GEOCHEMICAL PROSPECTING FOR CARBONATE-BEARING LEAD-ZINC DEPOSITS IN THE WESTERN ZAMANTI (ALADAĞLAR-YAHYALI) REGION

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ABSTRACT. — Characteristic sampling methods and dispersion types formed by secondary processes (karstification) have been determined for the exploration of burried carbonate-bearing lead-zinc deposits in the Aladağ Region by studying such minor elements as Cu, Pb and Zn. The most favorable geochemical prospection method in this area is determined to be soil surveying of the overburden, tectonically crushed zones and rock talus fans. The widespread secondary dispersions are created by chemical and mechanical accumulations. The dispersions cover rather wide areas, due to the soil formation, effects of surface-and undergroundwaters and glacial movements. A study of anomalies of Pb and Zn elements deposited by chemical means is the best way for the prospecting of burried ore deposits.

INTRODUCTION

The lead-zinc belt of Zamantı region is the most important mining district from the view of tonnage and distribution among the similar ore deposits of Taurus Mountains. Aladağ region is located in the western part of this belt in the vicinity of Yahyalı (Kayseri) and Çamardı (Niğde) (Fig- 1).

There are a lot of carbonate-bearing lead-zinc deposits and occurences in the Aladağ region. Some of these occurences and ore deposits, which were formed by karstification processes, are not exposed. Any effective geochemical prospecting method to find out either burried ore deposits showing no outcrops, or probable ore bodies between operating mines has not yet been developed for this area.

Kaleköy lead-zinc deposit situated in the central part of Zamantı in the eastern part of the studied area, was investigated by Köksoy (1964), who carried out his geochemical studies both directly upon the deposit and its surroundings. Because of the development of a residual soil cover on the Devonien limestones, suitable for a detailed geochemical prospection, he collected systematical soil samples and correlated SP anomalies. Number of occurences and ore deposits in the lead-zinc belt of Zamantı are found mainly in the sequences of carbonates of the different tectonic units deposited in different environments during the time between Devonien and Cretaceous. Because of absence of a proper soil cover on the rocks, systematical soil sampling was not possible. For this reason, the study carried out in Aladağ region, is considered to be the mosnt convement geochemical prospecting method applicable to the Zamantı belt. In the present study a suitable general geochemical prospecting method is proposed. In addition, definite sorts of secondary dispersion are also ascertained.

GEOLOGY

In the Aladağ region the following tectonic units are determined from north to south (Fig. 1):

— Yahyalı nappe (Devonian-Triassic)
— Siyah Aladağ nappe (Upper Devonian-Jurassic)
— Çataloturan nappe (Lower Carboniferous-Permian)
— Minaretepeler nappe (Upper Triassic)
— Beyaz Aladağ nappe (Upper Triassic-Jurassic)
— Aladağ ophiolitic melange (Upper Cretaceous)

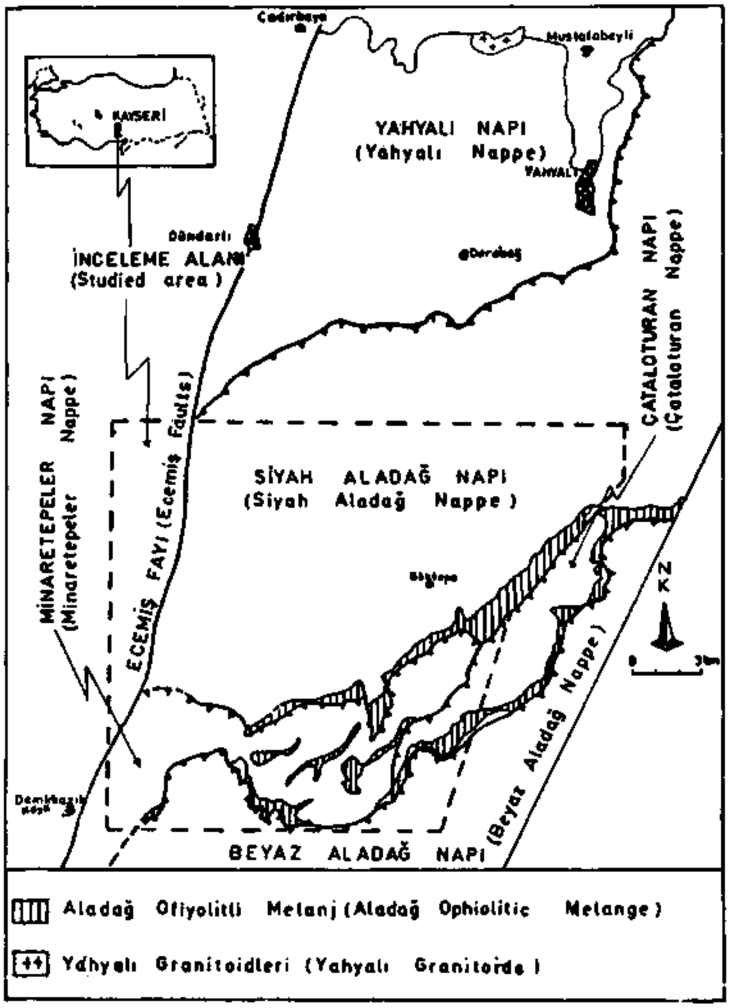

Fig. 1 - Location map and geological setting of studied area in the Aladağ Region.

Yahyalı Granitoids which exposed only along the northern border of Yahyalı nappe to the north of the studied area, intruded into these rocks. They lie under a thick sequence of nappes, placed one on top of the other.

Tertiary sediments are deposited only in a small area between Maden Boğazı and Minaretepeler section. Tectonic units, which have thrusted over each other, contain mainly platform carbonates. This region was overthrusted in Maestrichtian time (Tekeli, 1980). Apart from Beyaz Aladağ and Çataloturan nappes, all other nappes carry some traces of mineralization.

Primary carbonate-bearing lead-zinc in western Zamantı are deposits believed to be hydrothermal in origin and probably related to Yahyalı granitoids. This phase is represented mainly by sulphide ore minerals such as galenite and sphalerite. After the ore deposits were formed, they were redeposited again by multikarstification processes and meanwhile they were altered into secondary minerals such as smithsonite, serusite and limonite (Ayhan, 1983a, 1983b). Occurences, which are completely tectonically controlled, replaced the fractures of carbonate rocks, belonging to the above-mentioned three tectonic units. The largest unit of the studied area is the Siyah (Black) Aladağ nappe, which includes the biggest ore deposit.

GEOCHEMICAL PROSPECTION

Methods of sampling and analyses

In the studied area, because of intensive karstification, unsuitable climate conditions and topographic position, a convenient soil cover has not been developed. Very steep parts of the field are covered with the host rocks and talus fans at the both sides of valleys. A very thin overburden originated from its surrounding limestones has been developed only in more or less flat areas. In all other areas there aren't any sort of trees or other wide-spread plantation. Furthermore, the Aladağ Region is topographically in the highest position in the vicinity of Yahyalı and Çamardı, where extremely fractured carbonate rocks exposed. For this reason, no water springs exsist in any other formations apart from ophiolitic melange belts and marl-bearing sequences. There is only a seasonal water activity at the beginning of spring time.

Considering the mining activities in the Zamantı District from the Hitite times to present (exploitation and smelting (Metag and Stolberg, 1971), the roads and paths connected the deposits or near settlements, following gentle morphological grounds, valley floors and streams. Under these factors, in the studied area, it's concluded that a suitable geochemical prospection can not be carried out by getting systematical water and stream sediment samples.

In as much as mineralization controlled by tectonic activities, a geological map should include all detailled tectonic structures, before the geochemical prospection starts. The relation between mineralization and tectonic features was investigated during the field work and, hence what sorts of samples from where needed to be collected was established. It's suggested that, the sampling be carried out on profiles perpendicular to the tectonic lines having ore potentials or along certain fault zones and rock talus fans. Soil samples were taken with convenient intervals and enough numbers depending upon the topographic position of the area, the lengths of fracture zones, and the distribution of soil and talus fans. Sampling depth was selected due to thickness of soil and talus fans. Trenches were dug down to host rock where thin soil covers the surface. As the samples were taken from fine fractions of components of covers next to host rocks, sampling in thick covers was proceeded from relatively deeper zones (up to 1-2 m), where finest components of soil were present.

Soils on the ore-bearing fractures are red-brown in colour, because of Pb and Zn oxides. This situation can be easily distinguished in the field from typical mylonites of fault zones and guide probable mineralization part. Fractured zones show similar cases or same colors. 1159 soil samples (200-500 gr) were collected from 300km^2, dried, sieved to minus 80 meshes fraction and packed.

Development of the cheapest prospecting method to find out carbonate-bearing Pb-Zn deposite was the aim of this work; so base elements such as Cu, Pb and Zn were analysed. These elements hvea also successfully been used in exploration of many lead-zinc deposits. The elements in soil samples were analysed in the laboratories of MTA by Atomic Absorption Spectrometre. The results of analyses were carried into the computer and interpreted at the MTA computers center through the programming language of FORTRAN-4 with programmes of Listat and Poponal I and II.

Anomalies and their evaluation:

The Cu, Pb, Zn contents of soil samples, collected from Yahyalı granitoids, Aladağ ophiolitic melange belt, Tertiary sediments and other geological formations, except, the marl-mudstone sequences, were evaluated. Only four groups of these rock units; Siyah Aladağ-Permian limestones, Siyah Aladağ-Jurassic limestones, Minaretepeler limestones and Beyaz Aladağ-Limestones showed typical and certain anomaly populations (Fig. 2 and 3) and cumulative frequency curves of the Pb and Zn values measured from these limestones and plotted in the figure 4 and 5. As it's known from many geochemical studies, elements have log-normal distributions (Ahrens, 1954 and 1957). From this point of view, it's supposed that the Pb and Zn values dispersed in four different limestone groups show log-normal distribution. The values of both elements display narrow distributions arround the mean values and their log intervals were calculated as 0.20 (Table 1 and 2). In respect to this log interval, minimum 10 and maximum 16 classes were obtained in each group.

The cumulative frequency points plotted in the probability graphs indicate more than one straight line. The positive skewness point of these lines is known as threshold (t) value. As a background value (b) on the regular cumulative frequencies a point where the frequency line and the line drawn parallel to the absis from the 50 % point on the ordinate axis intersect, is taken as a background value. This value gives geometric average of results. Values lying over threshold, represent anomalies. Values of points obtained by intersecting of straight lines and probability lines at 97.5 % and 2.5 % on log probability plot, give ± 2 standard deviation.

All the cumulative frequency curves, which reflect the distribution of Pb element in four different carbonate units, show positive skewness (Fig. 4) The positive skewness ofcumulative frequency curves for Minaretepeler and Beyaz Aladağ limestones are found between 25 % and 35 % levels. This situation points out, that the populations in both limestones reveal high values (Lepeltier, 1969). Threshold values calculated for each unit are given in figure 4. Here, the part lying above the threshold line represents the main and normal population and the part below it anomalous populations. The distribution and threshold values of zinc element for the same rock groups, demonstrate same differences with respect to the Pb element (Fig. 5). For example, while on the straight lines indicate low values on the probability graphs for zinc, some breaks were observed, but no breaks on the lines of lead values. Low sensivity of the analyses is responsible for such sort of breaks like at the curve of Pb. 100 of the 463 samples taken from Siyah Aladağ-Permian limestones have low values under 40 ppm. Although these measurements were repeated by AAS three times, where the values over the error limits (± 20 %). This case caused some breaks and deviations in the low valued parts of the cumulative frequency curves.

The curves belonging to Siyah Aladağ-Permian limestones and Jurassic limestones give clearly positive skewnesses (Fig. 5). On the other hand, as it was illustrated on the curve of Siyah Aladağ-Permian limestbnes, the positive skewness is found sometimes just below 2.5 % probability line. Such a situation indicates little amounts of high values. If the breakings related to the low values for Minaretepeler and Beyaz Aladağ limestones are not taken into consideration. Although they don't show any important skewnesses (positive and negative) in these limits, they give a single distribution staying in the error limits (Lepeltier, 1969).

Table 1 - Distribution tables of Zn values for soil formation on the rocks (n= number of samples):
a - Siyah Aladağ-Permian limestones (n=463).
b - Siyah Aladağ-Jurassic limestones (n=445).
c - Minaretepeler limestones (n=179).
d - Beyaz Aladağ limestones (n=67).

Sınıf aralığı (Log. Int.)	*ppm*	*f*	*cf*	*% cf*
		a		
1.07	11.75	3	463	100.00
1.27	18.60	5	460	99.30
1.47	29.50	12	455	98.20
1.67	46.80	74	443	95.70
1.87	74.10	103	369	79.70
2.07	117.50	113	266	57.50
2.27	186.00	84	153	33.00
2.47	295.00	38	69	14.90
2.67	468.00	17	31	6.70
2.87	741.00	8	14	3.00
3.07	1175.00	1	6	1.30
3.27	1860.00	1	5	1.07
3.47	2950.00	1	4	0.86
3.67	4680.00	2	3	0.64
3.87	7410.00	1	1	0.21
4.07	11750.00			
		b		
1.47	29.5	2	445	100.00
1.67	46.8	16	443	99.70
1.87	74.1	71	427	96.00
2.07	117.5	131	356	80.00
2.27	186.0	105	225	50.50
2.47	295.0	84	120	27.00
2.67	468.0	17	36	8.00
2.87	741.0	9	19	4.20
3.07	1175.0	—	—	—
3.27	1860.0	5	10	2.20
3.47	2950.0	3	5	1.00
3.67	4680.0	2	2	0.45
3.87	7410.0			
		c		
1.47	29.8	4	179	100.00
1.67	46.8	2	175	97.70
1.87	74.1	14	173	93.60
2.07	117.5	32	159	88.80
2.27	186.0	43	127	70.90
2.47	295.0	41	84	46.90
2.67	468.0	24	43	24.00
2.87	741.0	12	19	10.60
3.07	1175.0	6	7	3.90
3.27	1860.0	1	1	0.56
3.47	2950.0			
		d		
1.47	29.5	—	—	—
1.67	46.8	3	67	100.00
1.87	74.1	1	64	95.50
2.07	117.5	18	63	94.00
2.27	186.0	19	45	67.00
2.47	295.0	7	26	38.80
2.67	468.0	12	19	28.35
2.87	741.0	6	7	10.44
3.07	1175.0	1	1	1.49
3.27	1860.0			

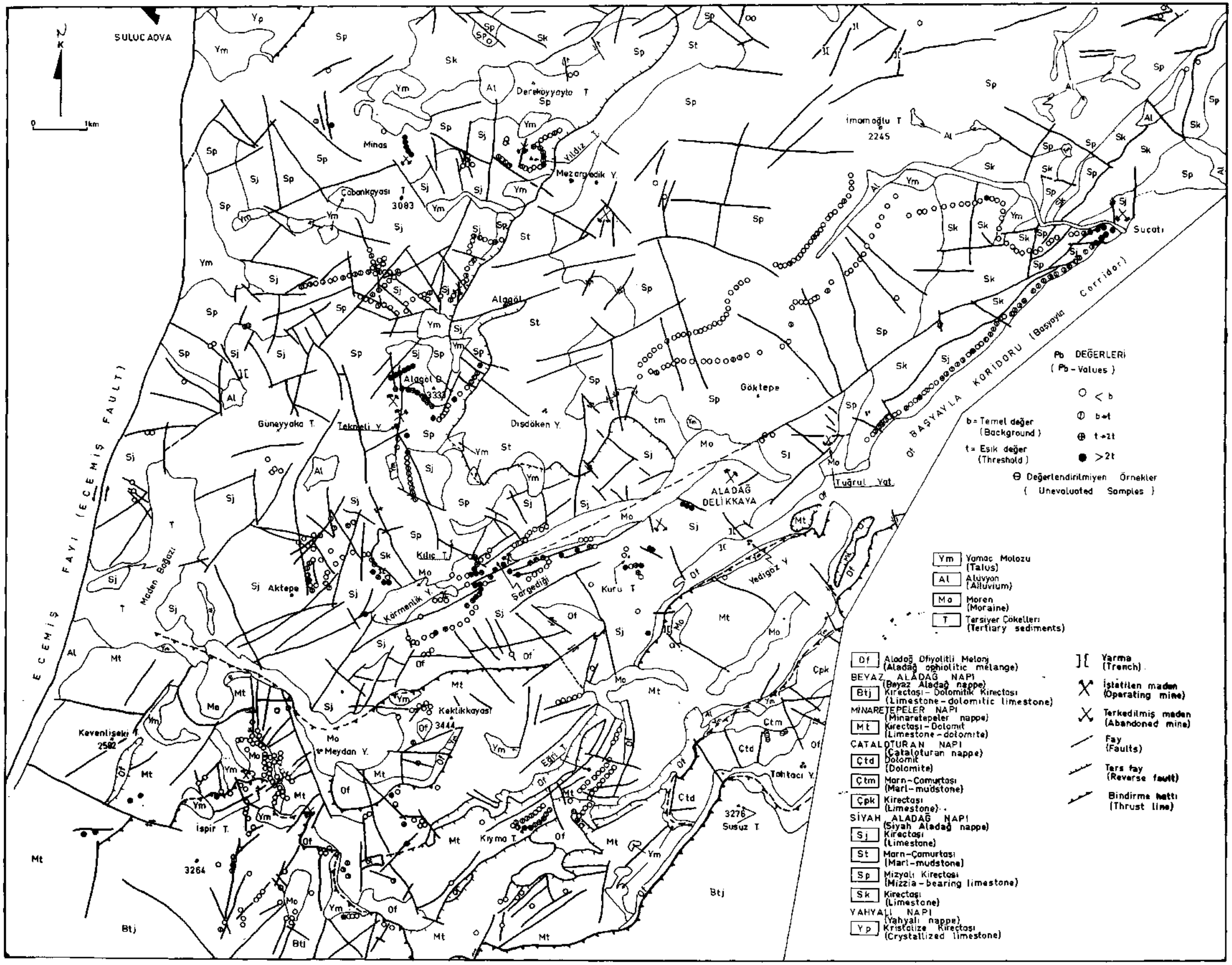

Fig. 2 - Geochemical anomaly map of the Western Zamantı for lead.

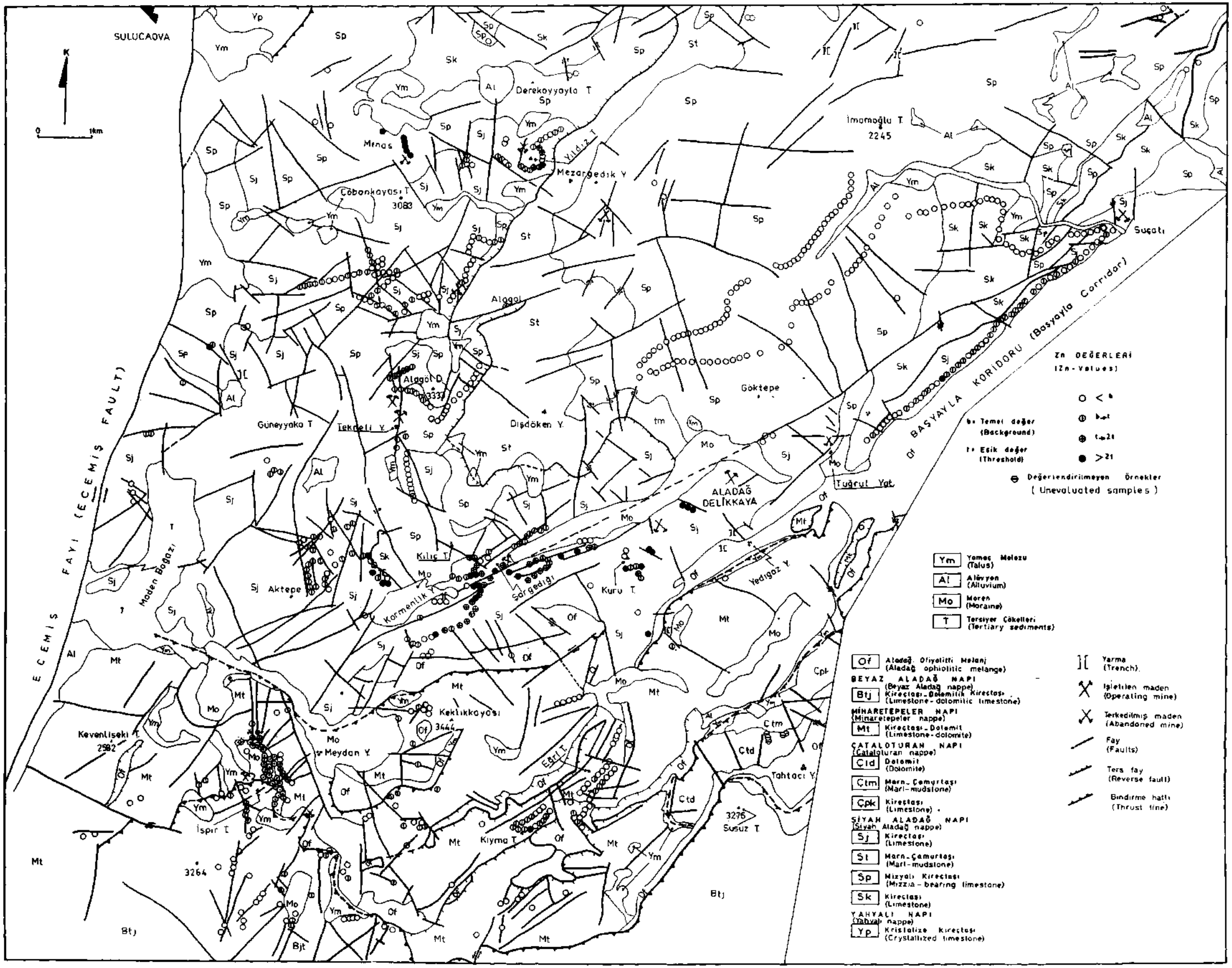

Fig. 3 - Geochemical anomaly map of the Western Zamantı for zinc.

Table 2 - Distribution tables of Pb values for soil formation on the rocks (n= number of samples):
a - Siyah Aladağ-Permian limestones (n=463).
b - Siyah Aladağ-Jurassic limestones (n=445).
c - Minaretepeler limestones (n=183).
d - Beyaz Aladağ limestones (n=68).

Sınıf aralığı (Log. Int.)	*ppm*	*f*	*cf*	*% cf*
		a		
1.27	18.6	4	463	100.00
1.47	29.5	114	459	99.00
1.67	46.8	138	345	74.50
1.87	74.1	113	207	44.70
2.07	117.5	54	94	20.30
2.27	186.0	19	40	8.60
2.47	295.0	9	21	4.50
2.67	468.0	5	12	2.60
2.87	741.0	—	—	—
3.07	1175.0	3	7	1.50
3.27	1860.0	3	4	0.86
3.47	2950.0	1	1	0.21
3.67	4680.0			
		b		
1.67	46.8	75	445	100.00
1.87	74.1	85	370	83.00
2.07	117.5	130	285	64.00
2.27	186.0	93	155	35.00
2.47	295.0	49	62	14.00
2.67	468.0	—	—	—
2.87	741.0	5	13	2.92
3.07	1175.0	—	—	—
3.27	1860.0	3	8	1.79
3.47	2950.0	1	5	1.00
3.67	4680.0	1	4	0.89
3.87	7410.0	3	3	0.67
4.07	11750.0			
		c		
1.27	18.6	—	—	—
1.47	29.5	5	180	100.00
1.67	46.8	42	175	97.20
1.87	74.1	63	133	73.80
2.07	117.5	30	73	40.50
2.27	186.0	16	43	23.80
2.47	295.0	11	27	15.00
2.67	468.0	10	16	8.80
2.87	741.0	5	6	3.30
3.07	1175.0	1	1	0.56
3.27	1860.0			
		d		
1.27	18.6	—	—	—
1.47	29.5	4	68	100.00
1.67	46.8	24	64	94.00
1.87	74.1	16	40	58.00
2.07	117.5	7	24	35.30
2.27	186.0	8	17	25.00
2.47	295.0	4	9	13.30
2.67	468.0	4	5	7.34
2.87	741.0	—	—	—
3.07	1175.0	1	1	1.49
3.27	1860.0			

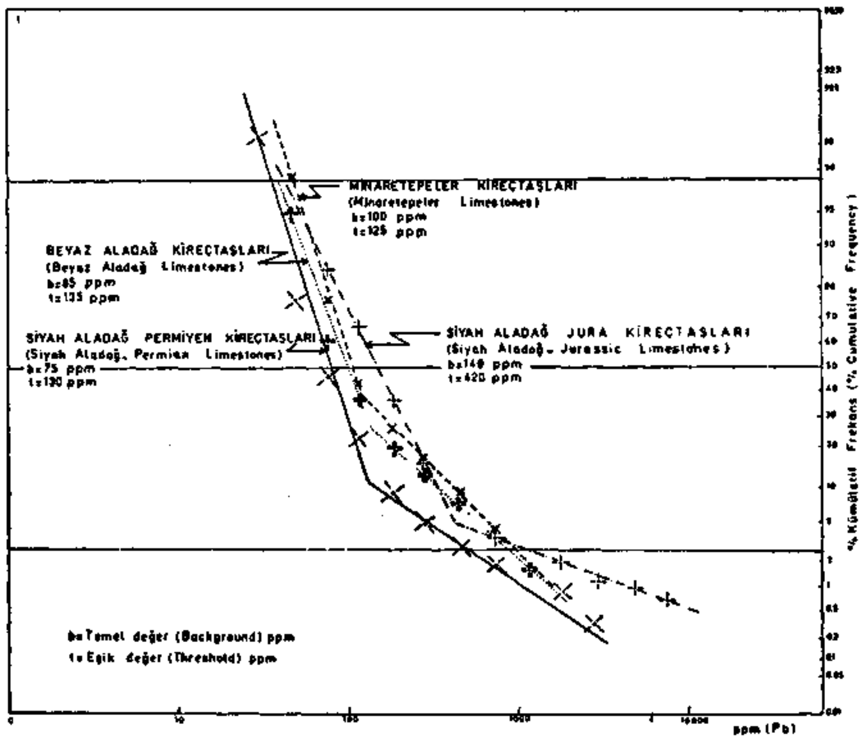

Fig. 4 - Cumulative frequency distribution of lead concentrations.

Although the inflection points of Freguency curves don't coincide with the line of + 2 standard deviation. In this method, the values correspond to the inflection points can be accepted as threshold values. This is simply because the samples collected from the known mineralized areas yielded high values of Pb and Zn and therefore cause the mean of the population to be high. In the north of İspir Tepe there is a moraine cover with a maximum thickness of 15 m., from where the soil samples were collected and Pb and Zn elements were determined. Their element contents reach up to 10.000 ppm. The main reason for high values is the İspir Tepe ore deposits, which occured next to the southwest of moraine covers. Ore minerals were transported from ore deposits which mentioned above by the effects of mechanical processes such as glacier. After that, they were dispersed into fine grained components of moraines by partly chemical alteration. Chemical dispersion has a wide dimension, especially where the Pb and Zn sulfides can be solved, chemically transported and deposited under oxidation conditions at pH=6-8.5 and Eh (+) (Garrels, 1951).

The probable sources of anomaly values determined from soil samples, which lie on the Jurassic limestones of Siyah Aladağ Nappe extending along western slope of Başyayla Corridor, can be interpreted as in the following ways: a) The anomalies indicate a burried occurrence situated under a ridge chain extending toward Göktepe region, b) They can be originated from solutions of the Aladağ-Delikkaya mine, occurrences in the vicinity of Göktepe and Tuğrul mine, c) Mechanical transportation by glacial movements. Considering the second probability, the anomaly is concerned within non-significant anomalies. Because the topographic position inconvenient for the solution to move, possibilities are weak to cause such anomalies. The same situation was observed along western slope of Zindandere in the east of Mezargedik occurences. On the other hand, it must be considered, that the distribution and the movements of acidic waters derived from a mining waste, might cause of such non-significant anomalies.

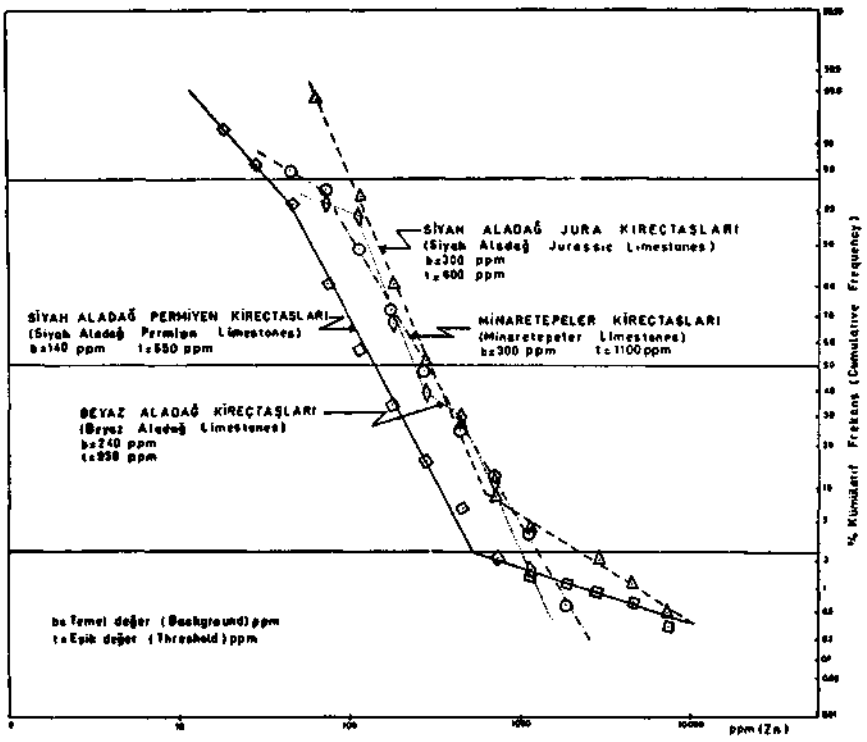

Fig. 5 - Cumulative frequency distribution of zinc concentrations.

Samples taken from the soil formation on the Upper Permian and Jurassic limestones of the Siyah Aladağ Nappe, contain high values of Pb and Zn. These values are higher than the values obtained in other countries. Zn contents of soil samples collected from different countries and determined by Swaine (1955) vary between 10 and 300 ppm with an average of 70 ppm. According to this researcher, the average value of soil is 15 ppm. The higher Pb and Zn anomaly values of samples taken from our area is related first of all to the widespread occurences exposed in the region. Morever, the elements bound in clays, iron oxides and organic materials would be transported to certain distances, is another fundamental reason for the high values. This concept was confirmed by the following factors: Carbonate sequences of Siyah Aladağ Nappe contain high bituminous material, and pyrite minerals were weathered into iron oxides during the karstification stages and therefore, clay minerals occurred in karkstification environment (Ayhan, 1983a).

Table 3 - Cu values of soil formations on the rocks.

Birim (Unit)	*Örnek Sayısı (Number of samples)*	*Min. değer (Min. value)*	*Mak. değer (Max. value)*
Siyah Aladağ - Permiyen	**238**	**5 ppm**	**264 ppm**
Siyah Aladağ - Jura	**384**	**6 ppm**	**66 ppm**
Minaretepeler	**157**	**12 ppm**	**89 ppm**
Beyaz Aladağ	**56**	**20 ppm**	**72 ppm**

The Zn contents of analysed samples are generally higher than Pb contents. Because, the metal ions such as Zn^{+2}, Cu^{+2}, Pb^{+2}, Hg^{+2} and Fe^{+3} posses a low geochemical mobility under supergen conditions and the mobility decreases from zinc to iron (Dall'Aglio and Tonani, 1972). Beside the mobilities of both elements, their solubility differences rulet the dimensions of secondary dispersions. Minerals such as cerussite and anglesite generated from galenite under oxidation conditions can not be desolved easly. On the other hand, zinc and copper sulphates formed under similar conditions can be easly soluble and they create widespread characteristic secondary dispersions (Levinson, 1974). The Pb values are relatively higher than the Zn values in İspir Tepe and Kargediği. Main reason for this situation is, both chemical dispersion occurred during multikarstification processes and mechanical dispersions appeared during glacial movements, which formed U-shaped valleys in this parts of the Aladağ Region.

Cu contents of soil samples collected from all carbonate sequences didn't give any anomalous populations. As it is observed in table 3, they showed copper content in the range of 5 to 264 ppm. However, most of the samples contain under 50 ppm Cu, copper values of samples taken from various parts of Tekneli Pb-Zn deposit vary between 20 and 100 ppm (Metag and Stolberg, 1971). On the other hand this element, which was measured in carbonate rocks of the same deposit, shows the varying values between 4 and 10 ppm (Ayhan, 1985). Copper minerals in Pb-Zn deposits of the region can be recognized only in microscopic scale. Therefore, soil formations found around this deposit include more Cu element than the soil formations of other sterile parts of the region. These indicate, that the higher Cu values could have been originated from lead-zinc occurrences.

CONCLUSIONS

Soil samples taken from talus fans, fractured zones and soil formations developed on five nappes lying one upon another in the Aladağ region were geochemically determined. Pb and Zn contents of soil formations on a few carbonate rocks belonging to Siyah Aladağ, Minaretepeler and Beyaz Aladağ gave typical and certain anomalous populations. The following threshold values were found on the cumulative frequency curves for Pb and Zn: Siyah Aladağ-Permian limestones: 130 ppm and 530 ppm, Siyah Aladağ-Jurassic limestones: 420 ppm and 600 ppm, Minaretepeler limestones : 125 ppm and 1100 ppm, Beyaz Aladağ limestones: 135 ppm and 240 ppm. Most of the cumulative lines show generally a positive skewness (and stay in the confidence limits, i.e. in general 5 %).

The results of analyses of the geochemical soil samples taken from the studied area having an irregular thin soil cover were interpreted together with field observations and three sorts of secondary dispersions obtained from lead-zinc prospection were distinquished:

1 — Dispersion through directly mixing of ore minerals with the soils during the formation of soil and rock talus fans,

2 — Dispersion through mechanical and chemical transportation of ore-forming constituents by underground waters into fractured tectonic lines and previously formed soil covers,

3 — Dispersions created both by the breaking out of the ore-bearing occurrences and by transportation of soil formations rich in Pb and Zn found in the vicinity of occurrences during glacial movements.

The chemical kind of dispersions especially posses a key character for the prospection of burried occurences. For this reason, the probably located occurences effected by these processes can be detected by sampling and interval of 20-50 m.

As primary mineralization originated from hydrothermal solutions which migrated and dispersed in short distances, except along some fractures and furthermore the anomalies derived from them have been fully overprinted by the widespread secondary dispersions, it's impossible for favorable geochemical prospection to be carried out by the primary dispersions.

Soil samples collected from the studied area show high values of Pb and Zn. These values are directly related to the presence of many occurrences in the region to effectiveness of glacial movements and to dispersions bounded with the clayey and bitumineous materials. Some Pb anomalies are higher than the Zn anomalies. This confirms, that the mechanical transportation and dispersion were effective than the chemical one in some places.

The anomalies obtained from the north of Kıyma Tepe, in the easthern part of Minaretepeler nappe, were created either by a probable mineralization situated at depth or by leakages originated from Aladağ-Delikkaya mine.

In the light of field observation and geochemical data, anomalies obtained from some parts of Kargediği, western slope of Zindandere and Başyayla Corridor, from the south and north part of Çobankaya Tepe indicate the necessity of a more close geochemical sampling (Detailed prospecting) and of excavation of shallow trenches and short galeries, where the high values of both minor elements were measured.

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