GEOCHEMICAL AND MINERALOGICAL ANALYSES OF THE MAZIDAĞI PHOSPHATES CONTAINING URANIUM, VANADIUM, FLUORINE AND OTHER TRACE ELEMENTS; AND VIEWS ON THE PROBABILITY OF URANIUM RECOVERY

Oğuz ARDA, Taner SALTOĞLU, Ercan ALPARSLAN and Tanıl AKYÜZ

Mineral Research and Exploration Institute of Turkey

SUMMARY. — Results obtained from the chemical analyses and semi-quantitative optical emission analyses of the Mazıdağı phosphates, found in the Karataş area, are evaluated in this paper. Applying the geochemical relationships between U, P_2O_5 and U and F elements, reserves of the whole area were evaluated as 7,419.5 tons of U_3O_8 and 2,722, 207 tons of F. Mineralogical study of these phosphates indicates that dahllite and cellophane, which constitute the bulk of phosphate minerals in the Mazıdağı rocks, contain elements such as U and F, as well as trace elements like V, Yb and Y. When quantitative analyses of the latter group of trace elements are completed, it will be possible to calculate their reserves, which, it is believed, will increase the economic value of the Mazıdağı phosphates. Moreover, it is considered that these phosphate minerals also contain some sulfur, but this can only be confirmed by further mineralogical and chemical studies.

A wide bibliographic study was also carried out on the recovery of uranium from similar phosphate beds in other parts of the world, and it showed that important work was done and various methods were developed.

It is suggested that laboratory tests should be carried out on both uranium and other trace elements, such as F, V, Y, etc. for their economical recovery by using one or combining several of these methods.

1. INTRODUCTION

The aim of this study is outlined as follows:

a. Determining the geochemical relationships between U, F, V and other trace elements found in the phosphate minerals of the Mazıdağı rocks.

b. Evaluating these relationships by taking into consideration the mineralogical and the petrological characters of the phosphate rocks.

c. Trying to find out the possibilities of recovering uranium as a by-product from the phosphate ores.

d. Finally, calculating the reserves of uranium and fluorine within the phosphate rocks by applying the geochemical relationships between uranium, fluorine elements and P_2O_5.

This work has been carried out by using the results obtained from the chemical analyses of 226 phosphate ore samples which were analyzed and listed in their work by Heimbach, Shoukry and Steiner (1974) from the German Geological Survey. These samples were collected by them during their field work in the Karataş area of Mazıdağı. The results of some semi-quantitative optical emission analyses were also used during the course of this study, which were taken from the same source mentioned above. Additionally, the calculation of uranium and fluorine reserves were made by using the data presetted by İ. Seyhan, Ü. Sündal, S. Yılmaz and I. Özoğul (1973).

The P_2O_5, SO_3, F and U values determined by the complete chemical analyses of the above-mentioned 226 phosphate samples are listed in Table 5, given at the end of this report. The German Group separated the Karataş phosphates into three groups: Table 1 compares the P_2O_5 percentage of each group with those found by analyses made in the Laboratory Department of M.T.A. Institute.

Table - 1

Ore type	P_2O_5 % (Heimbach, Shoukry, & Steiner, 1974)	P_2O_5 % (Laboratory Dpt. of M.T.A., 1973)
I. Light gray-colored ore with high P_2O_5 and low calcite content	32.09	31.3
II. Reddish brown, clayey ore with low calcite and P_2O_5 contents	21.53	18.0
III. Light gray-colored calcite ore with low P_2O_5 content	14.73	13-19

As seen in Table 1, the results obtained from phosphate analyses carried out by the German Group and the M.T.A. Laboratory do not differ much.

Phosphate samples taken from the Karataş area contain V, Yb, Y, Cr, Ni, Mn and Mo in trace amounts. Table 2 gives the semi-quantitative results obtained by the optical emission method as published by Heimbach, Shoukry and Steiner in 1974.

Table - 2

Element	Maximum (ppm)	Minimum (ppm)
Y	300	100
Yb	30	10
V	600	10
Cr	300	10
Ni	300	10
Mn	600	10
Mo	30	10

In the present work, the relationship between «V» which is given in Table 2 and «U», was investigated and an attempt was made to establish with which minerals these elements are associated.

The chemical data were plotted and studied from the graphs. For example, plotting the «U» values against the «P_2O_5» and «F» values. The curves shown on these graphs were drawn with the aid of a computer by using «Double Regression Analyzing Program».

2. GEOCHEMICAL AND MINERALOGICAL EVALUATION OF RESULTS OBTAINED FROM THE CHEMICAL ANALYSES OF THE MAZIDAĞI PHOSPHATE ORES; VIEWS ON THE POSSIBILITY OF RECOVERING URANIUM

2.1. A study of the relationship between U and P_2O_5 and application of this factor to the known phosphate reserves

The U (ppm) and P_2O_5 (%) values for a total of 440 analyses in number, as listed in Table 5, are shown on the diagram in Fig. 1. The U-P_2O_5-curve drawn on this diagram was plotted by the computer and the equation of this curve is worked out as follows:

$$Y (P_2O_5) = -0.0797+0.3929X(U)$$

It can be said that the «P_2O_5» percentage increases with the increase of «U» amount since the correlation is positive and the correlation factor (t_H=22.95) is high and therefore the relationship is important.

The «U» and the «P_2O_5» values which are shown on Fig. 1, represent the phosphate samples, taken from the Karataş area of the Mazıdağı region. As can be also seen in Table 1, the phosphate analyses of the Karataş area can be divided into three groups according to their P2O5 content and these values conform quite well to the figures of the whole Mazıdağı region obtained by M.T.A. Laboratory tests. Therefore, the relationship between U and P2O5, which is plotted on the diagram of Fig. 1, can be considered valid for the phosphate ores of the entire Mazıdağı region.

The «U» (ppm) / $P2O_5$ (%) ratio, as explained in the preceeding two paragraphs, is applied to the whole ore reserves of the Mazıdağı phosphates. The authors used the figures shown on Table 3, page 25 of the report (in Turkish) «Feasibility Survey on Phosphate Deposits of the Batı Kasrık Area, Mardin-Mazıdağı, Band 2, Reserves and Quality (1973) by Seyhan, Sündal, Yılmaz and Özoğul. The results are given on Table 3 and Table 4. However, it must be noted that the total «U» reserve depends on the results of the phosphate reserves and in case of any improvement in the phosphate reserves, the «U» reserves will also increase proportionally.

Table - 3

The uranium contents of the phosphate ores in the Mardin-Mazıdağı region

Deposits	*Visible (tons)*		*Probable (tons)*		*Possible (tons)*		*Total (tons)*	
	U	*U_3O_8*	*U*	*U_3O_8*	*U*	*U_3O_8*	*U*	*U_3O_8*
Semikan deposit	2,016.1	2,377.4	1,190.3	1,403.6	287.2	338.7	3,493.6	4,119.7
Kasrık deposit	479.5	565.4	484.4	571.2	119.5	140.9	1,083.4	1,277.5
Semikan+Kasrık deposits	2,495.6	2,942.8	1,674.7	1,974.8	406.7	479.6	4,577.0	5,397.2

Phosphate ore grade (approx.): **21.57 % P_2O_5**

Uranium ore grade (approx.): **55 ppm U or 64.9 ppm U_3O_8**

Table - 4

Uranium reserves of potential phosphate ores

Deposits	*Visible (tons)*		*Probable (tons)*		*Possible (tons)*		*Total (tons)*	
	U	*U_3O_8*	*U*	*U_3O_8*	*U*	*U_3O_8*	*U*	*U_3O_8*
Semikan deposit	329.4	388.4	231.1	272.5	66.9	78.9	627.4	739.8
Kasrık deposit	369.1	435.2	416.0	490.6	302.5	356.7	1,087.6	1,282.5
Semikan+Kasrık deposits	698.5	823.6	647.1	763.1	369.4	435.6	1,715.0	2,022.3

Phosphate ore grade (approx.): 12.4 % P2O5

Uranium ore grade (approx.): 32.5 ppm U or 38.3 U3O8

Total uranium content of mineable + potential phosphate ores:

U (tons)	U_3O_8(tons)
6292.0	7419.5

Phosphate ore grade (approx): 18.01 % P2O5

Uranium ore grade (approx.): 46.3 ppm U or 54.6 ppm U_3O_8

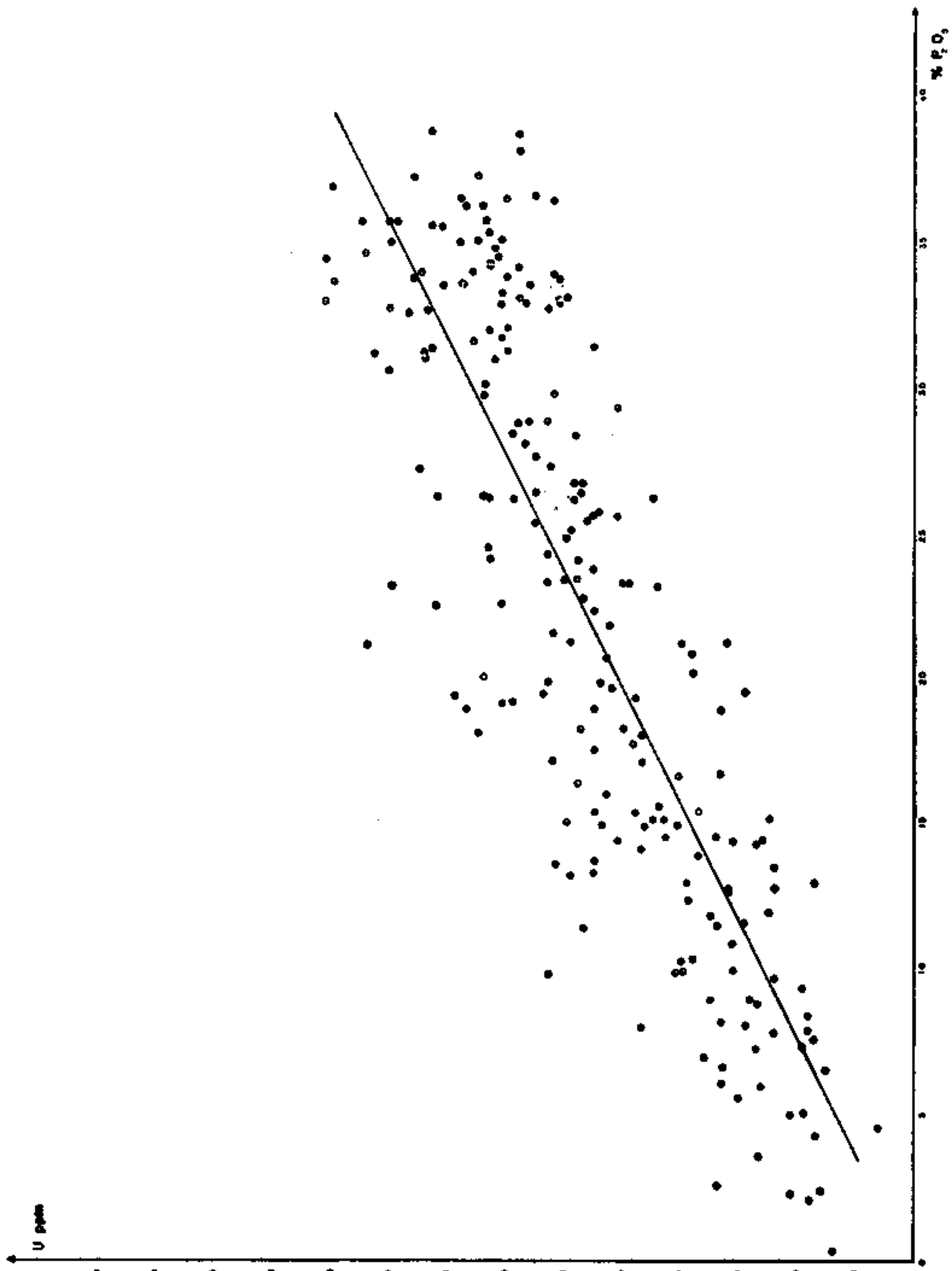

Fig. 1 - Diagram showing the U and P_2O_5 values of 226 phosphate ore samples taken from the Mazıdağı-Karataş area.

The results of this study can be summarized as follows: The mineable+potential U contents of the Mazıdağı phosphate deposits represent 6292 tons of uranium, or 7419.5 tons of U_3O_8. G. Önal (1975), who carried out similar studies, gives 10,600 tons for U_3O_8. Önal based his calculations on a ratio of U (ppm)/P_2O_5 (%) = 3, which represent some 10 to 12 analysis results of the U and P_2O_5 (personal communication). Thus, a result of 7419.5 tons of U_3O_8 seems to be more reliable, since it is based on a total number of 440 analyses of U and P_2O_5.

2.2. Isograde map of uranium

The isograde maps for phosphate ores can be transformed into the isograde maps for uranium based on the U/P_2O_5 ratio, described in Section 2.1. of this work. For example, Fig. 4 shows such a local distribution of the equivalent amount of uranium concentrations existing within the phosphate ores of the Karataş area. This type of work is also interesting since it shows the regional distribution pattern of uranium and its direction of enrichment within the phosphates.

2.3. Relationship between «U» and «F»

The data on U (ppm) and F (%) analyses which are listed in Table 5, are plotted on Figure 2. The U-F curve is drawn by the computer and it is expressed as follows:

$$Y\ (F)=0.0618+0.0421X(U)$$

This equation indicates a close correlation between the F and the U values. The increase in F corresponds to the increase in U, because it is a positive correlation. This relationship is important since the correlation factor (t_H=20.38) is a high value. In a study, similar to that carried out for the calculations of «U» reserves, the total fluorine reserves are calculated as 2,722,200 tons of fluorine in 1,972,040 tons of mineable phosphate ore plus 750,167 tons of potential phosphate ore. As it is the case for the «U» reserves, the fluorine reserves will increase proportionally with the increase of phosphate reserves.

2.4. Relationship between «U» and «SO_3»

The data on U (ppm) and SO_3 (%), which are given in Table 5, is plotted on Figure 3. The U-SO_3 curve, which is drawn by the computer, can be written as follows:

$$Y\ (SO_3)=0.2516+0.0066X(U)$$

The relationship is important since the correlation factor (t_H= 11.72) is a high value. The increase in «U» denotes also the increase in SO_3.

2.5. Relationship between «U» and «V»

The relationship between vanadium and uranium is not properly understood because the «V» values tabled in this study are of semi-quantitative character. However, if the «V» reserves of the Mazıdağı phosphates are required to be worked out, the analyses of vanadium should.be made quantitatively.

2.6. Mineralogie and petrographic characteristics of the Mazıdağı phosphate ores

Various types of phosphate ore samples from the Mazıdağı region are studied under the microscope by the Mineralogy-Petrography division of the Laboratory department of M.T.A. The results are summarized below;

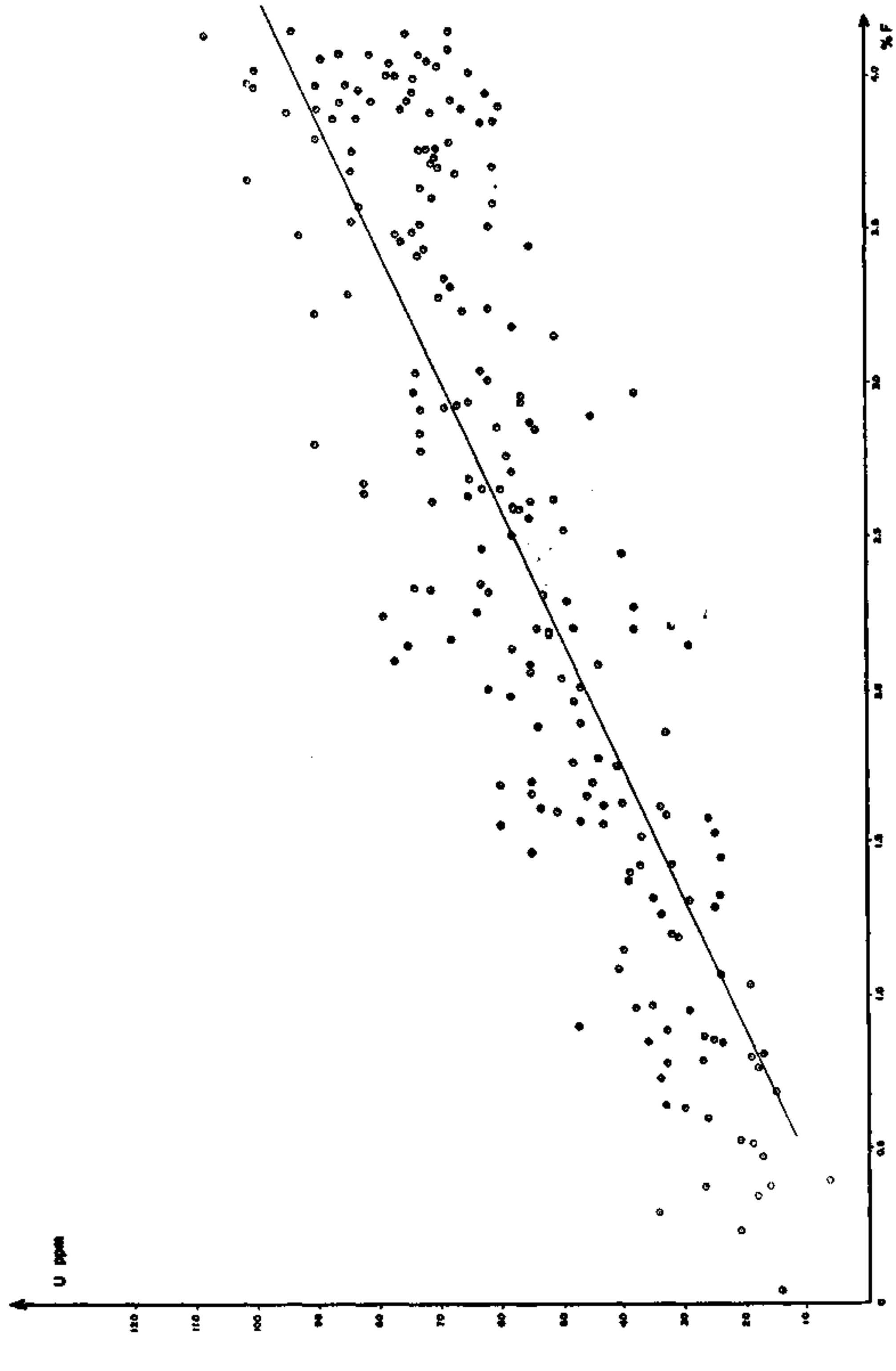

Fig. 2 - Diagram showing the F and U values of 226 phosphate ore samples taken from the Mazıdağı-Karataş area.

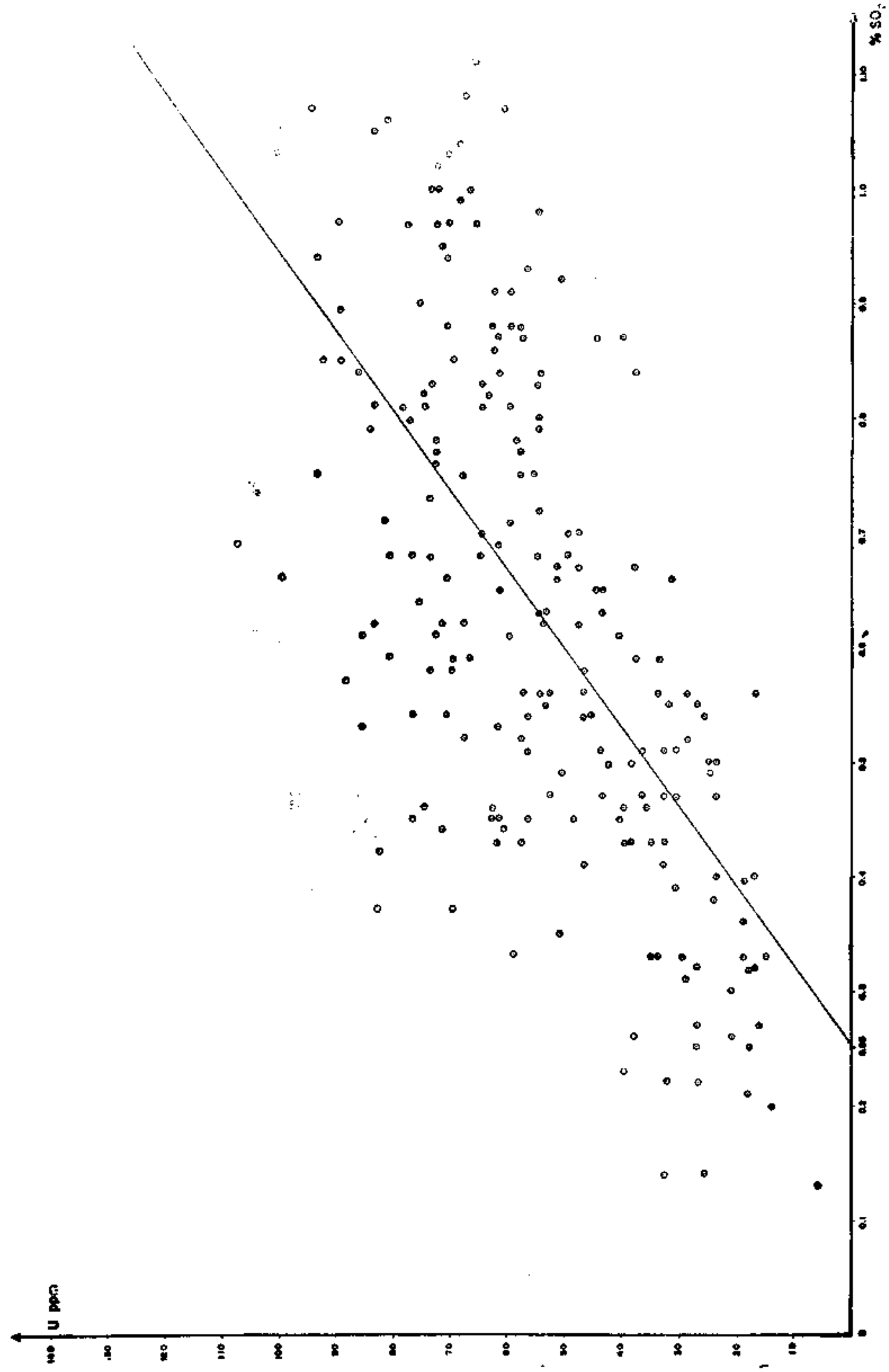

Fig. 3 – Diagram showing SO_3 and U values of 226 phosphate ore samples taken from the Mazıdağı-Karataş area.

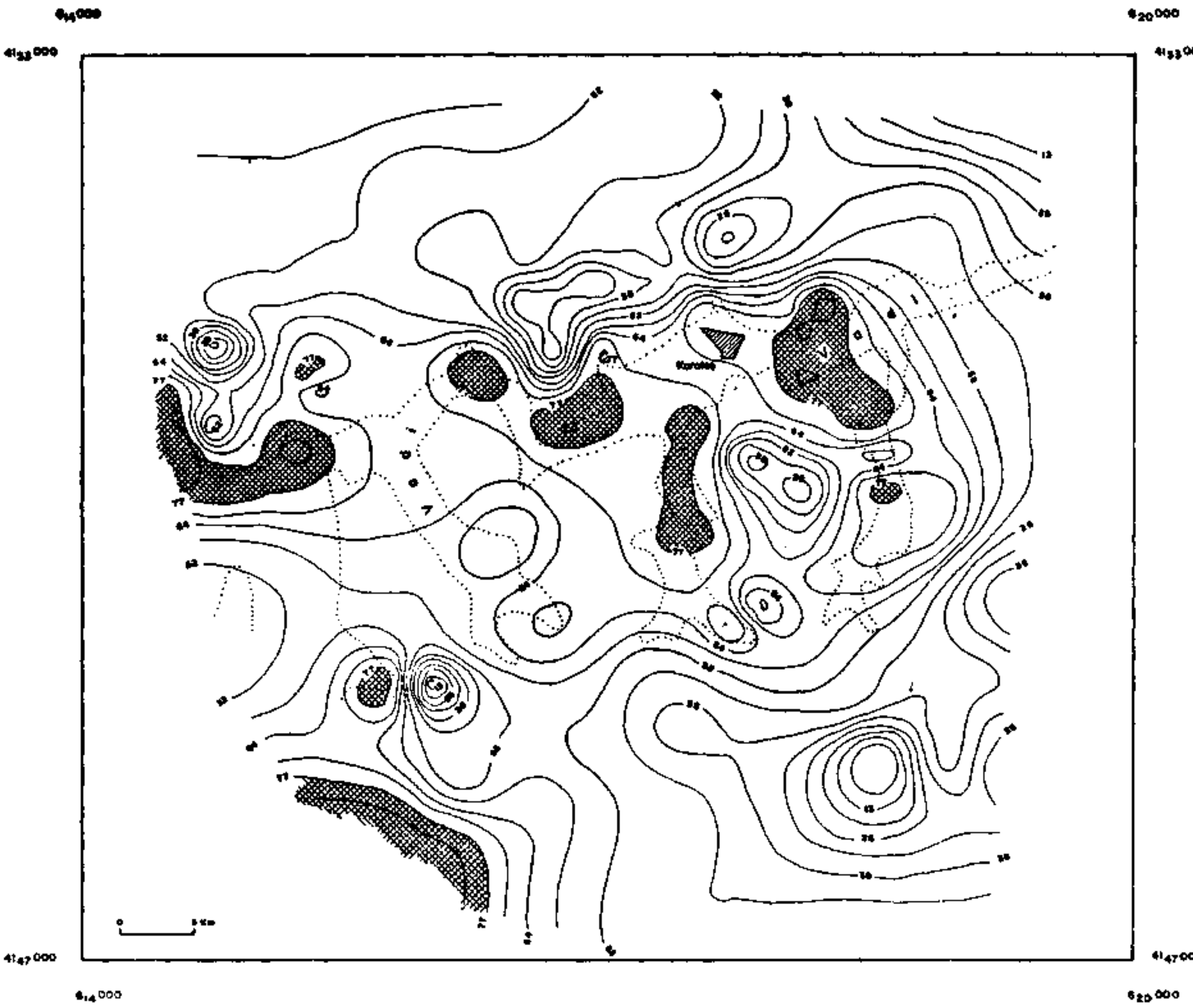

Fig. 4 - Uranium isograde map of the Mazıdağı-Karataş area. [Adapted from the «Phosphate isograde map of the Mazıdağı-Karataş area» prepared by W. Heimbach, B. Shoukry and S. Steiner in 1974.]

Elgin (1972) determined a sample which was taken from the Balpınar area of the Mazıdağı and he found out that the sample consists of quartz, allophane (silica-alumina-hydrogel) and a very small quantity of phosphate.

Dileköz (1972) studied a number of samples consisting of mainly phosphate minerals and phosphate occurrences within the cryptocrystalline quartz aggregates in the specimens collected from the Ekinciler, Arısu, Karataş localities of the Mazıdağı. He says that the main phosphate mineral is collophane with a lesser amount of dahllite, in comparison. The collophane occurs in round and ellipsoidal forms in microscopic diameters, while the dahllite shows bone structures. The grain size of these phosphorite minerals varies between 0.1 - 0.3 mm in diameter and they are usually associated with calcite and sometimes quartz crystal aggregates in micro or cryptocrystalline forms. The samples taken from the Kırakıç Tepe and the Karataş areas in the Mazıdağı region, were determined by Kraeff (1971) and Arda (1972) as phosphorite occurrences and limestones containing collophane and dahllite.

As described in the paragraphs above, minerals of the Mazıdağı phosphate ores are mainly composed of dahllite with a chemical composition of $[3Ca_3(PO_4)_2.CaCO_3]$ and cellophane which has a chemical formula of $[3Ca_3(PO_4)2.n(CaCO_3, F_2.O)X]$. Elgin (1968, 1971) found out that the small quantities of Ca^{2+} are replaced by U^{4+} in the phosphate minerals of specimens taken from the Ayvalık and Küçükkuyu areas of Çanakkale and also from the Köprübaşı-Taşharman areas.

This work substantiates the opinion that other phosphate ores in Turkey may also contain uranium, since the presence of U in the Mazıdağı phosphate rocks was proven. In section 2.1. of this paper the existence of uranium in the phosphate minerals in a regular geochemical relationship has been demonstrated and relationship of similar nature for the F element was also described in section 2.3.

Another interesting point revealed by this study is the geochemical relationship between phosphate minerals and SO_3 (section 2.4). This can be explained in two ways:

a. The PO_4^3– content of dahllite and cellophane minerals found in the Mazıdağı phosphate ores are replaced by small quantities of SO_2, SO_4^2– and VO_4^3–, as suggested by McKelvey (1967) in other phosphate ores. This view is confirmed by the fact that no sulphate mineral was observed in the phosphate ores during our mineralogical studies.

b. It is possible that some U in very small quantities and in the form of sulphate minerals may be encountered in association with clay minerals; however, no mineralogical or geochemical evidence is present to substantiate this second view.

Similar to McKelvey's views (1967), other rare elements found in the Mazıdağı phosphate ores may exist as a result of replacement of Ca^{2+} cation in phosphate minerals by such elements as V, Y, Yb and Mn in minor amounts. On the other hand, presence of such elements as Cr and Ni may indicate the probable existence of ultrabasic materials in trace amounts within phosphate ores. However, no opaque mineral containing Cr or Ni was found in the four polished sections of the phosphate minerals, that could confirm this hypothesis.

2.7. Views on the possibility of U recovery from the Mazıdağı phosphates

Phosphate ores generally contain U varying between 40 and 200 ppm. U contents of some phosphate ores from various parts of the world are given in Table 4.

Table - 4

Country of origin	*Uranium content (ppm)*
Jordan	**105-149**
Tunisia	**32-47**
Algeria	**110-132**
Israel	**120-140**
Florida and California (U.S.A.)	**40-60**
Mazıdağı (Turkey)	**31-66**

When U reserves in these phosphate ores are calculated, important figures are reached. Certainly they cannot be considered as primary U ores under the present economical and technological conditions. However, laboratory and pilot-plant testing carried out for years showed that U can be recovered economically as a by-product during the production of mineral fertilizer and phosphoric acid.

In the United States many studies have been carried out since 1950's for the economical recovery of U with an approximate U_3O_8 grade of 100 ppm in the phosphate ores of Florida and Western States. Dow Chemical Company, International Minerals and Blockson Chemical Company developed several forms of liquid-liquid extraction, ion-exchange recovery and neutralization methods (J. Clegg & D. Foley, 1958). Since 1960's, U recovery from the phosphate ores of California and other States became an important process (Galkin, 1964). Hurst and Crouse (1974) developed the most recent and the best method for U recovery during phosphoric acid production from the phosphate ores of Florida.

In Yugoslavia, where the phosphate fertilizers industry is. rapidly developing, laboratory studies are being carried out for U recovery during the technical-grade phosphoric acid production through liquid-liquid extraction (Deleon, Lazarevic, 1971).

In Spain, during the production of phosphoric acid, in 1975, a U_3O_8 recovery of 150-200 tons was calculated from a plant at Huelva, with an annual capacity of 400,000-500,000 tons of P_2O_5. The phosphate ore of this area contains 150 ppm of U (Gasos, 1971).

In India, laboratory studies were made on U recovery through combined methods of calcination and acid solving on the phosphate ores of Barbada-Chamsari Chulidar (Mussorie) area (Rambabu, Majmudar, 1971). Laboratory and pilot-plant testing carried out by the Atomic Energy Research Institute of Israel on U recovery from phosphate ores, through solving in hydrochloric acid, are highly advanced (Ketzinel, 1972). In addition, in some industrialized countries, which have no major uranium reserves, researches are being carried out on the recovery of U as a by-product from phosphate ores and some patents have already been granted.

Studies on the subject carried out up to date in Turkey are those conducted in the Laboratories of the Mining Faculty, in İstanbul Technical University, where leaching by H_2SO_4 and liquid-liquid extraction processes by octylphenyl phosphoric acid were performed (Önal, 1975).

Galkin (1964) suggests that an ore with 100-200 ppm U and 5-10 % P_2O_5 content can generally be processed economically. Thus, taking into consideration these figures, it may be assumed that some other by-products, such as F, V and rare earths, can be recovered, and the limits mentioned by Galkin (1964) for U and P_2O_5 can be pushed down even more.

Various methods are used at present in the production of mineral fertilizers and other by-products from phosphate ores. The most common are:

1. Calcination and gas reaction methods,
2. Solving the ores in H_2SO_4, HCl and HNO_3 acids and liquid-liquid extraction by use of convenient organic solvents.

Based on the type of phosphate ores and required production, one of these methods can be used. If necessary, combined methods or some other processes can be applied.

In order to obtain economically U and other rare elements as by-products during the production of phosphoric acid or mineral fertilizer from the Mazıdağı phosphates, some of the recovery processes briefly outlined above should be investigated in detail.

Table - 5

Sample no.	P_2O_5 (%)	SO_3 (%)	F (%)	U (ppm)
1	30.32	0.51	3.23	44
2	36.36	0.58	4.03	70
3	26.14	0.56	2.71	58
4	36.37	0.53	3.94	62
5	18.95	0.51	1.86	33
6	25.10	0.33	2.76	59
7	32.63	0.88	3.85	63
8	33.08	0.81	3.90	60
9	19.69	0.67	2.19	52
10	34.02	1.08	3.92	68
11	21.26	0.66	2.21	32
12	31.96	0.85	3.71	70
13	31.91	1.17	3.76	73
14	31.34	0.98	3.44	55
15	33.81	0.45	3.51	62
16	24.28	0.45	2.46	63
17	33.00	0.27	3.58	61
18	8.82	0.27	0.87	27
19	25.63	0.35	2.62	51
20	8.43	0.25	0.89	18
21	38.02	0.28	4.15	68
22	29.28	0.92	3.15	51
23	32.99	0.31	3.78	68
24	31.21	0.37	3.28	70
25	23.30	0.45	2.29	49
26	26.64	0.52	2.60	58
27	34.23	0.61	3.52	73
28	12.71	0.22	1.20	32
29	27.54	0.68	2.69	65
30	38.77	0.42	3.95	83
31	34.42	0.62	3.76	72
32	33.21	0.66	3.74	71
33	34.94	0.29	3.89	90
34	28.00	0.59	2.93	67
35	35.67	1.07	3.88	95
36	33.96	0.64	3.90	76
37	34.10	0.76	3.64	73
38	12.80	0.47	1.45	24
39	28.30	0.87	3.18	58
40	26.65	0.51	2.94	57
41	18.95	0.63	2.06	55
42	34.94	0.97	4.04	78
43	15.18	0.50	1.53	25
44	26.19	0.87	2.89	45
45	32.87	1.00	3.68	67
46	27.26	0.87	3.01	62
48	27.81	0.46	3.04	63
49	7.90	0.21	0.77	18
50	35.70	1.00	3.94	74
51	32.64	1.05	3.75	84
52	17.05	0.52	1.71	0
53	33.65	1.07	3.85	61
54	24.84	0.91	2.75	60

Table - 5 (cntd.)

Sample no.	P_2O_5 (%)	SO_3 (%)	F (%)	U (ppm)
55	31.62	0.97	3.72	71
56	36.24	0.54	4.00	77
57	34.98	0.81	4.14	75
58	33.44	0.59	3.92	81
59	35.33	0.63	4.15	44
60	23.31	0.70	2.52	50
61	2.27	0.26	0.24	21
62	2.68	0.07	0.29	34
63	34.73	0.95	4.06	72
64	25.56	0.84	2.87	55
65	32.89	0.44	3.70	61
66	31.28	0.37	3.57	83
67	36.78	0.66	3.96	100
68	37.10	0.61	4.07	86
69	7.01	0.46	0.85	36
70	9.88	0.45	1.06	63
71	9.88	0.45	1.09	41
72	22.31	0.56	2.56	55
73	30.13	1.15	3.49	74
74	25.69	0.55	2.85	54
75	23.72	0.79	2.62	55
76	10.88	0.39	1.19	31
77	18.06	0.58	2.01	47
78	19.41	0.81	2.24	79
79	19.31	0.67	2.20	48
80	9.37	0.40	1.04	19
81	28.75	0.97	3.23	66
82	20.06	0.73	2.33	74
83	22.55	1.03	2.61	71
84	26.22	0.71	2.67	82
85	17.53	0.83	2.08	55
86	24.46	1.00	2.83	73
87	35.31	1.02	4.07	73
88	31.09	0.85	3.48	93
89	4.31	0.32	0.47	17
90	5.72	0.33	0.64	30
91	18.94	0.68	2.09	77
92	13.71	0.68	1.47	55
93	13.37	0.71	1.56	60
94	6.18	0.41	0.78	33
95	22.48	1.06	2.63	82
96	11.61	0.52	1.31	29
97	24.09	0.97	2.77	73
98	26.23	0.58	2.97	74
99	14.98	0.62	1.78	54
100	15.42	0.70	1.76	48
101	10.24	0.23	1.15	40
102	19.23	0.62	2.16	68
103	19.86	0.63	2.20	54
104	14.43	0.51	3.14	31
105	14.38	0.49	1.60	51
106	6.57	0.33	0.69	15
107	8.96	0.33	0.97	35

Table - 5 (cntd.)

Sample no.	P_2O_5 (%)	SO_3 (%)	*F (%)*	*U (ppm)*
108	14.44	0.54	1.58	26
109	16.42	0.77	1.97	58
110	15.17	0.65	1.70	45
112	15.67	0.65	1.78	44
113	15.17	0.50	1.62	43
114	12.96	0.50	1.38	39
115	18.15	0.82	2.14	75
116	33.46	1.11	3.89	66
117	14.53	0.50	1.56	43
118	26.34	0.81	2.93	65
119	9.71	0.40	1.07	24
120	21.12	0.94	2.41	94
121	16.04	0.56	1.61	53
122	32.60	0.97	3.79	90
123	19.84	0.86	2.34	63
124	12.81	0.55	1.43	32
125	3.71	0.25	0.38	27
126	17.15	0.84	2.00	62
127	23.30	0.91	2.65	63
128	26.06	0.84	2.97	38
129	11.96	0.49	1.29	25
130	20.22	0.59	2.20	38
131	18.28	0.68	2.04	50
132	18.29	0.88	2.13	58
133	11.86	0.43	1.32	35
134	14.54	0.59	1.62	34
135	7.84	0.38	0.85	24
136	5.03	0.30	0.53	21
137	23.15	1.13	2.80	90
138	3.44	0.27	0.38	16
139	3.13	0.32	0.35	18
140	7.35	0.36	0.80	19
141	5.06	0.33	0.52	19
142	21.23	0.87	2.44	40
143	8.04	0.41	0.90	47
144	11.55	0.56	1.27	34
145	13.52	0.50	1.33	24
146	14.26	0.55	n.b.	27
147	13.66	0.65	n.b.	62
148	9.98	0.47	n.b.	31
149	25.39	0.75	n.b.	56
150	15.38	0.72	1.66	55
151	19.24	0.94	2.32	71
152	14.90	0.54	1.65	46
153	8.13	0.31	0.90	29
154	19.45	0.82	2.25	64
155	15.00	0.61	1.75	41
156	13.90	0.51	1.52	37
157	22.73	0.45	2.59	57
158	15.09	0.61	1.69	60
159	6.11	0.33	0.73	34
160	9.93	0.43	1.15	40

Table - 5 (cntd.)

Sample no.	P_2O_5 (%)	SO_3 (%)	*F (%)*	*U (ppm)*
161	12.41	0.43	1.40	39
162	7.60	0.40	0.81	17
163	11.44	0.54	1.32	57
164	19.57	0.56	2.14	29
165	36.44	0.80	4.00	78
166	16.73	0.43	1.59	33
167	37.18	0.46	3.92	75
168	29.68	0.68	3.03	74
169	23.14	0.47	2.08	44
170	34.98	0.54	3.60	71
171	30.90	0.44	3.43	72
172	35.62	0.57	4.06	89
173	24.06	0.75	2.59	58
175	31.01	0.62	3.52	84
176	31.03	0.81	3.69	84
177 a	0.40	0.20	0.04	14
177 b	4.61	0.13	0.40	6
178	29.78	0.43	3.24	62
179	17.15	0.56	1.89	47
180	33.96	0.79	3.97	85
181	33.72	0.53	3.81	86
182	7.32	0.32	0.79	27
183	17.73	0.62	1.96	48
184	20.88	0.67	2.27	38
185	36.47	0.70	4.01	65
186	38.61	0.52	4.09	68
187	20.72	0.47	2.31	53
188	13.00	0.56	1.44	17
189	32.93	1.03	3.66	101
190	30.51	0.92	3.22	90
191	23.42	0.43	2.50	58
192	33.52	0.45	3.48	77
193	13.33	0.80	1.70	55
194	32.86	0.88	3.88	71
195	25.33	0.83	2.63	65
196	34.50	0.75	4.15	94
197	21.23	0.78	2.14	59
198	33.50	0.77	3.41	73
200	27.17	1.13	3.29	85
201	0.44	0.04	n.b.	n.b.
202	31.56	0.70	3.37	137
203	35.53	0.29	3.86	83
204	35.42	0.68	4.07	81
205	21.82	0.66	2.18	52
206	35.56	0.85	3.97	90
207	36.16	0.83	3.99	74
208	31.63	0.90	3.46	76
209	21.54	0.69	2.32	62
210	8.20	0.47	0.89	33
211	23.36	0.88	2.65	60
212	26.13	0.99	2.92	69
213	14.12	0.54	1.57	47
214	15.43	0.47	1.43	37

Table - 5 (cntd.)

Sample no.	P_2O_5 (%)	SO_3 (%)	F (%)	U (ppm)
215	32.51	0.84	3.86	87
216	26.40	0.93	2.96	57
217	26.18	0.78	2.91	73
218	16.62	0.46	1.63	40
219	33.58	1.15	4.02	100
220	28.37	1.04	3.34	69
221	28.72	0.75	3.31	68
222	33.70	0.59	3.76	70
223	7.93	0.22	0.86	27
224	10.36	0.26	0.96	38
225	34.31	1.05	3.97	101
226	34.55	0.69	4.13	108
227	6.00	0.14	0.60	26
228	6.69	0.14	0.64	33

3. CONCLUSION

1. Geochemical studies revealed that U, F, V and other rare elements found in the Mazıdağı phosphate ores exist within the structure of such phosphate minerals as dahllite and collophane. However, for some elements, such as Cr and Ni, further mineralogical studies are necessary in order to determine with which minerals they are associated. Collophane and dahllite probably contain some S (in SO_2 or SO_4^{2-} form) (McKelvey, 1967). These also can be clarified further by mineralogical studies.

2. «U» reserves of the Mazıdağı phosphate ores in various grades were calculated as a total of 6,292 tons of uranium (or 7,419.5 tons of U3O8) through the geochemical relationship between «U» and «P_3O_5».

A total of 2,722,207 tons of F was estimated based on the geochemical relationship between U and F. The reserves of V, Y and some other rare elements found in trace amounts in the phosphate ores can be estimated only after quantitative analyses.

3. The methods to be applied for the recovery of U and other rare elements as by-products during the production of phosphoric acid and mineral fertilizer should be determined through extensive laboratory tests taking into consideration the types of convenient mineral fertilizers and the economical conditions, etc.

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