sr (ppm)	-0,2073	-0,0661	-0,0642	-0,03861	-0,3444	-0,2284	-0,30885	-0,422	-0,2852	1	
Sb (ppm)	0,73363	-0,0283	0,27264	-0,41364	0,0938	0,3754	0,25016	0,28433	0,38114	-0,26489	1

elements content in the soil, such as Mn, Ni, Co, Pb, Sr, Fe and Al are not reflected in relative proportion in plant's leaves.

In general, the average values of As, Zn, S, Au, Ag, Cd, Co, P, Na, K, Sb, Se, Y, Mn, Gd and Nd were determined to be higher in the leaves of the studied trees, which have direct contacts with the gold bearing quartz veins and sulphide veins.

The size of the trees in the study do not appear to be important for the accumulation of the heavy metallic elements in the leaves. *C. creticus*, which is the smallest plant among the studied trees, is noticed to be most sensitive to the soil chemistry. The *C. creticus*, contains Pb, Ni, Co, Cd, Mn, Fe, Au, Bi, P, Cr, Al, Na, Ga, Y, Ce, Pr, Nd, Sm and Dy in higher level than the rest.

Gold accumulation in the leaves were determined to have a reasonable high correlation coefficient with As. This element may be used to locate the gold enriched areas.

Finally, it can be stated that the leaves can be used as indicator for the gold bearing quartz veins and sulphide lodes.

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#### GENİŞLETİLMİŞ ÖZET

Hatay ili merkezine 11 km uzaklıkta bulunan Kisecik köyü ve çevresinde, altın ve gümüş içeren kuvars ve sülfür damarlarının bulunduğu bölgede, Çınar, Sandal, Kızılağaç, Söğüt, Pürem, Sakızlık, Çitembik, Karselit ve Pelit gibi 9 bitki türünden 23 yaprak örneği alınarak 50 element üzerinde yapılan çalışmada, bitkilerin, buldukları bölgede etkileneceği deruceleri araştırılmıştır (Şekil 1).

Seçilen bitkiler, sadece çalışılan bölgede yaygın olmayıp, Türkiye'nin batı ve güney taraflarında oldukça yaygın durmaktadır. Çalışma esnasında toplanan bitki yaprak numuneleri, daha önceki çalışmalarda (Aydal, 1989) altın içerdiği bilinen kuvars ve sülfür damarları ile, bunların dokanındaki alterasyon bölgeleriyle doğrudan temasta bulunan ağaçlardan alınmıştır. Ayrıca aynı ağaç tiplerinin, altın ve gümüş içermediği bilinen,

gübre, diyabaz ve harzburit gibi kayaların üzerinde yetişenlerden de yaprak örneği alınmıştır.

Altın ve gümüş içeren kuvars ve sülfür damarları ile doğrudan temasta görülen bitkilerdeki As değerinin ortalama olarak 3.57 ppm, aynı bitkilerin madenle doğrudan temasta bulunmadığı bir bölgeden alınan numunelerdeki As ortalama değeri ise 0.656 ppm olarak bulunmuştur. Benzer şekilde, Zn değerleri ortalama olarak (33.56-22.49 ppm), S (%0.16-0.12), Au (1.86-1.63 ppb), Ag (9.8-7.42 ppb), Cd (0.128-0.066 ppm), Co (0.39-0.27 ppm), F (%0.088-0.074), Na (%0.018-0.009), K (%0.60-0.57), Se (0.206-0.13 ppm), Y (0.087-0.06 ppm), Mn (118-105.97 ppm), Gd (0.026-0.013 ppm), Nd (0.069-0.038 ppm) ve Sb (0.05-0.038ppm) olarak bulunmuştur (Çizelge 1).

Bunun yanı sıra, bir kuvars veya sülfür damarlarıyla doğrudan bir bağlantı görülmeyen bölgelerde, aynı bitkiler kullanılarak yapılan çalışmada, bu kez büksterin, özellikle, bulunduğu bölgedeki ultrabazik kayalardan etkilendikleri ve Mg, Ni, Fe, Mo, Cr, B, Sr, Ca, Ba, Al, Bi, Pr ve Co değerlerinin daha yüksek olduğu belirlenmiştir. Buna göre, bu bölgedeki bitkilerden elde edilen Mg ortalama değeri % 0.422 iken, bu değer kuvars ve sülfür damarları üzerindeki bitkilerde % 0.342 olduğu, benzer şekilde Ni değerinin ortalama olarak her iki bölgede (15.12-4.31 ppm), Fe (%0.057-0.027), Mo (0.0313-0.027 ppm), Cr (1.36-0.85 ppm), B (33.0-25.86 ppm) Sr (21.63-21.02 ppm), Ba (3.47-3.26 ppm), Ca (% 1.0085-0.93), Al (% 0.033-0.021), Bi (0.036-0.032 ppm), Hg (14.5-10ppb) ve Co değerinin (0.134-0.116 ppm) gibi farklılıklar gösterdiği belirlenmiştir.

Bakır, kurşun, kadmiyum ve cıva'nın ortamda aşırı artışı bu bitki metabolizmasını yakından ilgilendirdiği ve zehirlenmeye sebep olduğu bilinmektedir. Ancak çalışılan bölgede özellikle bakır ve kurşunun bazı bitkiler tarafından özellikle tercih edilebilirliği görülmüştür. Maden bölgesindeki susuz topraklarda Pürem, Sakızlık ve Pelit gibi bitkilerde, kurşunun ise Pelit ve Pürem gibi küçük boyutlu bitkilerde artışı, madence steril olduğu düşünülen sulu bölgelerde ise, bakır ve kurşunun birlikte artarak Çınar, Söğüt, Sandal gibi iri boyutlu bitkilerde daha fazla yoğunlaştığı belirlenmiştir.

Damarlar üzerinde bulunan bitkiler ve madence steril olduğu düşünülen bölgelerde bulunan bitkil-

erdeki Te, Ga, Nd, Sm ve Dy değerleri farklılık göstermemektedir. Ayrıca, bitkilerdeki U, Th, V, La, Y, W, Ti, Ho, Tl, Er, Tm, Yb ve Lu değerleri ise dedeksiyon limitlerini altında olması sebebiyle belirlenmemiştir.

Ancak ortaya çıkan bir başka önemli sonuçta, bitkiler içindeki element artış ve ekşilişinin bitki cinsinin yanısıra, elementlerin su içindeki hareketlilik katsayısını bağlı olduğunun da ortaya konmuş olmasıdır. Bunun göre kayalarda ve ocuklarda fazla miktarda olmalarına rağmen demir ve alüminyum gibi elementler, hareketlilik katsayılarının düşüklüğü sebebiyle yapraklarda çok düşük değerlerde bulunmaktadırlar. Buna karşılık, Mn, Co, Pb, Ni, ve Sr gibi, çalışılan bölgede oldukça az bulunan elementler, sudaki hareketlilik katsayılarının fazla olması sebebiyle yapraklarda oldukça fazla değerde çitabilmektedirler.

Çalışılan bölgede bulunan ortandan en çok etkilenen bitkilerin Pürem ve Söğüt olduğu görülmektedir. Ortadaki Pb, Ni, Co, Mn, Fe, Au, Cd (Maden bölgesi), Bi, Pr, Cr, Al, Na, Ga, Y, Ce, Pr, Nd, Sm, Gd ve Dy (madence steril bölgede) elementlerinin en çok Pürem tarafından bünnyeye alındığı, bunun yanısıra Mo, Zn, Ca, Mg, Se ve S'ün maden bölgesinde, Co, Mn ve Cd'nin damarların bulunduğu steril bölgede Söğüt'de daha çok zenginleştiği belirlenmiştir.

Bu verilerin ışığı altında, bitkilere, elementlerin davranış mekanizmalarına ve çevreye çeşitli bağımlılıklar olmasının rağmen, altın ve gümüş içeren kuvars ve sülfür damarlarının yerlerini bulunmasında bu bitkilerin rahatlıkla kullanılabilirliği belirlenmiştir.

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