Ulvi Can Ünlügenç

Dear Colleagues,

The Chamber of Mining, Metallurgical and Geological Engineers of the Union of the Chambers of the Cyprus Turkish Engineers and Architects decided to revise and reorganize the publicity of this journal.

From this issue of the journal will be under the supervision of a board, distinguished members of which are selected among different well known universities of the subject.

You now have in your hand an issue with higher quality of material and a new cover. I believe that you will find the scientific level of the contents higher and more interesting than before as a result of selected subjects from among those with letter quality. The new dimension of the journal echieved as a result of the contemporary approaches and the unexhausted efforts will help to produce scientific answers to the geological questions that exist in Cyprus, Middle East and Mediterranean.

On behalf of the members of the Union, I want to take this opportunity to thank and wish success to all who contributed in all ways to make this issue organized, supervised, published and distributed.

Bektaş GÖZE
President
Union of the Chambers of the Cyprus
Turkish Engineers and Architects

TO THE READERS

GEOSOUND/YERBİLİMCİNİN SESİ (No's 14 and 15) The Union of the Chambers of Cyprus Turkish Engineers and Architects, Bulletin is publised in English, French and Deutsch and Turkish.

Yerbilimcinin Sesi/Geosound is publised by financial contribution of the adverts provided by certain establishments menaging the activities related to earthsciences.

The first article " The use of Computer Programs in the Calculation of Cation Numbers and Various Geochemical Parameters " prepeared by M.Sezai Kırıkoğlu and Selahattin İlktaç consists of the evoluation of the micro-probe results, especially in the calculation of the cati:n numbers and various geochemical parameters for mineral groups. It also includes silicates and chromium spinels,preparation of computer programs for analysis respectively.

The next article the "Tectonic Setting of The Porhyry and Massive Sulphide Deposits of the Circum Black Sea " prepeared by Şener Üşümezsoy explains the orogenic evolution of orogen, ophiolitic,magmatic arc and suture based on the investigation, and the relation between massive sulphide deposits and tectonism has been determined. The classification of porphyry type deposits based on tectonism has been made.

The third article the " Kıta ve Okyanus Kabukları Üzerinde Gelişen Çökelme Ortamları ve Fasiyesleri/ Depositional Environments and Their Facies Devoloping on Oceanic and Continental Crusts " prepeared by Sungu L. Gökçen,Nizamettin Kazancı and Ergün Gökten states a role of importance of the environments such as oceanic or continental basement.

The last article the "Geothermal Activity in Turkey " done by Cavit Demirkol will be most useful for Turkey because of problems of energy.

For togetherness in the forthcoming Geosound's....

Sincerely Yours

Mr. Halil I.ERDİM

Chief Editor

G E O S O U N D

YERBİLİMCİNİN SESİ

EYLOL 1987 Sayı 14-15
SEPTEMBER *No*

BULLETIN OF THE UNION OF THE CHAMBERS OF CYPRUS TURKISH ENGINEERS AND ARCHITECTS, CHAMBER OF MINING, METALLURGICAL AND GEOLOGICAL ENGINEERS

İÇİNDEKİLER / C O N T E N T S

Kapak Resmi:Ali Kayası(K.Maraş)'ındaki orta ve kalın taneli kumtaşı ardalanması/Cover Pictur:Medium and coarse grained massive sandstone succession at Alikayası Area(K.Maraş)(Anıl,1987).

YERBİLİMCİNİN SESİ | EYLÜL 1987 | Sayı 14-15
GEOSOUND | SEPTEMBER | No

THE USE OF COMPUTER PROGRAMS IN THE CALCULATION OF CATION NUMBERS AND VARIOUS GEOCHEMICAL PARAMETERS

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Abstract: Chemical analysis of various minerals is performed satisfactonly by the electron microprobe. Computer programs are necessary in the evaluation of the microprobe results, especially in the calculation of the cation numbers and various geochemical parameters for the mineral groups. This paper explains the use of a such computer program has been prepared for chromite.

1. INTRODUCTION

Silicates are the major rock forming minerals. The study of the chemical composition of the silicates is important in various fields of earth sciences such as mineralogy, petrography, petrology, mineral deposits and geochemistry. First of all the mineral, whose composition is known, can be characterized most correctly. This is specially true for mineral groups such as plagioclase feldspars, amphibole and pyroxene, where the classification of the mineral is by its composition. The chemical composition of the minerals is also important in geochemistry in providing clues to the genesis of the rock. Similar studies on ore minerals have provided information of the genesis of the host rock, and the ore, and on the mechanizm of the emplacement of the ore.

With the help of the microprobe the chemical composition of the minerals can be determined quickly and accurately. Suitable corrections must be applied to the rough probe results to obtains meaningfull mineral compositions. The first think to do is to determine the cation numbers. Only after this recalculation special parameters can be calculated for the minerals.

The recalculation of the cation numbers and determination of geochemical parameters by hand is long winded. In this study computer programs for such calculations (Appendix 1 and 2) prepared by the authors for the silicate minerals and chromium spinels will be discussed and examples will be presented. The microprobe analyses used in the examples are taken from Kırıkoğlu (1983 and 1987).

Computer programs for drawing diagrams from the cation numbers and from other geochemical parameters are outside the scope of this paper.

2. SILICATES and CHROMIUM SPINELS

One of the principal aims of geochemistry is the meaningfull representation of the compositions of the silicate minerals which are the main constituents of the rocks. The calculation of the cation numbers and subsequently the Or (orthoclase), Ab (albite) and An (anorthite) values from the oxide analysis of feldspars, allows us to name the feldspar minerals. For example a feldspar with the formula of $Or_6Ab_{71}An_{23}$ clearly belongs to the plagioclase group and is an oligoclase.

Similarly the calculation of Ca, Mg and Fe + Mn percentages from the oxide analysis of pyroxenes will allow us to correctly identify the particular pyroxene mineral. For example a pyroxene of composition $Ca_{49}Mg_{31}Fe_{20}$ is a clinopyroxene and can be categorised as augite. On the other hand a pyroxene of composition $Ca_9Mg_{55}Fe_{36}$ is an orthopyroxene (Deer et al 1967).

One can increase the number of such examples. For example the calculation of the cation numbers from the serpantine analysis allows use to correlate Fe and Mg in the mineral structure. Furthermore such an analysis enables us to calculate the H_2O^+ released during the serpentinization process.

Another case where the use of computer programs is inescapable is the evaluation of the amphibole microprobe analysis. The calculation of the cation numbers from the amphibole oxide analysis requires longwinded calculations and is left out of the present study. This topic is treated by Kırıkoğlu (1983).

The determination of the mineral chemistry of the chromium-spinels is important as it provides data on the physicochemical conditions of the formation of the ultrabasic rocks. Chromium-spinels are very stable minerals and stand even extreme conditions of alterations. In many cases they represent the only original minerals from the primary rock.

The element percentages of the chromium-spinels reflect the conditions of the formations and therefore provide clues to the genesis of the rock. Chromium analysis are best done by microprobe. The calculations of the cation numbers and various geochemical parameters involves computers programs using as raw data the elemental oxide values. Chromites with known cation numbers can be classified in the suitable diagrams and the composition of the magnetite rims around chromite and its relation to the chromite core can be evaluated (Kırıkoğlu, 1986). In addition the calculated chromite analysis can be compared in composition and genetically with chromites from other deposits of the world.

3. THE PREPARATION OF COMPUTER PROGRAMS

The preparation of computer programs for the calculation of the cation numbers and various geochemical parameters for feldspar, pyroxene, serpentine and chromium-spinels are discussed below.

The preparatory calculations for computer input are the same for all the discussed mineral groups except the chromium-spinels (Table 1). The first input data for the program is the major element

Table 1
Calculation of the cation numbers from the silicate analysis. As an example the cation number of feldspar is calculated on the basis of 32 oxygen atoms.

Oxide	Weight %	Mol.Wt.	Wt/Mol.Wt.		
SiO_2	61.373	60.085	1.0214	x 2 =	2.0429
TiO_2	0.000	79.899	0.0000	x 2 =	0.0000
Al_2O_3	24.062	101.960	0.2360	x 3 =	0.7080
FeO	0.290	71.846	0.0040		0.0040
MgO	0.000	40.304	0.0000		0.0000
CaO	4.810	56.079	0.0858		0.0858
Na_2O	8.122	61.979	0.1310		0.1310
K_2O	1.167	94.203	0.0124		0.0124
MnO	0.034	70.937	0.0005		0.0005
Total	99.859				2.9846

The calculation is done on the basis of 32 oxygen atoms

2.9846 : 32 = 0.0933 and 1 : 0.0934 = 10.7217

Si	1.0214 x 10.7217 =	10.9511
Ti	0.0000 x 10.7217 =	0.0000
Al	2 x 0.2360 x 10.7217 =	5.0606
Fe	0.0040 x 10.7217 =	0.0429
Mg	0.0000 x 10.7217 =	0.0000
Ca	0.0858 x 10.7217 =	0.9199
Na	2 x 0.1310 x 10.7217 =	2.8091
K	2 x 0.0124 x 10.7217 =	0.2659
Mn	0.0005 x 10.7217 =	0.0054

oxide data for the silicates. These are SiO_2, TiO_2, Al_2O_3, FeO (total iron), MgO, CaO, Na_2O, K_2O and MnO weight percentages. From these values the elemental percentages of Si, Ti, Al, Fe, Mg, Ca, Na, K and Mn are calculated by the computer.

The second input data for the program are the molecular oxide constants for the respective elements. The program calculates at this stage the % weight/molecular weight ratios and adds up the ratios for each element (Table 1).

Until this stage the process is the same for feldspar, pyroxene and serpentine, at the next stage a specific number of oxygen atoms for each mineral group is included in the program. The number of oxygen is 32 for same feldspars, 6 for pyroxenes and 9 for serpentine. The division of the number of oxygen atoms by the % weight/molecular weight ratios and reciprocating the resultant number constitutes the next stage. The resultant number is taken as a constant for the next process. Table 1 shows examples of such a process for 32 oxygens. This constant, when multiplied by the oxide analysis of the element, will give the cation number of this element.

With the calculation of the cation numbers, a major part of the calculations are completed. The calculations which follow essentially the same part for the mineral groups, are different for the calculations of the geochemical parameters. These are discussed separately below.

3.1. Feldspars

Feldspar minerals which can be grouped under alkali feldspar and plagioclase are named according to their Or, Ab and An percentages. The cation numbers, calculated as discussed above, for K (Or), Na (Ab) and Ca (An) are taken together as 100 % and each is recalculated (Table 2). Table 3 shows the calculation of the cation numbers and Or-Ab-An triangular diagram and the feldspar is thus named (Figure 1).

Table 2
Calculation of Or-Ab-An values
for feldspars from the cation numbers.

Cations	Cation numbers	Or-Ab-An values	
K	0.2659	Or	6.65
Na	2.8091	Ab	70.32
Ca	0.9199	An	23.03
Total	3.9949	Total	100.00

Table 3
Cation numbers and Or-Ab-An
parameters calculation from the feldspar analysis.

Sample Nr	1	2	3	4	5
SiO_2	65.93	64.02	65.50	60.64	59.67
TiO_2	0.25	0.00	0.01	0.03	0.00
Al_2O_3	18.41	18.75	20.68	25.24	25.44
FeO	3.27	0.21	0.36	0.27	0.27
MgO	0.09	0.02	0.01	0.00	0.00
CaO	0.05	0.00	0.89	4.88	7.35
Na_2O	1.56	5.17	7.85	3.22	7.58
K_2O	11.72	9.92	5.11	1.12	0.55
MnO	0.05	0.00	0.00	0.02	0.01
Total	101.33	98.09	100.41	101.42	100.87
The calculation is done on the basis of 32 oxygen atoms.					
Si	11.94	11.86	11.66	10.72	10.60
Ti	0.03	0.00	0.00	0.00	0.00
Al	3.93	4.09	4.34	5.26	5.33
Fe	0.50	0.03	0.05	0.04	0.04
Mg	0.02	0.01	0.00	0.00	0.00
Ca	0.01	0.00	0.17	0.92	1.40
Na	0.55	1.86	2.71	3.16	2.61
K	2.71	2.34	1.16	0.25	0.12
Mn	0.01	0.00	0.00	0.00	0.00
Or	82.90	55.80	28.75	5.83	2.99
Ab	16.80	44.20	67.04	72.85	63.18
An	0.30	0.00	4.21	21.32	33.83

Table 4

Calculation of the pyroxene cation numbers.

Oxide	Weight %	Mol.Wt.	Wt/Mol.Wt.			
SiO_2	54.191	60.085	0.9019	x 2	=	1.8038
TiO_2	0.169	79.899	0.0021	x 2	=	0.0042
Al_2O_3	0.964	101.960	0.0095	x 3	=	0.0284
FeO	3.661	71.846	0.0510			0.0510
MgO	16.262	40.304	0.4035			0.4035
CaO	24.736	56.079	0.4411			0.4411
Na_2O	0.351	61.979	0.0057			0.0057
K_2O	0.000	94.203	0.0000			0.0000
MnO	0.128	70.937	0.0018			0.0018
Total	100.461					2.7395

The calculation is done on the basis of 6 oxygen atoms.

2.7395 : 6 = 0.4566 and 1 : 0.4566 = 2.1902

Si	0.9019 x 2.1902	=	1.9753
Ti	0.0021 x 2.1902	=	0.0046
Al	2 x 0.0095 x 2.1902	=	0.0416
Fe	0.0510 x 2.1902	=	0.1117
Mg	0.4035 x 2.1902	=	0.8837
Ca	0.4411 x 2.1902	=	0.9661
Na	2 x 0.0057 x 2.1902	=	0.0250
K	2 x 0.0000 x 2.1902	=	0.0000
Mn	0.0018 x 2.1902	=	0.0039

up and recalculated to 100 % (Table 4 and 5). Table 6 shows the results of this calculation using the computer program in the appendix 1.

Table 5

Calculation of the Ca, Mg and Fe + Mn percentages in pyroxene.

Cations	Cation numbers	Ca-Mg-Fe-Mn values
Ca	0.9661	49.16
Mg	0.8837	44.96
Fe	0.1117	5.68
Mn.	0.0039	0.20
Total	1.9654	100.00

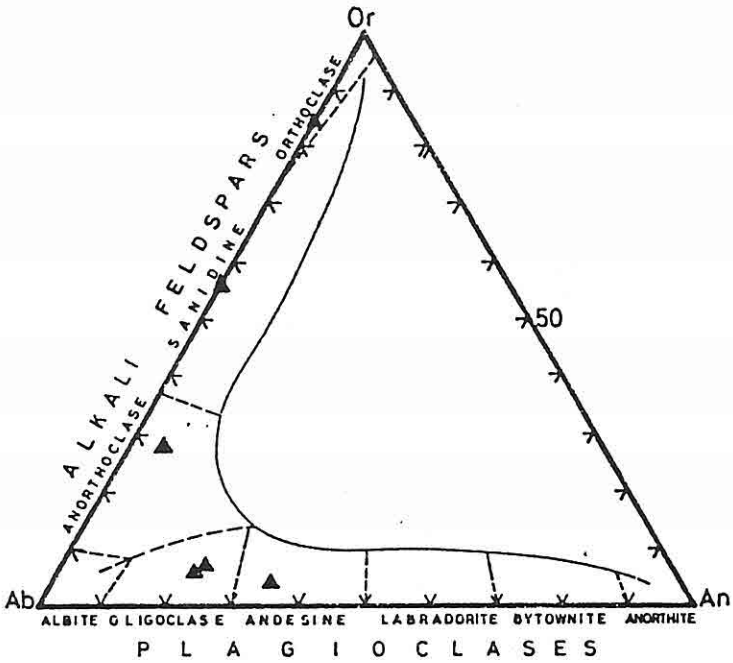

Fig. 1: Or-Ab-An triangular diagram for feldspars (Tröger, 1969).

The alkali feldspars are orthoclase of a mean composition of $Ab_{16.8}An_{0.3}Or_{82.9}$, sanidin of $Ab_{44.2}An_{0}Or_{55.8}$ and anorthoclase $Ab_{67.0}$-$An_{4.2}Or_{28.8}$. The anorthite content of the analysed plagioclase feldspars ranges between $An_{21.3}$ and $An_{33.8}$. Plagioclase is also rich in albite (up to Ab_{73}). Thus the analysed plagioclase can be named as oligoclase and andesine (Figure 1).

3.2. Pyroxene

The Ca, Mg and Fe + Mn cation numbers of the pyroxenes are added

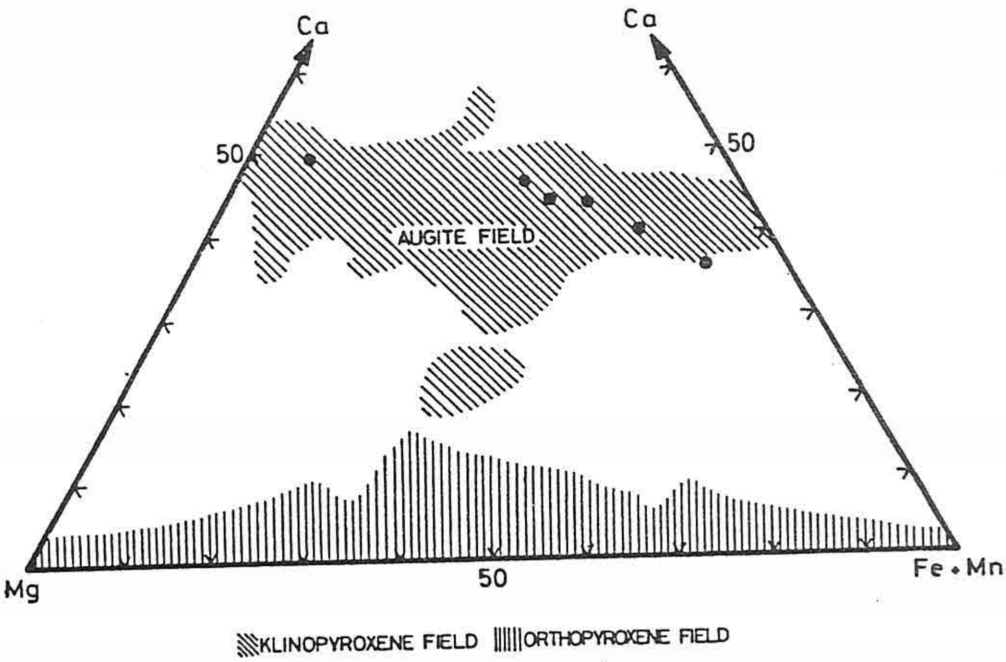

Fig. 2: Ca-Mg-Fe+Mn triangular diagram for pyroxenes.

Table 6
Cation numbers and Ca-Mg-Fe-Mn
parameters calculated from the pyroxene analysis.

Sample Nr	1	2	3	4	5
SiO_2	48.68	49.58	50.02	50.61	49.89
TiO_2	0.41	0.24	0.24	0.13	0.23
Al_2O_3	1.46	1.16	1.04	0.93	2.71
FeO	26.46	29.15	20.16	18.68	16.98
MgO	2.25	3.87	5.69	6.67	8.00
CaO	14.07	16.65	18.37	19.47	21.06
Na_2O	5.61	4.43	3.80	3.25	1.70
K_2O	0.00	0.04	0.00	0.00	0.00
MnO	1.31	1.67	1.37	1.38	0.55
Total	100.25	100.79	100.69	101.12	101.12
The calculation is done on the basis of 6 oxygen atoms.					
Si	1.978	1.980	1.973	1.974	1.922
Ti	0.012	0.007	0.007	0.004	0.007
Al	0.070	0.055	0.048	0.043	0.123
Fe	0.899	0.773	0.665	0.609	0.547
Mg	0.137	0.231	0.335	0.388	0.460
Ca	0.612	0.712	0.777	0.814	0.869
Na	0.441	0.343	0.291	0.246	0.127
K	0.000	0.002	0.000	0.000	0.000
Mn	0.045	0.056	0.046	0.045	0.018
Ca	36.15	40.16	42.62	43.86	45.88
Mg	8.09	13.03	18.38	20.91	24.29
Fe	53.10	43.60	36.48	32.81	28.88
Mn	2.66	3.21	2.52	2.42	0.95

These values are inserted in the Ca-Mg-Fe triangular diagram and the pyroxene is thus named (Figure 2).

The results of the calculations indicate that the pyroxenes are clinopyroxene and the Ca-Mg-Fe percentages do not show much variation (between $Ca_{49}Mg_{45}Fe_6$ and $Ca_{36}Mg_8Fe_{56}$). Pyroxene of this composition named as augite (Figure 2).

3.3. Serpentine

The geochemical parameter required in the serpentine, whose cation number is calculated as in pyroxene and feldspar, is the 100 Mg / Mg + Fe ratio (Table 7).

Table 7
Calculation of the serpentine cation numbers and 100 Mg/Mg+Fe parameters.

Oxide	Weight %	Mol.Wt.	Wt/Mol.Wt.			
SiO_2	44.301	60.085	0.7373	x 2	=	1.4746
Al_2O_3	1.067	101.960	0.0105	x 3	=	0.0314
FeO	4.029	71.846	0.0561		=	0.0561
MgO	36.337	40.304	0.9016		=	0.9016
CaO	0.284	56.079	0.0051			0.0051
Cr_2O_3	0.826	152.020	0.0054	x 3	=	0.0162
Total	86.927					2.4862

The calculation is done on the basis of 9 oxygen atoms.

2.4862 : 9 = 0.2762 and 1 : 0.2762 = 3.6200

Si	0.7373 x 3.62	=	2.6690
Al	2 x 0.0105 x 3.62	=	0.0760
Fe	0.0561 x 3.62	=	0.2031
Mg	0.9016 x 3.62	=	3.2638
Ca	0.0051 x 3.62	=	0.0185
Cr	2 x 0.0054 x 3.62	=	0.0391

$$\frac{100\ Mg}{Mg + Fe} = \frac{100 \times 3.2638}{3.2638 + 0.2031} = 94.11$$

Table 8 shows the cation numbers and the 100 Mg / Mg + Fe ratios for the serpentine calculated by the computer program.

Table 8
Calculated cation numbers and parameters for serpantine.

Sample Nr	1	2	3	4	5
SiO_2	44.30	40.03	42.68	41.78	42.16
Al_2O_3	1.07	0.06	1.03	1.60	0.95
FeO	4.03	10.15	3.99	3.55	3.67
MgO	36.34	35.14	35.96	36.00	36.15
CaO	0.28	0.60	0.13	0.01	0.00
Cr_2O_3	0.83	0.01	0.78	0.77	0.55
Total	86.85	85.99	84.57	83.71	83.48
The calculation is done on the basis of 9 oxygen atoms.					
Si	2.67	2.54	2.65	2.61	2.64
Al	0.08	0.00	0.08	0.12	0.07
Fe	0.20	0.54	0.21	0.19	0.19
Mg	3.26	3.33	3.32	3.36	3.38
Ca	0.02	0.04	0.01	0.00	0.00
Cr	0.04	0.00	0.04	0.04	0.03
$\frac{100\ Mg}{Mg + Fe}$	94.22	86.05	94.05	94.65	94.68

The FeO content of the serpentine varies between 3.55 % and 10.15 % and the FeO / MgO ratio is greater than one.

This indicates that the iron released by the alteration of the olivin is only partly accepted by the antigorite and the rest is included in the sulphide and oxide phases in the rock.

3.4. Chromium Spinels

The calculation of the cation numbers and geochemical parameters from the oxide analysis of the chromium spinels is discussed in detail below.

The account is an illustration of the method described by Ageed (1979) for the calculation of ionic content of chromite unit cells and end-members from their analysis.

STEP 1: Calculation of ionic content of chromite unit cells.

Assuming a unit cell content of 8 (RO . R_2O_3) for the spinel structure, the number of atoms of each metal present in the unit cell can be calculated. The calculation can be made as follows:

a) Molecular ratios of the oxides are obtained by dividing the percentage of each oxide by its molecular weight.

b) The ratio RO to R_2O_3 is then calculated after subtracting ilmenite and the silicate impurities.

Note: In samples having a ratio of RO to R_2O_3 appreciably less than 1, oxidation of ferrous to ferric oxide may be assumed, and the analysis are to be recalculated to agree with the spinel fomula.

c) The molecular ratios are then recalculated to atoms per unit cell, assuming 8 bivalent and 16 trivalent metal ions as given by Bragg (1966).

The above steps were followed for the calculation of the ionic content of the Okçuköy chromite (Kırıkoğlu, 1983; sample 33, table 11) as given below:

	Wt%	MWt.	M.ratios	atoms/unit cell	
Cr_2O_3	48.44	152.02	0.3187	Cr	9.83
Al_2O_3	18.58	101.94	0.1822	Al	5.68
Fe_2O_3	2.00	159.68	0.0125	Fe^{3+}	0.39
			0.5134		16.00

	Wt%	MWt.	M.ratios	atoms/unit cell	
FeO	22.89	71.84	0.3174	Fe^{2+}	4.96
MgO	7.68	40.32	0.1906	Mg	2.98
MnO	0.30	70.93	0.0042	Mn	0.06
CaO	0.00	56.08	0.0000	Ca	0.00
			0.5122		8.00

	Wt%	MWt.	M.ratios
TiO_2	0.09	79.90	0.0012
SiO_2	0.01	60.06	0.0001

$$\frac{RO}{R_2O_3} = \frac{0.5122}{0.5134} = 1$$

STEP 2: Expression of the analysis in terms of end-members. End-member formulae per unit cell are calculated by the following equations:

Spinel ($MgAl_2O_4$) = Al / 2

Magnesiochromite ($MgCr_2O_4$) = Mg - Al / 2

Ferrochromite ($FeCr_2O_4$) = (Cr + Al) / 2 - Mg

Magnetite ($FeFe_2O_4$) = (Fe^{2+} + Mg) - (Cr + Al) / 2 = Fe^{3+} / 2

where each of the elements is given in atoms per unit cell.

To calculate the weight percentages of end-members, the fomulas per unit cell are multiplied by the molecular weights of the end-members and recalculated to 100 per cent.

As an example, the end-members of sample 33 -given above- are calculated below:

THE USE COMPUTER PROGRAMS

	Formulas/unit cell	Formula MWt/unit cell	Wt%
Spinel	2.84	403	25.97
Magnesiochromite	0.20	38	2.45
Ferrochromite	4.76	1066	68.68
Magnetite	0.20	45	2.90
		1552	100.00

Table 9

Various geochemical parameters and cation numbers calculated from the microprobe analysis of chromium spinels using computer programs (' analyzed, " calculated).

Sample Nr	1	2	3	4	5
FeO'	27.30	37.12	26.22	29.38	14.35
FeO"	23.00	22.53	23.04	25.73	11.15
Fe_2O_3"	5.43	14.65	2.29	5.71	6.44
Cr_2O_3	47.94	41.14	48.59	49.72	58.85
Al_2O_3	15.87	13.98	17.97	13.17	8.87
MgO	7.20	7.90	7.64	5.21	14.48
MnO	0.46	0.33	0.41	0.32	0.00
TiO_2	0.09	0.07	0.07	0.11	0.19
CaO	0.00	0.00	0.00	0.00	0.00
SiO_2	0.02	0.00	0.00	0.03	0.02
Total	98.88	99.94	100.90	97.94	96.76
The calculation is done on the basis of 32 oxygen atoms.					
Cr	9.99	8.67	10.02	10.63	12.04
Al	4.93	4.39	5.53	4.20	2.71
Fe^{+3}	1.08	2.94	0.45	1.17	1.25
Fe^{+2}	5.06	5.02	4.93	5.82	2.41
Mg	2.84	2.90	2.97	2.10	5.59
Mn	0.10	0.08	0.10	0.08	0.00
Ti	0.02	0.02	0.02	0.02	0.04
Cr/Fe	1.51	1.01	1.70	1.42	3.06
RO/R_2O_3	1.00	1.00	1.00	1.00	0.99
MgO/RO	36.63	37.20	38.28	27.20	69.83
$MgAl_2O_4$	22.18	19.54	25.24	18.40	12.39
$MgCr_2O_4$	5.77	9.46	3.79	0.93	52.52
$FeCr_2O_4$	64.13	49.72	67.63	72.35	25.74
$FeFe_2O_4$	7.92	21.28	3.34	8.32	9.35
$TiFe_2O_4$	0.25	0.25	0.25	0.25	0.50
X Al_2O_4	30.74	27.37	34.48	26.18	16.85
X Cr_2O_4	62.28	54.05	62.47	66.27	74.88
X Fe_2O_4	6.73	18.33	2.80	7.30	7.77
X = (Mg, Mn, Fe)					

Table 9 shows the results of this calculation using the computer program in the appendix 2. The resultant values are plotted in the $Al / Fe^{3+} + Cr + Al - Fe^{3+} / Fe^{3+} + Cr + Al - Cr / Fe^{3+} + Cr + Al$ triangular diagram and the chromite is thus named (Figure 3).

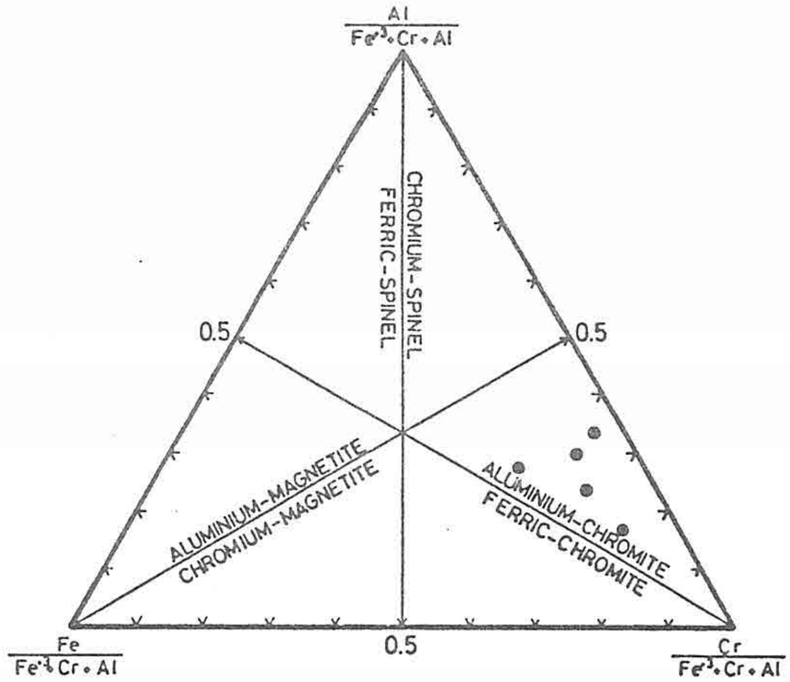

Fig. 3: The classification of the chromium-spinels in the Haslam et al.(1976) triangular diagram.

4. RESULTS

This paper discusses the use of computer programs in the evaluation of the analytical results. The program and the guide lines for the preparation of the program for the calculation of cation numbers and geochemical parameters for feldspar, pyroxene and serpentine and chromium spinel are presented. The mineral analysis data used as examples in the program are the silicates from the Karaburunsivri tepe phonolite, the serpentine and chromium spinels from the Okçuköy metaophiolite.

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APPENDIX 1

```
1 REM**********************************
2 REM* CALCULATION OF THE CATION NUMBERS
3 REM* FROM THE SILICATE ANALYSES
6 REM**********************************
8 POKE53280,1:POKE53281,1
9 R$=CHR$(83)+CHR$(46)+CHR$(73)+CHR$(76)+CHR$(75)+CHR$(84)+CHR$(65)+CHR$(67)
10 DIM A$(18),X$(35),Z$(3,35):W=32
50 REM *********************************
80 PRINT"(CLR) CALCULATION OF THE CATION NUMBERS FROM THE SILICATE ANALYSES
99 PRINT"(DOWN)(DOWN)(DOWN)";R$;"
100 REM READING THE SILICATES
105 REM ********************************
110 FOR N=1 TO 18:READ A$(N):NEXT
115 REM ********************************
120 REM READING THE MOLE WEIGHTS OF THE SILICATES
125 REM ********************************
130 FOR N=1 TO 9:READ A(N):NEXT
139 REM ********************************
140 REM WEIGHT PERCENTAGE
141 REM ********************************
142 PRINT"(DOWN)(DOWN)(DOWN)1)Feldspar ",,,"2)Serpontine",,,"3)Hornblend",,,"4)Pyroxene";
143 IFVE=1THENW=32
144 IFVE=2THENW=9
145 IFVE=3THENW=24
146 IFVE=4THENW=6
147 IFVE<0ORVE>4THEN142
148 INPUT"ORNEK ADI:";I$
149 IFVE=2 THENA$(7)="CR203 ":A$(16)="CR2X ":A(7)=150
154 INPUT"(DOWN)Solution in one page MAX.3";J
155 FORK=1 TO J
157 PRINT"(CLR) Input the necessary data ";K;" . Data ":INPUT"Sample";L$(K)
158 L$(K)=L$(K)+"                    ":L$(K)=LEFT$(L$(K),15)
159 FOR N=1 TO 9
160 PRINTA$(N);:INPUT B(N):NEXT
170 PRINT:INPUT"Are the data correct (E/H): ": D$
190 IF D$="H" THEN 157
199 REM ********************************
200 REM CALCULATION OF THE WEIGHT/MOLE WEIGHT PERCENTAGE
201 REM ********************************
205 FOR N=1 TO 9
210 C(N)=B(N)/A(N):NEXTN
219 REM ********************************
220 REM CALCULATION OF THE FIRST RESULTS
221 REM ********************************
230 D(1)=C(1)*2:D(2)=C(2)*2:D(3)=C(3)*3:D(7)=D(7)*3
240 FOR N=4 TO 9
250 D(N)=C(N):NEXT
259 REM ********************************
260 REM SUM OF THE TOTAL WEIGHT AND RESULTS
261 REM ********************************
265 TA=0:TS=0
270 FOR N=1 TO 9
280 TA=TA+B(N):TS=TS+D(N):NEXT
289 REM ********************************
290 REM DIVISION OF TS TO THE OXYGEN ATOMS AND ITS RECIPROCAL
291 REM ********************************
300 X1=TS/W:X2=1/X1
309 REM ********************************
310 REM FINAL RESULTS
311 REM ********************************
312 C(3)=C(3)*2:C(7)=C(7)*2:C(8)=C(8)*2
315 FOR N=1 TO 9
320 E(N)=C(N)*X2:NEXT
321 REM ********************************
330 ONVEGOTO400,500,600,700
351 REM ********************************
389 REM FELDSPAR
391 REM ********************************
400 TF=E(6)+E(7)+E(8)
410 AN=((E(6)*100)/TF):X$(28)=STR$(AN)
420 AB=((E(7)*100)/TF):X$(29)=STR$(AB)
430 ZZ=((E(8)*100)/TF):X$(30)=STR$(ZZ)
440 GOTO800
485 REM ********************************
490 REM SERPENTINE
495 REM ********************************
500 S1=100*E(5):S2=E(5)+E(4):SS=S1/S2:X$(28)=STR$(SS)
510 GOTO800
600 GOTO800
689 REM ********************************
690 REM PYROXENE
691 REM ********************************
700 TP=E(4)+E(5)+E(6)+E(9)
710 FE=((E(4)*100)/TP):X$(28)=STR$(FE)
720 MG=((E(5)*100)/TP):X$(29)=STR$(MG)
730 CA=((E(6)*100)/TP):X$(30)=STR$(CA)
740 MN=((E(9)*100)/TP):X$(31)=STR$(MN)
750 GOTO800
760 REM*********************************
770 REM CHANGE FROM NUMERIC TO ALPHA NUMERIC VARIABLES
780 REM*********************************
800 FORN=1 TO 9
810 X$(N)=STR$(B(N)):NEXT
820 FORN=10TO 18
830 X$(N)=STR$(D(N-9)):NEXT
840 FORN=19TO 27
850 X$(N)=STR$(E(N-18)):NEXT
900 FOR N=1 TO 31
910 X$(N)=X$(N)+"                    ":X$(N)=LEFT$(X$(N),15):NEXTN
915 FORN=1 TO 35
920 Z$(K,N)=X$(N):NEXTN:GOSUB2000:H$(K,1)=STR$(TA):H$(K,2)=STR$(TS):NEXTK
930 FORN=1 TO 3:FORK=1 TO 3:H$(N,K)=H$(N,K)+"
940 H$(N,K)=LEFT$(H$(N,K),14):NEXTK:NEXTN
950 INPUT"(DOWN)(DOWN)printer output (E/H):";M$
960 IFM$="E"THEN 1000
970 RUN
985 REM*********************************
990 REM REGULATION OF THE PRINTER OUTPUT
995 REM*********************************
1000 OPEN4,4
1001 PRINT#4,CHR$(27);CHR$(72);CHR$(27);"M";CHR$(10);CHR$(27);"D";CHR$(75)
1002 PRINT#4,CHR$(27);CHR$(45);CHR$(1)
1003 PRINT#4,"CALCULATION OF THE CATION NUMBERS FROM THE SILICATE ANALYSES:PRIN
1005 PRINT#4,"sample":I$
1006 PRINT#4,"NO    :";L$(1);" ";L$(2);" ";L$(3)
1008 FORN=1 TO 65:PRINT#4," ";:NEXTN:PRINT#4
1010 FOR N=1 TO 9
1020 PRINT#4,A$(N);Z$(1,N);" |";Z$(2,N);" |";Z$(3,N):NEXT
1040 FORN=1 TO 65:PRINT#4," ";:NEXTN:PRINT#4
1045 PRINT#4,"TOPL. ";H$(1,1);"  |";H$(2,1);"  |";H$(3,1)
1046 FORN=1 TO 65:PRINT#4," ";:NEXTN:PRINT#4
1047 PRINT#4,"THE CALCULATION PERFORMED ON THE BASIS OF ";W;" OXYGEN ATOMS"
1048 FORN=1 TO 65:PRINT#4," ";:NEXTN:PRINT#4
1050 FORN=19 TO 27
1060 PRINT#4,A$(N-9);Z$(1,N);" |";Z$(2,N);" |";Z$(3,N):NEXT
1070 FORN=1 TO 65:PRINT#4," ";:NEXTN:PRINT#4
1080 ONVEGOTO1100,1200,1300,1400
1100 PRINT#4,"AN   :";Z$(1,28);" |";Z$(2,28);" |";Z$(3,28)
1110 PRINT#4,"AB   :";Z$(1,29);" |";Z$(2,29);" |";Z$(3,29)
1120 PRINT#4,"OR   :";Z$(1,30);" |";Z$(2,30);" |";Z$(3,30)
1130 FORN=1 TO 65:PRINT#4," ";:NEXTN:PRINT#4:CLOSE4:GOSUB50000:RUN
1200 PRINT#4,"result :";Z$(1,28);" |";Z$(2,28);" |";Z$(3,28)
1210 FORN=1 TO 65:PRINT#4," ";:NEXTN:PRINT#4:CLOSE4:GOSUB50000:NEXTR:RUN
1300 REM:RUN
1400 PRINT#4,"%FE   :";Z$(1,28);" |";Z$(2,28);" |";Z$(3,28)
1410 PRINT#4,"%MG   :";Z$(1,29);" |";Z$(2,29);" |";Z$(3,29)
1420 PRINT#4,"%CA   :";Z$(1,30);" |";Z$(2,30);" |";Z$(3,30)
1430 PRINT#4,"%MN   :";Z$(1,31);" |";Z$(2,31);" |";Z$(3,31)
1440 FORN=1 TO 65:PRINT#4," ";:NEXTN:PRINT#4:NEXTR:RUN
1890 REM********************************
1900 REM REGULATION OF THE SCREEN OUTPUT
1910 REM********************************
2000 PRINT"(CLR)"
2010 FORN=1 TO 9:PRINTA$(N);B(N):GOSUB60000:NEXT:GOSUB50000
2020 PRINT"(CLR)":FORN=1 TO 9:PRINTA$(N+9);E(N):GOSUB60000:NEXT:GOSUB50000
2030 IFVE=1 THEN 2050
2040 GOTO 2060
2050 PRINT"(CLR)":PRINT"AN:";AN:GOSUB60000:PRINT"AB:";AB:GOSUB60000:PRINT"OR:";ZZ:GOSUB5
2060 IF VE=2 THEN PRINT"(CLR)100*MG/MG+MN=";SS:GOSUB50000:RETURN
2070 IFVE=3THEN RETURN
2080 PRINT"(CLR)FE:";FE:GOSUB60000:PRINT"MG:";MG:GOSUB60000:PRINT"CA:";CA:GOSUB60000:PRI
2090 GOSUB60000:GOSUB50000:RETURN
9999 REM *******************************
10000 REM SILICATE DATA
10001 REM ******************************
10010 DATA SIO2  ,TIO2  ,AL2O3 ,FEO   ,MGO   ,CAO   ,NA2O  ,K2O   ,"MNO   "
10020 DATA SI    ,TI    ,AL2X  ,FE    ,MG    ,CA    ,NA2X  ,K2X   ,"MN    "
10029 REM ******************************
10030 REM MOLE WEIGHTS
10031 REM ******************************
10040 DATA 60.085,79.899,101.960,71.846,40.304,56.079,61.979,94.203,70.937
44990 REM ******************************
45000 REM SUBPROGRAMS
45010 REM ******************************
50000 PRINT"(DOWN)(DOWN) PUSH ANY ONE OF THE KEYS
50010 GET T$:IF T$="" THEN 50010
50020 RETURN
60000 FORG=1 TO 20:PRINT"_";:NEXTG:PRINT:RETURN

READY.
```

APPENDIX 2

```
1 REM!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
2 REM CALCULATION OF CHROMIUM SPINELS
5 REM!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
4 DIMZ$(100),S$(5,28),B$(30)
6 FORN=1 TO 9:READA(N),B$(N):NEXTN
20 FOR N=11 TO 28:READ B$(N):NEXTN
30 FORN=3 TO 9:READC(N):NEXT
35 POKE53280,1:POKE53281,1
50 PRINT"(CLR)(RVS) CHROMIUM SPINELS (DOWN)(DOWN)(DOWN)(LEFT)(LEFT)(LEFT)
  (LEFT)(LEFT)(LEFT)(LEFT)(OFF)
100 PRINT:INPUT" Solution in one page(Max.5)"; M
110 IF M>5 OR M<0 THEN 100
115 INPUT"(DOWN)(DOWN) Sample number:"; RR $
120 FOR MM=1 TO M
200 PRINT"(CLR) Data input";MM;".ICIN(DOWN)(DOWN)":INPUT" S. Nr. ";I $(HH)
210 FORN=1 TO 9
220 IF N=1 THEN INPUT"(DOWN)1.FEO :";T0:GOTO250
225 V$(MM)=STR$(T0)
230 IF N=2 THEN 250
240 PRINTB$(N);:INPUTC(N)
250 NEXTN
260 I1=((C(3)/A(3))+(C(4)/A(4)))*A(2)
265 INPUT"(DOWN)(DOWN)(DOWN) ARE THE DATA CORRECT(E/H)"; Q $
267 IF Q$<>"E"THEN 210
270 I2=((C(5)/A(5))+(C(6)/A(6))+(C(8)/A(8)))
280 I3=((C(7)/A(7))+(C(9)/A(9)))
290 I4=((I2-I3)*A(1))*10
300 I5=I1*A(1):I6=I4*A(2):I7=I5-I5:I8=A(1)+A(2):I9=I7/I8:C=T0-I9
310 C(1)=C:C(2)=T0-C(1):T=0:K1=0
325 FORN=1 TO 9:T1=T1+C(N):NEXTN:V(MM)=T1
330 FORN=2 TO 4:D(N)=C(N)/A(N):K1=K1+D(N):NEXTN:REM N.KATIONS
340 FOR N=2 TO 4:I(N)=(D(N)*32/K1):NEXTN:REM CR,AL,FE3
350 F(1)=C(1)/A(1):F(2)=C(5)/A(5):F(3)=C(6)/A(6):F(4)=C(8)/A(8)
360 F5=C(7)/A(7):F(6)=C(9)/A(9)
370 F=F(1)+F(2)+F(3)+F(4)
380 FORN=1 TO 4:I(N)=(I(N)*8)/F:NEXTN:REM FE2,MG,MN,CA
385 I(5)=(F5*8)/(F+F5)
390 R2=K1-F(4)-F(5):REM R2O3
400 X=F/R2:REM RO/R2O3
410 L=C(3)*1.6042:L1=C(1)*1.7772:L2=C(2)*1.4991:LL=L/(L1+L2):REM CR/FE
415 FF=I(2)+I(3)
420 J=(100*FF)/F:REM MGO/RO
430 AY(1)=(I(4)/2):REM MGAL2O4
440 AY(2)=(I(2)+I(3)-AY(1))*50:REM MGCR2O4
445 AY(1)=(AY(1))*(1.9)
450 AY(3)=((I(3)+I(4))/2)-(I(2)+I(3)):AY(2)=AY(2)*233.7:REM FECR2O4
466 AY(4)=(I(2)/2)*230.8:REM FEFE2O4
465 IP=0
470 FORN=1 TO 4:IP=IP+AY(N):NEXT
480 FORN=1 TO 4:D(N)=(AY(N)*100)/IP:NEXT
490 Y(1)=INT((I3*I(5))*1000)+.5):REM TIFE2O4
500 G=C(4)*1000:G1=G/2:Y(2)=INT((G+G1)+.5):REM SAL2O4
510 G=C(3)*1000:G1=G/2:Y(3)=INT((G+G1)+.5):REM SCR2O4
520 G=C(2)*1000:G1=G/2:Y(4)=INT((G+G1)+.5): REM SFE2O4
530 FORN=1 TO 4:I6=I6+Y(N):NEXT
540 FORN=1 TO 4:Z(N)=(Y(N)*100)/I6:NEXT
550 FOR N=2 TO 10:I$(N)=STR$(C(N)):NEXT:I$(1)=STR$(C(1))
560 I$(11)=STR$(I(5)):I$(12)=STR$(I(3)):I$(13)=STR$(I(4)):I$(14)=STR$(I(3))
570 FORN=15 TO 17:I$(N)=STR$(I(N-14)):NEXT
580 I$(18)=STR$(L):I$(19)=STR$(X):I$(20)=STR$(J)
590 FOR N=21 TO 24:I$(N)=STR$(D(N-20)):NEXT
600 FOR N=25 TO 28:I$(N)=STR$(Z(N-24)):NEXT
610 FOR N=1 TO 28:I$(N)=I$(N)+"        ":I$(N)=LEFT$(I$(N),6):NEXT
620 FOR N=1 TO 28:S$(MM,N)=I$(N):NEXT
625 PRINT"(CLR)"
630 FORN=1 TO 9
635 GOSUB50000
640 PRINTB$(N);S$(MM,N):NEXTN
650 GOSUB30000:PRINT"(CLR)"
660 FORN=11 TO 17
665 GOSUB50000
670 PRINTB$(N);S$(MM,N):NEXT:GOSUB30000
680 PRINT"(CLR)"
682 FORN=18 TO 24
684 GOSUB50000
686 PRINTB$(N);S$(MM,N):NEXT:GOSUB30000
687 PRINT"(CLR)"
688 FORN=25 TO 28
689 GOSUB50000
690 PRINTB$(N);S$(MM,N):NEXT:GOSUB30000
691 NEXT MM:PRINT"(CLR)"
694 FORN=1 TO 5:I$(N)=I$(N)+"        ":I$(N)=LEFT$(I$(N),6):NEXT
695 FORN=1 TO 5:V$(N)=V$(N)+"        ":V$(N)=LEFT$(V$(N),6):NEXT
696 FORN=1TO5:J$(N)=STR$(V(N)):J$(N)=J$(N)+"        ":J$(N)=LEFT$(J$(N),6)
697 V(N)=VAL(J$(N)):NEXT
698 INPUT"(CLR) PRINTER OUTPUT(E/H): "; NM $
699 IFNM$="H"THEN RUN
700 OPEN1,4
701 PRINT#4,CHR$(27);CHR$(72);CHR$(27);"N";CHR$(20);CHR$(27);"D";CHR$(75)
702 PRINT#4,CHR$(27);CHR$(15);CHR$(1)
703 PRINT#1,"Sample:";RR$:PRINT#4
705 PRINT#4,"S. Nr. :";"I ";I$(1);" I";I$(2);" I";I$(3);" I";I$(4);" I";I$(5)
708 PRINT#4,"TOP.FEO:";"I ";V$(1);" I";V$(2);" I";V$(3);" I";V$(4);" I";V$(5)
710 FOR N=1 TO 28
712 IFN=10THENPRINT#4,"TOPLAM :";"I ";J$(1);" I";J$(2);" I";
716 IFN=10THENPRINT#4,J$(3);" I";J$(4);" I";J$(5);" I"
718 IFN=10THENGOSUB15000:PRINT#4," Cation calculation on the basis of 32 O
719 IFN=10THENGOSUB15000:GOTO 740
720 PRINT#4,B$(N);"I ";
730 PRINT#4,S$(1,N);" I";S$(2,N);" I";S$(3,N);" I";S$(4,N);" I";S$(5,N);" I"
735 IFN=9 S =17 OR N=20 OR N=24 OR N=28THENGOSUB15000
740 NEXTN:PRINT#4,"2+(MG,MN,FE)":CLOSE4:GOSUB30000:RUN
1000 FOR N=3 TO 9:READ C(N):NEXTN:RETURN
10000 DATA 71.84,"FEO    :",159.68,"FE2O3  :"
10005 DATA 152.02,"CR2O3  :",101.94,"AL2O3  :",40.32
10010 DATA "MGO    :",70.93,"MNO    :",79.90,"TIO2   :"
10015 DATA 56.08,"CAO    :",60.06,"SIO2   :"
10020 DATA "TI    :","CR    :","AL    :","FE3   :","FE2   :","MG    :"
10030 DATA "MN    :","CR/FE  :","RO/R2O3:","MGO/RO :","MGAL2O4:","MGCR2O4:"
10040 DATA "FECR2O4:","FEFE2O4:"
10050 DATA "TIFE2O4:","SAL2O4 :","SCR2O4 :","SFE2O4 :"
15000 PRINT#4,"________________________________________________________________
15010 RETURN
20000 DATA 46.443,18.576,7.684,0.30,.094,0.0,.009
30000 PRINT"(DOWN)(DOWN)(DOWN) PUSH ANY ONE OF THE KEYS
30010 GET A$:IF A$="" THEN 30010
30020 RETURN
50000 FORKK=1 TO 20:PRINT"—";:NEXTKK:PRINT:RETURN

READY.
```

YERBİLİMCİNİN SESİ	EYLÜL 1987	Sayı 14-15
GEOSOUND	*SEPTEMBER*	*No*

THE TECTONIC SETTING OF THE PORPHYRY AND MASSIVE SULPHIDE DEPOSITS OF THE CIRCUM BLACK SEA

Şener OŞOMEZSOY (*)

Key Words: Tectonic Setting, Porphyry, Massive Sulphide, Black Sea

ABSTRACT

Reinterpretation of the orogenic evolution of Circum Black Sea Suture belt lead us to classification of the massive sulphide deposits and porphry type mineralization based on the tectonic setting. Fore Range massive sulphide deposits of Devonian age in the Great Caucasian orogen belt is considered back arc opening related massive sulphide deposits. Formation of the Küre massive sulphide of lower Jurassic age in the Northern Pontian belt, Southern Slope polly metallic stratiform deposits of Liassic age and polly metallic stratiform deposits of the late Triassic age in Strandja belt is suggested as related to the early stage rifting of the opening of the Cimmerian basin. Timok - Srednegora - Eastern Pontian, Somekheto - Karabakh polly metallic massive sulphide deposits of late Cretaceous age is considered extensional arc or inter arc basin related massive sulphide deposits. Formation of the Southern Anatolian Massive sulphide deposits of Eocene age is accepted as related to the early stage volcanic of the Maden basin which is opened by the strike slup events. On the other hand the other massive sulphide deposits in the Southern Anatolian copper deposit belt must be related to the oceanic spreading basalts.

Porphyry type deposits are divided, into three type, compresional arc related, extensional arc related and post collisional arc related porphyry copper deposits. Banat (Southern Carpathian) Timok, Srednogora Strandja porphry Cu-Mo deposits of late Cretacaus age are related to the compressional

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arc intrusions. Pampak - Zangezurian Stokwork - Skarntype Cu-Mo and W deposits Paleocene to Oligocene age are formed related to the multi-rifted extensional arc intrusions. Serbo Macedonian porphry Cu deposits and Kerman region porphyry Cu deposits were formed related to the post collisional magmatic arc plutons.

1. INTRODUCTION

Metallogenic analyses of the massive sulphide and porphry deposits of the Alpine folded belts that extending from Carpathian to Zagros belts was held by the Tvalchrelidze (1) on the base of secondary geosynclinal concept. Jankovic (2) had put forward the concept of the Tethyan Eurosian metallogenic belt that was developed as a consequence of the closure of Tethyan ocean by the northward dipping subduction beneath the Trans Eurasia margin. Alpine metallogenic evolution of the Northeastern Mediterranean region was discussed by Jankovic (3) in the light of the Tethyan evolution of the Alpine system (4), General features of the Porphyry copper and massive sulphide deposits of the North Eastern Mediterranean region has been descripted by Jankovic (5). Evolution of the Caucasian metallogenic belt (6,7,8) and of the Eastern Black Sea (9,10) metallogenic belt have been interpreted base on the plate tectonic evolutionary model of Caucasian - Pontian belt of Adamià et al. (11). The geological and minerological details of the Srednogoran (12,13,14) Timok (15) and Banat (16,17,18) regions porphry copper and massive sulphide deposits of Carpathian-Balkan-Alpine belt have been introduced. Sillitoe (19) have interpreted the Carpathian-Balkan porphry copper deposits in the Cordillerean perspective base on the Burcfiel (20) model's on the evolution Carpathian-Balkan orocline.

Metallogenic evolution and tectonic setting of the Circum Black Sea massive sulphide and porphry deposits will be reinterpreted in the context of the orogenic evolutionary models of the author (21).

OROGEN BELTS

Hercynian orogen belts are divided into the northern and the southern branches. The northern branches extends along the Balkanide and Great Caucasian belt. The southern branch extends along the Serbo Macedonian, Southern Pontian and Transcaucasian belt. Staraplanina Hercynian orogen belt take place between Moesian Platform on the north and Rhodope massif in the south. Great Caucasian Hercynian orogen belt lies adjacent the southern peripheries of the Scythian platform (22). The southern Hercynian belt wrapped around the southern margin of the Rhodope-Pontide-Transcaucasian belt. Serbo Macedonian Hercynian orogen belt extends Rhodope massif and Pelagonian massif. Southern Pontian Hercynian orogen belt is overlain by the Permo Carboniferous deposits. Southern Pontian Hercynian orogen belt was succeeded by the early Triassic collisional orogeny belt which lie between Menderes massif and Pontian block (23).

Cimmerian orogen belt located in the northern and the southern peripheries of the Black Sea. The northern Dobruca-Crimean and Great Caucasian Cimmerian belt is overlain by the late Jurassic deposits (24). The southern Cimmerian orogen belt extends from Circum Rhodope, Strandja to Küre orogen belt (25,26,27,28).

Alpine orogen belts consist of mainly four branches which are encountered at the East Anatolian accretionary belt. Vardar-Izmir-Ankara-Erzincan branch which is located between Rhodope Pontide block and Apullian-Anatolian platform. Sevan-Akera Quradagh branch extends between Transcaucasian and Northwetern Iran platform (29) Bitlis orogen belt lie between Anatolian and Arabian platform (30). Southern continuation of the Bitlis belt extends to the Zagros orogen belt (See Fig. 1).

OPHIOLITIC BELTS

Continental accretion belts of the Circum Black Sea region are constituted by the oceanic assemblages which include ophiolite complex, subduction complex, pelagic deposits or rift related tholeitic volcanic (Fig. 2).

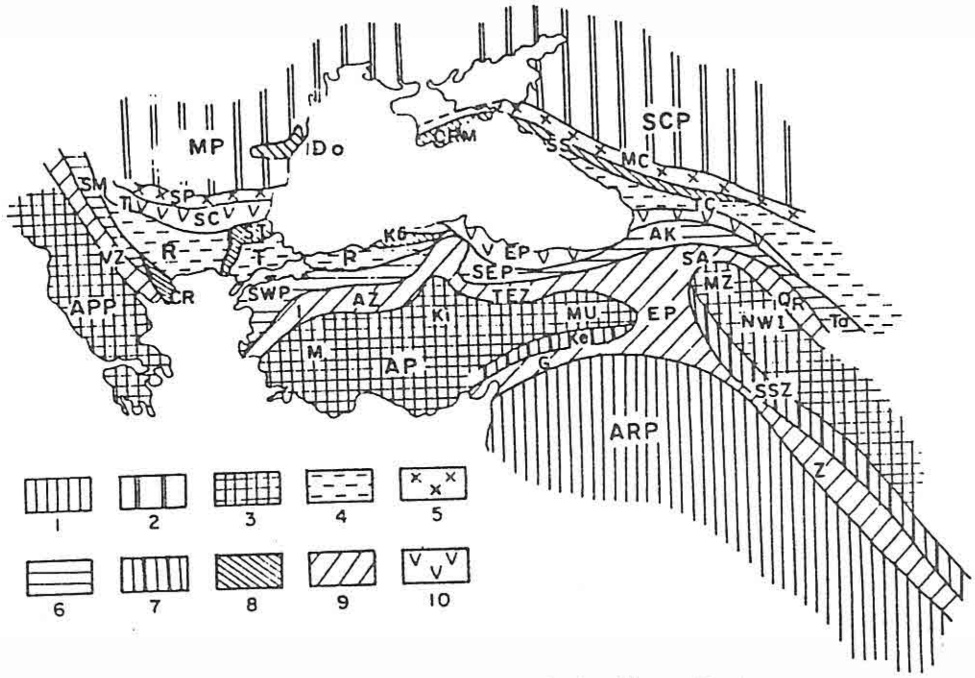

Fig. 1.- Orogenic belts and continental fragments of the Circum Black Sea orogenic belts, 1. Gondwanaland 2. Laurasia, 3. Gondwanian fragments, 4. Laurasian fragments, 5. Hercynian orogen belt, 6. Late Hercynian-Eocimmerian orogen belts, 7. Non collisional Cimmerian orogen belts, 8. Collisional Cimmerian orogen belts, 9. Alpine orogen belts, 10. Laramian orogen belts. AP. Arabian platform M.p. Meosian platform, SCP. Sythian platform, APP. Apullian platform, AP. Anatolian platform, NWI, Northwest Iran platform, R. Rodop block, T. Thracian, block, P. Pontian block, TC. TransCaucasian block, SP. Stara Planina, MC. Main Caucasian range, SM. Serbo Macedonian, SWP. South west Pontian AK. Artvin Karabakh, Ta. Talesh, CR. Circum Rhodope, ST. Skar-Strandja, Kü. Kure, CRM. Crimean, SS. Southern Slope, Ke. Keban, SSZ. Senandaj Sirjan, V. Vardar, IAZ. İzmir-Ankara Zone, SA. Sevan-Akera, QR. Quradagh, EP. Eas Anatolian prism, Z. Zagros, G. Guleman, M. Menderes massif, Kı Kırşehir massif, MU. Munzur platform, Ti. Timok, SG. Srednogora, EP. Eastern Pontian, B. Baskul.

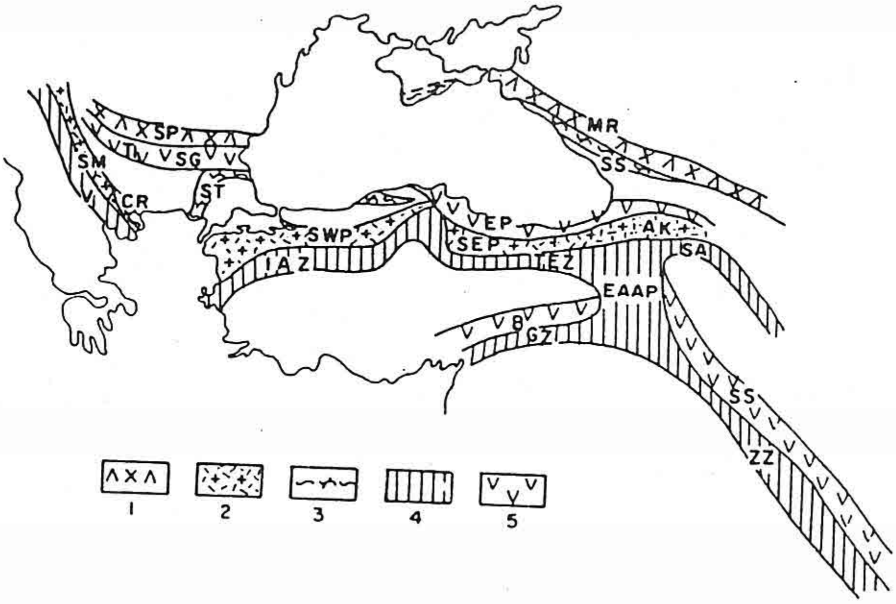

Fig. 2- Ophiolithe belts, Magmatic arcs, Ophiolithe-arc ensemble and deep sea deposits of the Circum Black Sea orogen belts
1) Ophiolithe-arc ensemble of the Straplanina, Mrun Range Hercynian orogen belts.
2) Ophiolithe-arc ensemble of the Serbo Macedonian Southern Pontian. Transcaucasian Hercynian Fecimmerian orogen belt.
3) Deep Sea deposits and volcanic belt of the Circum Rhodope-Strandja-Küre-Crimean-Southern Slope belt Cimmerian orogen belt.
4) Vardar-İzmir-Ankara; Tokat, Erzincan, Sevon-Akeora-Quaradagh; Gu'eman; ophiolithe belt of NeoTethyon.

Stara Planina Hercynian orogen belt includes Diabase Phillitoid complex which consist of tholeitic volcanics and flysh of Early to Mid Paleozoic age (31). Main range magmatic arc belt is bounded by the Fore range ophiolites of Mid Paleozoic age in the north and root zone ophiolite in the south (22). Diabase phillitoid complex of Mid Paleozoic age extends along the Kriastide belt which delineate the boundry of the Rhodope massif and Serbo Macedonian zone, Serbo-Macedonian zone includes dismembered ophiolites of late Paleozoic age.

Southwestern Pontian belt ophiolite bearing subduction complex of Pre Permian age extends along the Ezine-Mudanya-Elmacık ophiolite belts (23,33). Kazdağı-Söğüt-Simavdağı ophiolite complexes of pre late Triassic age of the SW Pontian accretionary belt are reprsenet the obducted oceanic crust of the Paleo Tethyan. Elekdağ (27) and Tokat massif (34) ophiolitic belts of the Southern Pontian belt extends to the Transcaucasian ophiolite belt of pre Liassic age (35). Southern Pontian and Transcaucasian ophiolite belts are the Western continuation of the Masshat-Talesh ophiolite belts of pre late Triassic.

Circum Rhodope orogen belt includes pelagic deposits of Liassic age and ophiolite bodies of jurassic age (32). Bazalitic meta volcanic of Sivriler formation of Jurassic Age of the Istranca orogen belt (26) and Küre basalts and Akgöl flysh of Liassic age of the Northern Pontian belt (36) represents the intra siallic Cimmerian Basin (28) Tauridian flysh of late Triassic age of Crimean belt and Sleyt basalt association of Liassic age of the Southern slope of Great Caucasian (24) are also product of the Cimmerian basin. Widespread ophiolite complex of the Neo Tethyan extends from Vardar zone to İzmir-Ankara zone which includes late Cretaceaus ophiolitic melange and obducted ordered ophiolites nappes. Tokat-Erzincan ophiolite belts are eastern continuation of the Izmir-Ankara zone. Sevan-Akera-Quaradagh ophiolite belt of the Minor Caucasian (29,37) are the eastern most extension of the Northern branches of Neo Tethyan. Southern ophiolite belt of NeoTethyan extends from Kızıldağ to Guleman ophiolite complex which were obducted over the Arabian foreland along the Bitlis belt. Maden complex comprising the tholeitic volcanics interlayered with the deep sea deposits on the Bitlis belt in the SE Anatolia, represents the product of the strike slip related rift basin of Eocene age which opened following the collision of the Keban-Malatya and Bitlis-Pötürge belts.

MAGMATIC ARC BELTS

Hercynian magmatic arc can be divided into the Northern and the Southern belts. The Northern Hercynian magmatic arc extends along the Stara Planina zone of the Great Caucasian belts which are consist of calcalkaline batholites of Devonian-Early Carboniferous age (22,38) (Fig. 2). The southern Hercynian magmatic arc extends along the Serbo Macedonian, Southern Pontian and Transcaucasian belt and represented by the root zone batholites of the arc massif of Pre Permian age (23,32,35). The Southern Hercynian magmatic arc batholites were overlain by the deposits of Permian age.

Calcalkaline batholite of late Jurassic age of the Circum Rhodope (32), Strandja (26), Küre (39), and Southern slope (11) belts are represent the magmatic arc that are the product of the A type subduction of Mid Jurassic age (28).

NeoTethyan magmatic arc belts may be divided into the Norhernmost, the Northern and the Southern belts. The Northernmost arc belt prolong from Banat, Timok, Srednogora, Strandja, Eastern Black Sea to Transcaucasian belt. Timok-Srednogora arc belt consist of volcano-Sedimentary complex of late Cretaceaus age (40). Srednegora volcanic belt extends to the North-western Pontian volcano-sedimentary belt of late Cretaceous age. The Eastern Black Sea (10) and Transcaucasian (11) volcanic belt of late Cretaceaus age are the Easternmost extension of the Northern most volcanic arc belt of NeoTethyan. The extensional magmatic arc belt of the Northern most belt was transformed to compressional arc belt during the latest Cretaceaus time and Volcano sedimentary complex of the extensional arc belt was intruded by the calcalkaline batholites (10,26,41).

Timok-Srednogora-Northwestern Pontian magmatic arc was shifted to the Southern margin of the Rhodope-Pontide belt. Serbo Macedonian, South Pontian arc belt comprises calcalkaline volcanics and plutonics of Paleocen-Eocene age (32,42). Th- Northern magmatic arc extends along thesoutheastern Pontian-Miskano-Zongezurian belt which are consist of alkaline volcanics and plutonics of paleocene age (29,43). Yüksekova volcano plutonic complex of the Bitlis belt (30) represents the continental margin or island arc belt which are product of the southern NeoTethyan.

SUTURE BELTS

Hercynian suture belt extend along the Stara Planina zone of Balkanide wbre Rhodope massif fused to the Moesian platform (43). Main range Island arc of Devonian age of the Great Caucasian belt accreted to the Scythian platform along the Main Range Hercynian suture belt (22). Serbo Macedonian island arc complex is jammed between Pelogonian Massif and Rhodope Massif during the Late Hcrynian suturing events. SW Pontian Hercynian Island arc complex fused to the Pontian block during the Late Carboniferous time. Menderes massif collided to Pontian block along the SW Pontian orogen belt (23). Early Triassic suture belt Central Iran platform attached to the Turan Platform along the Mashat-Talesh suture belt of Early Triassic age (21).

Cimmerian suture belts extends along the southern and northern cost of the Black Sea. Southern Cimmerian suture prolong from Circum Rhodope-Strandja loopped belt, to Küre orogen belt. The Northern Cimmerian suture extends along the Dobruca, Crimean and Southern slope of Great Caucasian belt (28).

Alpine suture belts linked at the East Anatolian accretionary belt. Apullian-Anatolian platform fused to Rhodope-Pontide belt along the Vardar-Izmir-Ankara-Erzincan alpine suture belt. Sevan-Akera-Quaradagh Alpine suture extend between Transcaucasian block and NW Iran platform. Bitlis suture belt takes place at the north of the Bitlis-Pötürge belt of Arabian platform and Keban belt of the Anatolian Block. Bitlis suture belt extends to the Zagros suture belt where Arabian platform collided to the Iran platform (Fig. 3) (21).

METALLOGENIC BELTS

Orogenic analysis of the Circum Black Sea orogen belts lead us to classification metallogenic belts based on the tectonic setting (Fig. 3).

Massive sulphide deposits of the Circum Black Sea may be divided into five tectonic settings. These are back arc, extentional arc, intra sialic rifting, strike slip rifting and oceanic spreading.

Back arc related massive sulphide deposits are represent by Fore Range massive sulphide deposits of Devonian age (Table II) which were formed related to the bimodal basic volcanics of Devonian age (6,7,8).

Extentional arc related massive sulphide is the most important deposits of the Circum Black Sea region. Timok, Srednogora, Eastern Black Sea and Transcaucasian belt massive sulphide deposits are well present arc related deposits (Table III). Eastern Black Sea massive sulphide deposits are mainly composed of polymetallic deposits which related to the upper dasitic series of late Creteacous age. They are genetically related to the dasitic domes and located in to dasitc pyroclastic rocks of the Srednegora extentional arc (13,14). Bor deposits in the Timok region. Consist of polymettàlic stratiform deposits in the andesitic pyroclastic rocks (15). Somhek-Karabakh polymettalic massive sulphide deposits are located in the calcalkaline volcanics of Lower Jurassic and Upper Cretaceaous age (6).

Southern Slope stratiform type deposits of Liassic age is typical stratiform type deposits of Liassic age is typical stratiform deposits, related to the bimodal rift volcanic of the opening of the intra sialic basin. Southern Slope stratiform type deposits were located in the Liassic flysch deposits and basaltic volcanics (6,7,8) (Table I). Kure massive sulphide

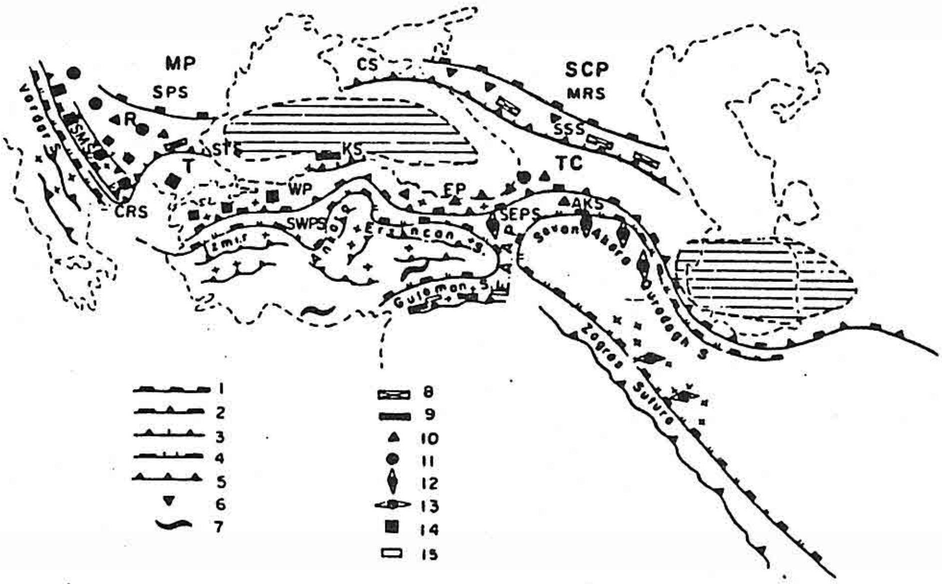

Fig. 3.- Suture belts and type of the mineral deposit of the Circum Black Sea orogen belts. 1. Stara Planina-Main Range Hercynian suture, 2. Serbo Macedonian-Southern Pontian-Artvin Karabakh-Talesh Paleo Tethyan suture, 3. Circum Rhodope-Skar Strandja Kure-Crimean-Southern Slope Cimmerian suture, 4. Vardar-İzmir-Ankara-Tokat-Erzincan; Sevan-Akera-Quradagh; Guleman-Ispendere Göksun; Zogros Neo Tethyan suture, 5. Foreland thrusts belt, 6. Back arc spreading related massive sulphide copper deposits of the Fore Range belt of Great Caucasian, 7. Stratabound Pb-Zn-Ba deposits of the Tauride belt, 8. Rift related polly metallic stratiform sulphide deposits of strandja, Southern Slope belt, 9. Oceanic spreading related massive sulphide copper deposits of the Kure, Guleman belt, 10. Extensional arc related polly metallic massive sulphide deposits of the Timok-Srednogoro-Eastern Pontian-Transcaucasian arc, 11. Compressional arc related porphry Cu-Mo deposits of the Banat, Timok, Svednogoro and Strandja belt. 12. Multi rifted arc related stokwork type. Mo deposits of thePampak-Zangezurian, Azarbayjan-South Eastern Pontian belt, 13. Post Collisional subduction related porphyry Copper deposits of the Serbo Macedonian and Kerman belt. 14. Post collisional magmatic arc related vein and skarn type Pb-Zn deposits of the SW pontian belt and Rhodope massive. 15. Strike slip events related massive sulphide deposits of Siirt Madenköy.

TABLE I

Rift related mineral deposits				
Tectonic Setting	Age	Association	Type of Deposits	Example
Intra continental rift	Permian Triassic	Dolomitic limestone	Statabound Pb-Zn-Ba	Alanya, Gazipaşa (Karalar, Gümüşdere) Anamur (Ortakonuş) Keban
Rift	Late Triassic Liassic	Tholeitic volcanics, Shales	Polymetallic Cu-Pb-Zn	Great Caucasion Southern Slope (Kızıldere, Fiziltchay, Katsdak, Katekh, Strandja (Gramitokova)
Strike Slip Rift	Eocene	Tholeitic volcanics, Shales	Pyritic massive sülphide	Southern Anatolian copper belt, Maden (Ergani), Madenköy (Siirt)

TABLE I. Rift related mineral deposits.

TABLE II

Oceanic spreading related Massive sulphide deposits				
Tectonic setting	Age	Association	Type of Deposits	Examples
Marginal basin Spreading	Mid Devonian	Tholeiitic basalts, flysch	Pyritic Massive Sulphide	Great Caucasion Fore Range (Beskess, Bykovskoe, Urupi, Khudes Skalistoe)
Oceanic Spreading	Liassic	Tholeiitic Basalts Flysch	Pyritic Massive Sulphide	Pontian (Küre)
Oceanic Spreading	Late Jurassic	Tholeiitic Basalts Pelagic Clay	Pyritic Massive Sulphide	Southeastern Anatolian (Ergani)

TABLE II. Oceanic spreading related massive sulphide deposits.

sulphide deposit which located above the basaltic pillow lave and overlain by the black sleyt of Liassic age (Table II) (36).

Cyprus type massive sulphide deposits are represented by Ergani Maden massive sulphide copper deposits which is located above the spilitic pillow lave of the Guleman ophiolite of Jurassic age (44) (Table II). Southern Anatolian massive sulphide deposits related to the basaltic volcanism of Eocene age are represent strike slip events related riftin stage deposits. Siirt Maden massive sulphide deposit located above the spilitic lave and overlaid by the black shale of Eocene age (45)(Table I).

Stratabound type carbonate hosted lead Zinc-barite deposits of the Tauride belt are located in the shallow water carbonlate deposits of Paleozoic and Triassic age (46) which are deposited in the Tauride rift of Permian Triassic age (Table I).

Compressional magmatic arc related porphyry type deposits extends from Banat, Timok, Srednogora, to Strandja belt (Table IV). Porphry Cu-Mo deposit, in the Banat region are related to the magmatic, plutons of paleocene age which are located in the SE trending lineaments. Skarn type Cu mineralization accompained to the porphry Cu-Mo deposits in the Banat region (17). Bor porphry copper deposits are overlain by the massive sulphide deposits. Porphyry type mineralization located in the shallow level porphry stocks bellow the main massive sulphide deposit. Majdenpeck porphry Cu deposit formed in the deep steated granodioritic intrusion (15).

Medet and Assrail deposits in the Panagjuriste ore region in Srednogora bet represents the porphyry type Cu deposits. Medet porphyry deposits is formed in the deep seated granodioritic plutons. Whereas Assrail deposit is located in the shallw porphry stock (13,14). Stockwork type İkiztepeler molybdenite deposits in the Strandja region is formed in the Potassic alteration zone in the granitic plutons (26).

Stockwork type molybdenite deposits in the Pampak-Zangezurian zone of the Minor Caucasian are formed related to the monzonitic plutons of Paleocene to oligocene age which were emplaced in the extentional magmatic arc belt (1,6) (Table III).

TABLE III

Extensional arc and back arc rift related mineral deposits				
Tectonic setting	Age	Association	Type of Deposits	Examples
Extensional arc	Late Jurassic Late Creta - ceous	Differentiated tholeiitic volcanics	Massive Sulphide Pyritic Cu Polymetallic Pb - Zn - Cu Pb - Zn - Cu - Ba	Timok (Bor, Lipa, Krassen) Penagyuristhe (Radtka, Elshitsa, Krasen) Burgas (Chelopech) E Pontide (Murgul, Tunca, Kutlu-lar, Kolarak, Madenköy, Lahanas Kuvarshan) Somekheto-Karabakh (Alaverdy, Shamly, Kafan, Keda-bek, Akhtala)
Back arc rifting	Eocene Oligocene	Calcalkaline alkaline subvolcanic stock	Porphyry Stockwork Cu - Mo Skarn type Cu - Mo - W	Pontide Merzifon (Bakırçay) Artvin (Balcılı, Ulutaş) Pambak, Zangezurian (Kadjaran, Agarak, Dastakert, Ankaven, Aygedson) Quradagh (Qurachilar, Qaraderek)

TABLE IV

Back arc thrusting related porphyry type deposits				
Tectonic setting	Age	Association	Type of Deposits	Examples
Back arc thrust magmatic belt	Paleo - cene	Calc alkaline batholite stock	Porphyry Cu Porphyry Cu - Mo	Banat, Western Belt (Moldova, Nova, Stina pari, Sosca Montana, Ciclova, Oravita Maidan) Central Belt (Lapus-nic Nosavat, Purcariu, Lilieci, Cofu, Ascutita, Bozavlç) Eastern Belt (Mraconia) Bor (Mojdanpek, Veliki krivelj, Valjo str., Dumitri Potala, Mali krivelj, Cerova) Srednagora (Medet, Vlajkov vrh., Assarel, Tcar, Asen, Pa-telova) Strandja, Demirköy (İkiztepe) Somekheto-Karabakh (Mamuli, Spok, Tekhut)

TABLE III. Illustration of the extensional arc and back arc rift related mineral deposits, based on age, association, type of deposits and examples.

TABLE IV. Illustration of the oceanic spreading related massive sulphide deposits, based on age, association, type of deposits and examples.

TABLE V

Post collisional subduction related deposits				
Tectonic setting	Age	Association	Type of Deposits	Examples
Foreland thrusting related magmatic belt	Eocene - Oligocene Oligocene - Miocene	Calcalkaline Subvolcanics Stock, dyke	Porphyry Cu	Serbomacedonian, Zehtova (Bucim, Borov Do) E Chelkıdı (Skouries, Fisko Alâtine, Ditaja) Krousıa (Vati I, Jerokarlo, Panto Kerossie) Kerman (Sor Chesmeh, Larhan, Bande Manzor)
Foreland thrusting related magmatic belt	Oligocene - Miocene	Calcalkaline Subvolcanics Pluton, stcok, dome	Vein-replacement skarn Pb-Zn- ±Cu ± Sb	Rhodope, Osogova (Gyveshava, Rouen) Central Rhodope (Madan, Nedelino, Da-vid Kova Lake) Skor (Ustrem, Lessova) Serbo Macedonia, Kopoanik (Trepca, Belo Brdo, Nova Brdo, Tonjevo, Alvalica, Kıznıca, Calija) Lece (Lece, Djavolja Voras) Zeletova (Dobrova) Macedonia (Sose Toroniko, Zletovska, Rijeka) E Chealekidiki (Stratonik) W Egean (Laurlan) Biga peninsula (Balya, Arap-uçan dere, Handeresi, Altınoluk) Dur-sunbey (Göçü köyü) İvrindi, Simav

Porphry copper deposits in the Serbomacedonian zone are located in the Bucim and Eastern Chalkidiki region. Serbomacedonian type porphyry copper deposits occured related to the subvolcanic porphry stock of Oligocene age (47). Sarchesme porphry copper deposits occured in the subvolcanic stock of Tertiary age in the Kerman region (48). Serbomacedonian and Kerman region porphyry deposits are formed in the post collisional magmatic arc (Table V).

EVOLUTION

Hercynian orogeny belt is recorded along the southern peripheries of the Moesian-Scythian platform. The Balkan Caucasian arc-trench system and the back arc basin was accreted to the Moesian-Scythian platform by the elimination of the Hercynian ocean (22,43). The Rhodope-Pontide-Trans-caucasian block was fused to Moesian platform along the Sataraplannina collisional belt. Hercynian ocean was reduced to the Svanetia remnant bain. The Fore Range massive sulphide Cu deposits were generated concerning of the opening of the Fore Range back arc basin (Fig. 4 a) (6,8).

The western continuation of Mashhad-Talesh Paleo Tethyan suture belt located along the Artvin-Karabakh variscan-Eocimerian, cordillerian orogeny

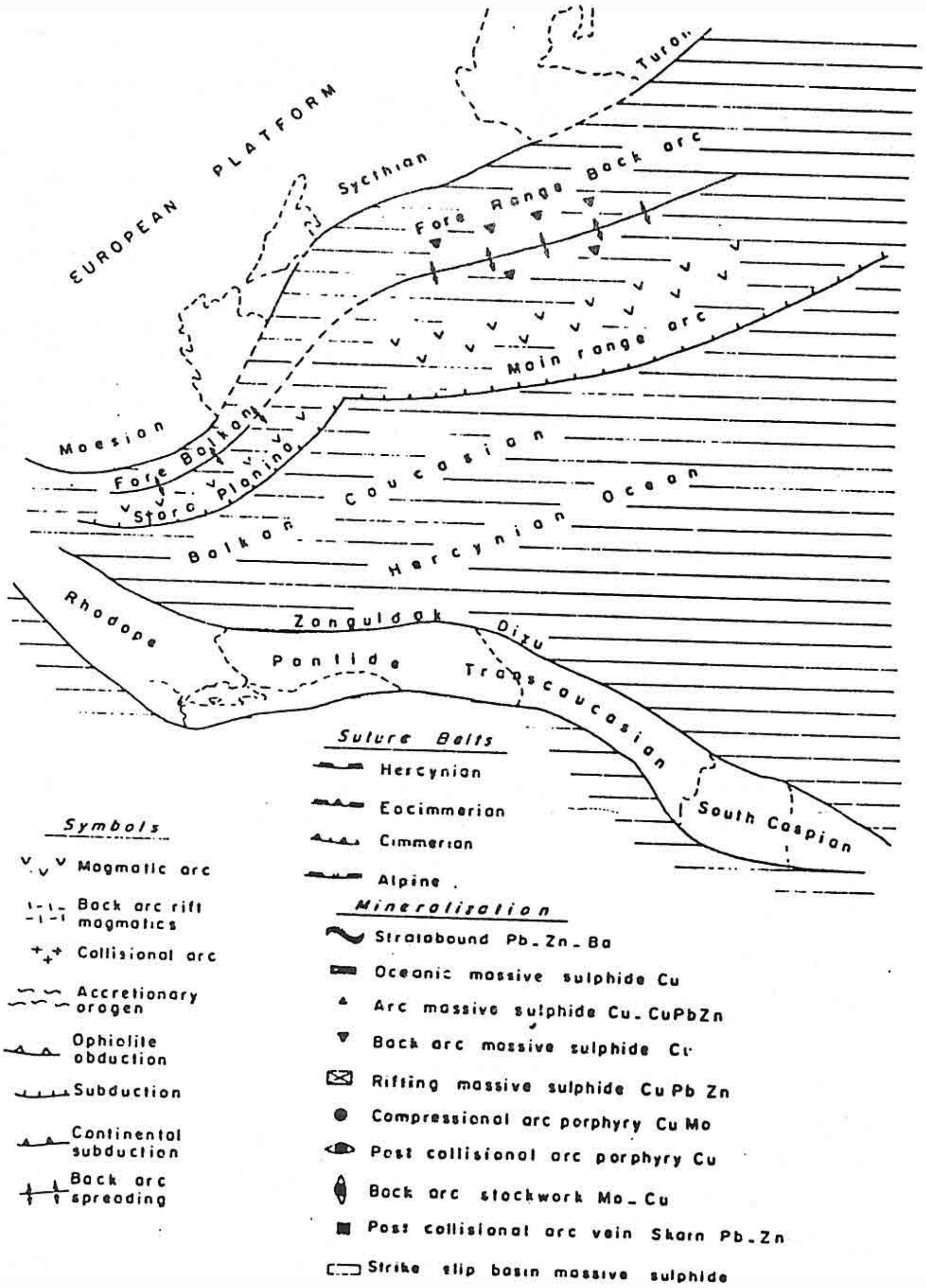

Fig. 4 a: Closuring of Balkan-Caucasian Hercynian Ocean by the northward dipping subduction beneath the Moesian-Scythian platform; construction of the Stara Planina and Main Range magmatic arc; Opening of the Fore Balkan and Fore Range marginal basin; formation of the Fore Range massive sulphide deposits related to the back arc basin volcanics. In the Mid Devonian-Mid Carboniferous time interval.

belt (35,49) and the Southern Pontian-Serbo Macedonian Variscan Eocimmerian collisional orogen belts (23,32) which were produced by continental fusion Apullian-Anatolian, Central Iran platform to Rhodope-Pontide-Transcaucasian belt (21). By the disappearing of Paleo Tethyan. Sevan-Akera ocean were inheried from Paleo Tethys (49). Tauride rift trough and Zagros ocean were generated during the closure of Paleo Tethyan. Stratabound type Pb-Zn-Ba deposits were formed in the Tauride rift trough (46) (Fig. 4 b).

Cimmerian ocean was opened during the late Triassic time along the Svanetia remnant basin related with the Atlantic opening, following the terminally closure of Paleo Tethyan (Fig. 4 c). Circum Rhodope-Eastern Thracian-Strandja-Küre-Crimean-Southern Slope Cimmerian orogen belts (28) were developed by the consequence of closure of Cimmerian Ocean during the late Jurassic collisional type Cimmerian orogen (21,28).

Finally Axios-Thracian-Pontian-Transcaucasian Stripe was welded to Rhodope Main range belt. Küre (36), Southern slope (6,8) Strandja Massive Sulphide deposits were generated rift related basic volcanics or oceanic splites of Cimmerian ocean (Fig. 4 c).

Vardar ocean was prolonged to the eastward and Izmir-Ankara-Erzincan branch was generated. Guleman ocean was opened between Keban and Bitlis belt (Yazgan, 1983). Subsequently Neo Tethys was procceded to expand during the late jurassic-late cretaceous time, South Anatolian massive sulphide Copper deposits of late jurassic age were generated during the spreading of the Guleman ocean (44) (Fig. 4 d).

The Timok-Srednegora-Northern Pontian-Transcaucasian extensional arc, or the back arc rift (10,11,41). were generated as a consequence of the closure of the Vardar-Izmir-Ankara-Erzincan and the Sevan-Akera-Quaradagh branches of the Neo Tethys during the Upper Cretaceaus time. The Extensional arc, or the back arc system was transformed to compressional thrust magmatic belt during the Laramian orogenesis. The massive sulphide Cu, Cu-Pb-Zn deposits were generated relating with the extensional arc volcanics of Upper Cretaceaus age (Fig. 4 e). On the other hand the porphry Cu deposits

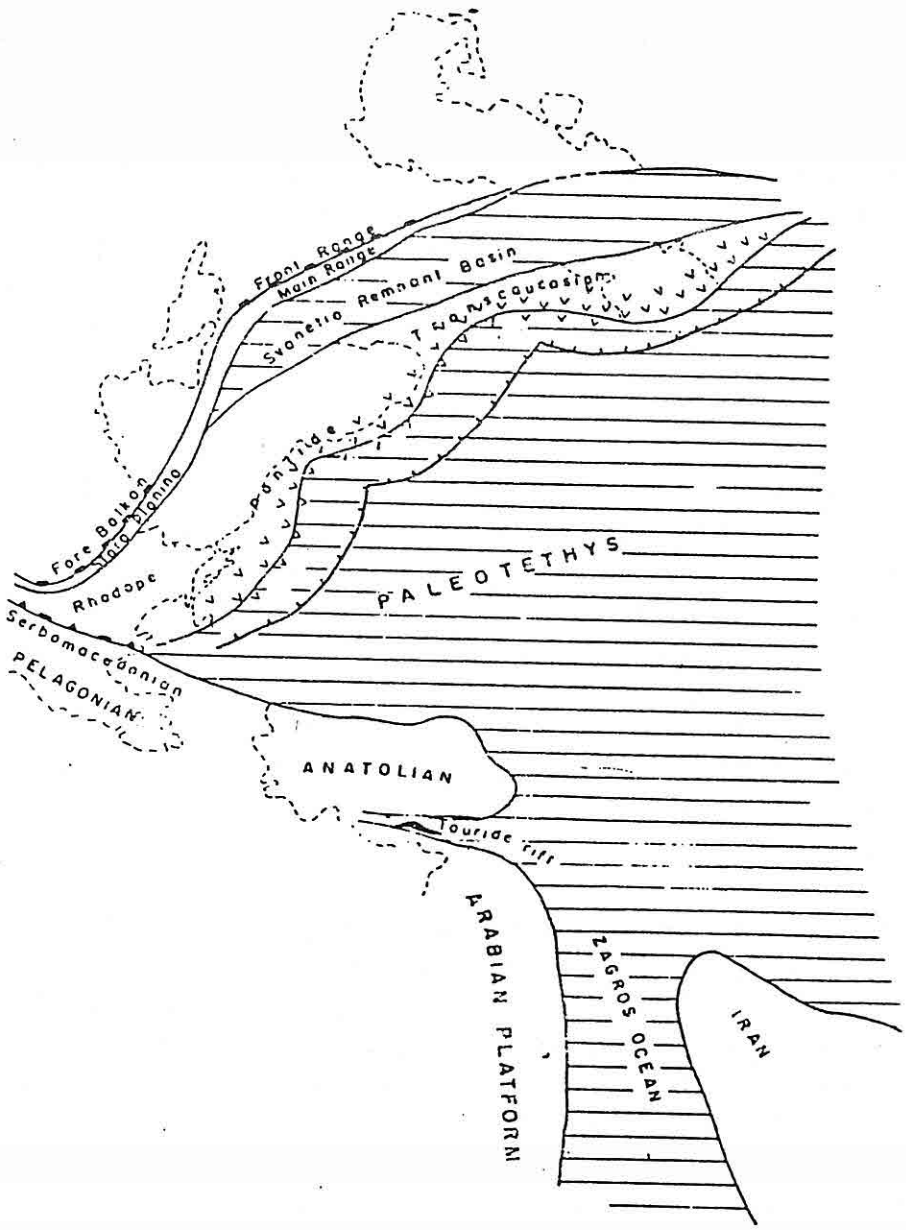

Fig. 4 b: Closure of Paleo Tethyan by the Northward dipping subduction beneath the Rhodope-Pontide Transcaucasian belt; drifting of the Iran platform and rifting of Anatolian. Apullian platform from the northern margin of Africa as a consequence of closure of Paleo Tethys; Construction of the Southern Pontian-Artvin Karabakh arc-trench system; and formation of the stratabound type Pb-Zn-Ba deposits of the Tauride belt related to the opening of the Tauride rift. In the Late Carboniferous Late Triassic time interval.

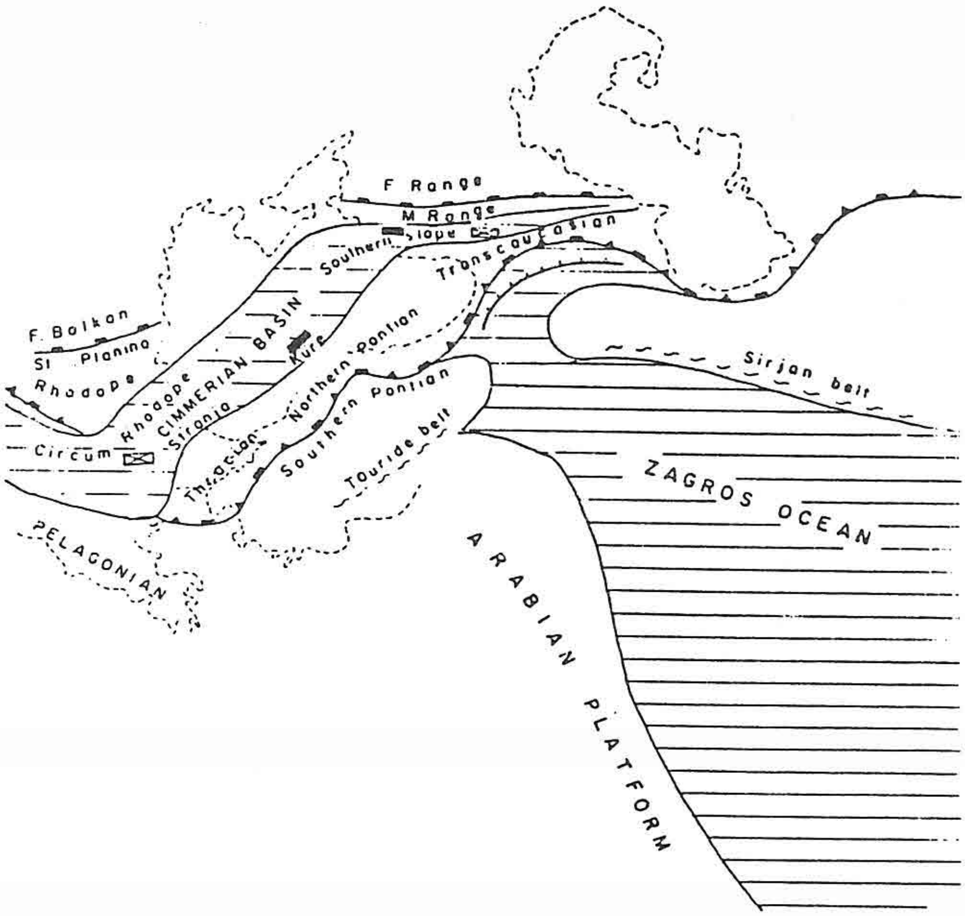

Fig. 4 c: Opening of the Circum Rhodope-Strandja-Küre-Crimean southern slope Cimmerian basin following the terminally closing of Paleo Tethyan by the collision of the Apullian-Anatolian platform to the Rhodope-Pontide belt; and formation of the Southern Slope- Küre and Strandja belts stratiform polly metallic sulphide and piritic massive sulphide deposits. In the Late Triassic Late Jurassic time interval.

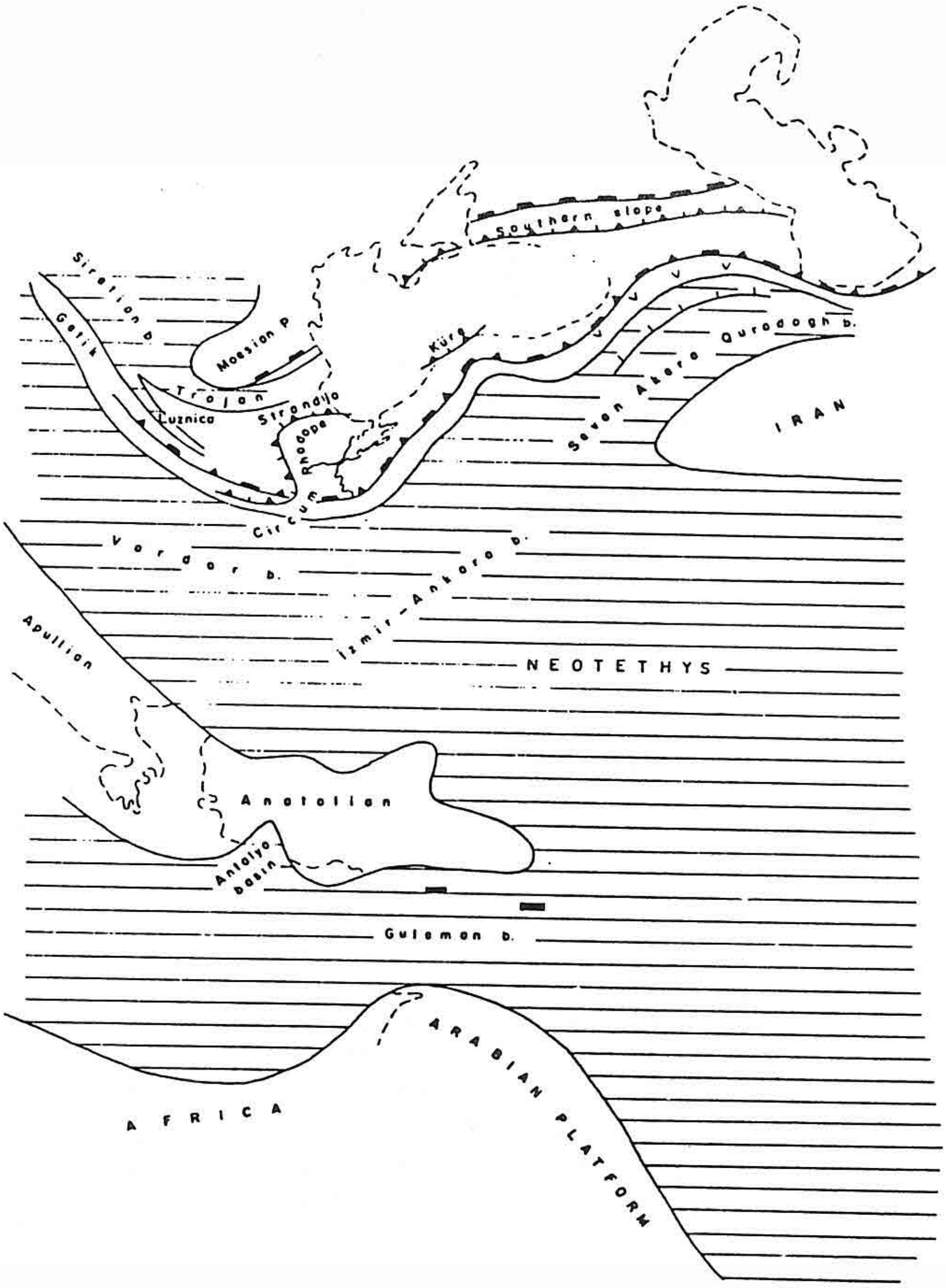

Fig. 4 d: Opening of the Siretian; Vardar-İzmir-Ankara-Erzincan; Sevan-Akera Quradagh; Guleman branches of NeoTethyan in the Late Jurassic - Early Cretaceous time interval.

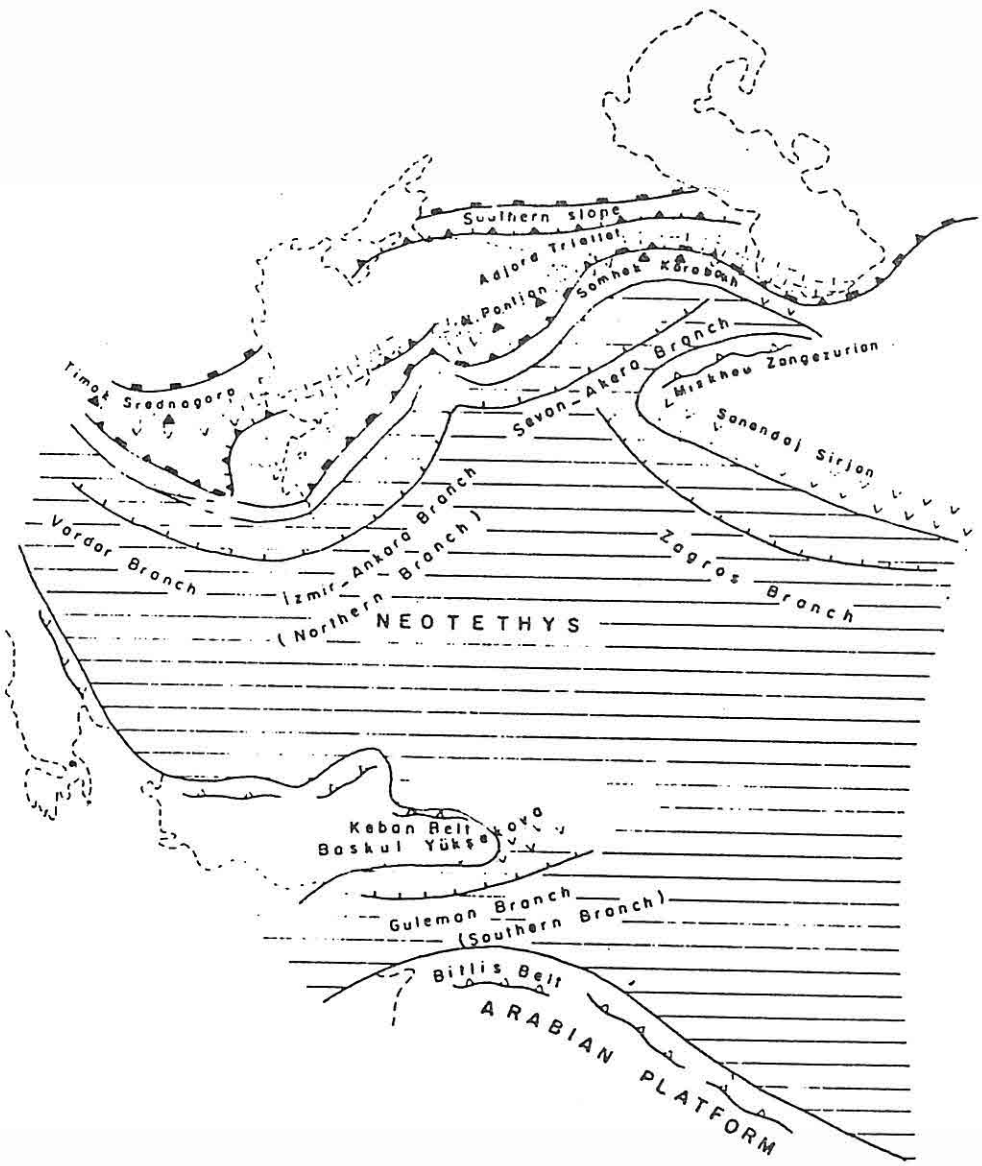

Fig. 4 e: Evolution of the Timok-Srednogora-Northern Pontian Transcaucasian extensional continental margin arc on inter arc basin of the Northern most arc belt of Neo Tethyon and formation of the polly metallic massive sulphide deposits of Banat, Panagyuriathe, Eastern Black Sea, Somhek Karabakh; construction Baskil continental margin arc and Yüksekova island arc in Late Cretaceous time.

were formed concerning of the thrust-magmatic belt plutons of Paleocene age (Fig. 4 f).

The Sevan-Akera-Quaradagh branch western part of the Vardar ocean were closured during the Laramian orogenesis. The Miskhan-Zangezurian belt was fused to Transcaucasian block (11) and the Apulian platform was welded to Rhodope block (20).

The Zagros ocean was consumed by northward dipping the subduction underneath the Sanandaj-Sirjan belt of the Central Iran platform. Consequently the Upper continental margin arc of Upper Cretaceaus age was constructed over the Sanandaj-Sirjan belt (51).

The Guleman ocean was closured as a consequence of the northward dipping subduction beneath the Keban belt, and was terminally closed by the continental collision of Keban and Bitlis belt during the latest Cretaceaus time (39). The Yüksekova magmatic arc was jammed between the Keban and the Bitlis belt. The Neo Tethys was reduced to simple V shape following the disappearing of branches. Closure of Neo Tethys was proceeded by the northward dipping subduction underneath the Rhodope-Pontide-Central Iran belt(29). The Southern Rhodope-Southern Pontian-Miskhan Zangezurian-Northern Azarbayjan continental margin arc and the Black Sea-Adjora Triallet-Southern Caspian marginal Sea were generated behind the continental margin arc belt during the Paleocene time. The Miskhan-Zangezurian, the Northern Azarbayjan stockwork type Cu-Mo-W deposits were formed (Fig. 4 g) in subduction related plutons of Eocene-Oligocene age.

Maden basin of Maestrichtian Mid Eocene age was opened by the strike slip events on the Bitlis belt during the closure of Erzincan-Zagros ocean by the northward dipping subduction beneath the Eastern Pontian-Central Iran platform during the Paleogene time. Southern Anatolian massive sulphide deposits of Eocene age in the Maden complex (45) were occured related to the tholelitic basalts of Maden basin which opened as a result of the strike slip events (Fig. 4 f).

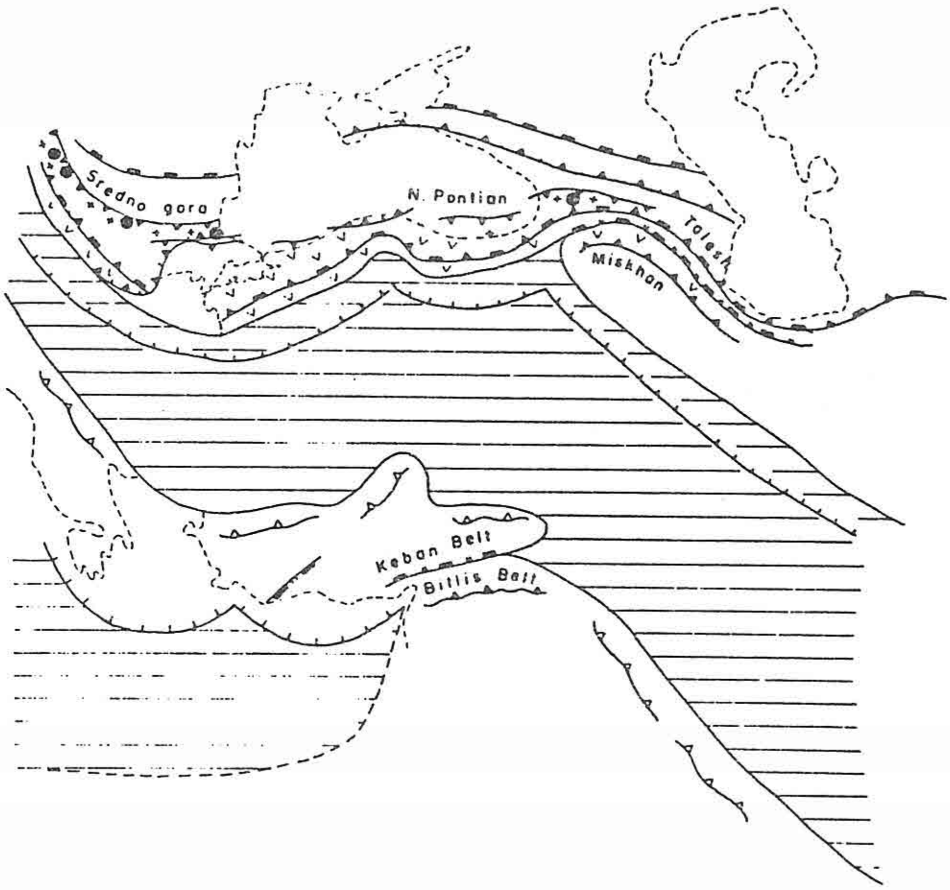

Fig. 4 f: Closing of the Guleman Ocean and Sevan-Akera-Quradagh Ocean in Pre Maestrichtion time; Closing of the Timok-Srednogora-Northern Pontian-Trans caucasian inter arc basin by the Laramian compressional events; emplacement of Banat Timok-Srednogora-Strandja Northern Pontian. Transcaucasian belt batholit ; and formation of the compressional arc related porphry Cu-Mo deposits. In the Latest Cretaceous-Paleocene time interval.

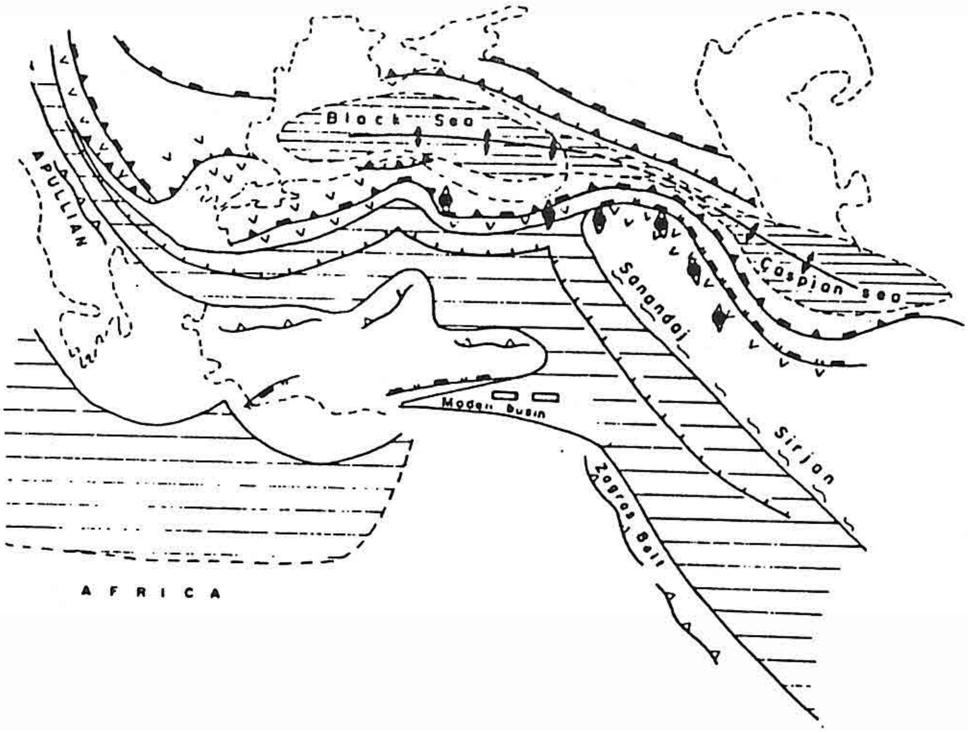

Fig. 4 g: Generation of the Black Sea, oceanic crust as a back arc basin related to closure of Erzincan-Zagros Ocean by the northward dipping subduction beneath the East Pontian. NW Iran platform during the Paleogene time; construction of the extensional arc along the Eastern Pontian-NW Iran belt (Northern magmatic arc of the NeoTethyan) and formation of the extensional arc related stockwork type Mo deposits in the Eastern Pontian - Pambak - Zangezurian belt: Evolution of the SW pontian - Serbo Macedonian magmatic arc (Northern magmatic arc of Neo Tethyan) as consequence of the continental subduction of Apulkan-Anatolian blocks; Opening of the Maden basin related to the strike-slip events following the Bitlis suturing and deposition of the Southeast Anatolian massive sulphide deposits in the Maden complex. In the Maestrichian Late Eocene time interval.

a) Kenet kuşakları (sütür zonları): Bu kuşaklar fosil yitim zonlarını temsil ederler. Fasiyeslerin çoğunluğu karasal olup ofiyolitik melanj ve değişik okyanusal tortullar üzerinde gelişen havzalardır. Buralarda evaporit ve sabka tipi tortullarla molas fasiyesleri tipiktir. Zagros'lar boyunca İran körfezi evaporitleri (52,16) ile Himalaya'lar eteklerindeki Siwalik grubu (53) belirgin örneklerdir. Bu havzalarda ortaya çıkan molas fasiyesi ardalanmalı depolanmış ve 1-35 m arasında yukarı incelmeli istifler halinde görülürler. Çarpışma sonrasında meydana gelen serbestlemeler ve genişleme tektoniği bir takım grabenlerin ve dağ-eteği havzaların oluşmasına yol açar. Alüvyal yelpazeler bu havzalarda tipiktir.

b) Okyanusal-kıtasal levha yaklaşım kuşakları: Pasifik tipi kıta kenarlarının oluşumunu sağlayan bu tip levha hareketlerinde, yiten ve üstleyen levhalarda tektonik ve volkanik etkinliklerin yoğun olduğu bir dizi depolanma havzası meydana gelir. Bunlar magmatik yay-gerisi karasal veya denizel ortamlar, yay-önü karasal fasiyesler, şelf, kıta yamacı ve hendekten oluşan depolanma alanlarıdır. Yay-gerisi karasal ortamlardaki tortullar diğer yerlerdeki benzerlerinden farklı değildir. Yalnızca buralarda çokça volkanik katkı beklenir. Yay-önü alüvyal yelpazelerde volkanik katkılar daha sınırlı olup bunlar sığ denizel fasiyeslere geçerler. Hendekte çoğunlukla kıta yamacına paralel gelişen türbidit yelpazeleri ofiyolitli melanj oluşumlarıyla katkılanır. Bu kesim tortulları önemli oranlarda volkanik katkı içermezler. Şelfte meydana gelebilecek tansiyon etkisi birbirlerinden ayrı ve paralel uzanan alt çökelme alanlarının oluşumuna yol açabilir. Başka bir deyişle istiflerin yanal devamlılığı Atlantik tipi kıta kenarlarına göre daha sınırlıdır. Bu havzalar kara kökenli malzemenin derinlere ulaşmasını engelleyebilecekleri gibi (54,17) platformun bu şekilde parçalanmasıyla da derinlere büyük bloklar aktarılabilir. Yiten levhanın üst üste bindirmeler halindeki yığışım prizmalarını meydana getirmesi de bu havzaların tipik özelliğidir.

Bu grup içinde magmatik yay-gerisi ortamlar özel bir yer tutarlar. Yitimin kıta kenarından başlayarak yaklaşık 250 km kıta içerisinde meydana getireceği tansiyon etkisi bir takım yay-gerisi havzaların açılmasını sonuçlar (55). Bu tür bölgeler riftleşme merkezinin devamlı değişmesi yüzünden zaman içerisinde bir seri havza meydana getirirler. Volkanik katkılı sedimantasyonla karakterize edilen bu havzalardan her yeni meydana gelen aktif kıta kenarına yakın yer alır (54). Oldukça büyük kalınlıklara ulaşan volkanik katkılı türbidit istifleri bu havzaların önemli karakterlerindendir (Gökten,1986).

The Apulian-Anatolian block was collided to Rhodope-Western Pontian belt during the Paleocene-Eocene time. Considerable amount of the lower crust of the Apulian-Anatolian platform was subducted by the detachment of the brittle upper crust by the south vergenant foreland thrusting (20). Finnaly subduction related arc magmatism of Eocene-Oligocene age were generated (42). The Serbo Macedonian belt porphry Cu deposits and the Southern Rhodope-Pontide skarn-vein type Pb,Zn belt were formed related with magmatism rocks of Eocene-Oligocene age (47).

The Arabian platform was fused to the Central Iran during the latest Oligocene early Miocene time. The Kerman region continental margin arc was generated consequence of subduction of the lower crust of the Arabian platform resulting with Zagros belt thrusting. The Porphry copper deposits of the Kerman region were orginated from subvolcanic intrusions of Oligocene age concerning of Subduction of the lower crust of Arabian platform (48) (Fig. 4 h).

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YERBİLİMCİNİN SESİ EYLÜL 1987 Sayı 14-15
GEOSOUND SEPTEMBER No

KITA VE OKYANUS KABUKLARI ÜZERİNDE GELİŞEN ÇÖKELME ORTAMLARI VE FASİYESLERİ

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ÖZET: Depolanma ve tektoniğin ilişkileri öteden beri bilinmekte ise de bunların istiflere ne şekilde yansıdığı üzerinde yakın zamanlarda daha çok durulmağa başlanmıştır. Özellikle tektonik kontrollu bir çok havzanın ortaya çıkarılması istif yorumlanmasına destek sağladığı gibi ortam sınıflamalarında tektoniğin temel öge olarak kabul edilmesini de gerektirmiştir. Küçük boyutlu birikme alanlarının tortul özellikleri benzerse de çok kalın istiflerin çökelmesinde, istifin oluştuğu havzaların kıtasal veya okyanusal kökenli oluşunun önemli rolü vardır. Yaşlı istiflerde bazı ölçütlerle bunları ayırmak mümkündür.

DEPOSITIONAL ENVIRONMENTS AND THEIR FACIES DEVELOPING ON OCEANIC AND CONTINENTAL CRUSTS

ABSTRACT: However the relations between sedimentation and tectonics and their influences to the lithology were known since very long time, recently they are made subject in many studies extensively. Today the tectonics especially is considered as the main element of the classification of depositional environments and give support to the interpretation of the sequences. Although the sedimentary characteristics of the small basins are similar, for the big basins, the main tectonic feature of the environment such as being on an oceanic or continental basement, plays an important role in the accumulation and characteristics of very thick sedimentary piles.

GİRİŞ

Tortul fasiyeslerin geliştiği çökelme ortamları, birbirlerinden fiziksel, kimyasal ve biyolojik özellikleriyle ayrılan yeryüzü parçaları olarak tarif edilir ve değişen yerel şartlar alt bölümlerin ayrılmasını gerektirebilir (1,2). Bu alanlarda depolanma esas olarak su varlığı, su derinliği, enerji cinsi, ortam topografyası gibi fiziksel, su kimyası ve canlı varlıkların etkisi gibi kimyasal ve biyolojik faktörlerin kontrolü altındadır. Tektoniğin depolanmaya etkisi ise ortamın fiziksel yapısını yani geometrisini değiştirmekte,ayrıca volkanizma olaylarına neden olarak depolanmanın bağlı olduğu koşulları kontrol etmektedir. Bütün bu etkiler ortamsal gelişimin üç boyutlu anlatımı olan "fasiyes/istif" çeşitlenmesinde görünür hale gelir. Bu nedenle fasiyes tipleri ve istif ile çökel havzalarının tektonik gelişimleri arasında sıkı bir ilişki bulunmaktadır.

Sedimentasyon ve tektonik ilişkiler üzerinde yapılan çalışma ve yorumları plaka/levha tektoniği kuramı öncesi ve sonrası olmak üzere ayırmak yerinde olur. Önceki çalışmalar "jeosenklinal ve orojenez" fikirleri üzerine kurulmuş olup bir çok araştırıcı tortul istifleri bu temel kavramlar doğrultusunda yorumlamışlardır (3,4,5,6,7,8). Alp-Himalaya zinciri ve buradaki olayların esas alındığı bu kavramlar içerisinde jeosenklinal ve kraton gibi iki temel öge yer alır. Kratonlar kıtasal kaynak alanları,jeosenklinaller ise denizel ve tektonik kontrollu depolanma havzaları olup,kratonlara yakınlık,volkanizma varlığı ve denizel havzaların niteliklerine göre çeşitlendikleri ve orojeneze bağlı olarak üç evreli bir gelişim gösterdikleri kabul edilir (7,9). Bu evreler sırasıyla:

a) <u>Orojenez öncesi-Prefiliş fasiyesi</u>: Granitik veya metamorfik bir temel üzerinde,ya da tektonizmadan korunmuş bir karbonat platformu üzerinde gelişen ince taneli derin deniz tortullarıyla temsil edilir.

b) <u>Orojenez evresi-Filiş fasiyesi</u>: Genelde kumtaşı-marn ardalanması şeklindeki bu fasiyes orojenez sonrasında,paroksizmadan hemen önce gelişir.

c) <u>Orojenez sonrası-Molas fasiyesi</u>: Orojenez etkisinin zayıfladığı,paroksizma sonrası oluşan karasal ve sığ denizel tortullarla belirlenmektedir.

Yeryuvarının tektonik çatısı 1960' ların sonlarından itibaren önce Global Tektonik,daha sonra 70'li yılların başlarında yerine geliştirilen Plaka Tektoniği ile açıklanırken,eski kavramlar da bu yeni teori içinde yerlerini bulmuşlardır. Jeosenklinal kavramı bu yeni teoride okyanusal havza olarak ele alınmaktadır. Levha tektoniği için klasikleşmiş yayınlarda (10, 11,12,13,14,15,16) bir yandan levha tektoniğinin ilkeleri ortaya konurken bir yandan da jeosenklinal kavramının bu kuramdaki yeri ve özellikleri belirlenmeğe çalışılmıştır. Bugün depolanma ortamları kıta veya okyanusal türden kabuk üzerinde bulunduğuna göre sınıflanabilmekte ve havza karakterlerinin levha hareketleriyle denetlendiği kabul edilmektedir.

Tortullaşma havzalarının levha hareketleri ve dolayısıyla tektonikten etkilendikleri dikkate alındığında,tortul ortam sınıflamalarında bu etkinin de düşünülmesi gerektiği ortaya çıkar. Bu sınıflamada temel güçlüklerden biri hidrodinamik şartların değişmemesi yüzünden farklı yerlerdeki depolanma havzalarında benzerli istiflerin meydana gelebilmesidir. Bunun yanında levha tektoniği kuramıyla birlikte çek-ayır (Pull-apart) gibi yeni bazı havza tiplerinin de,tümüyle tektonik kontrollu olduklarının anlaşılmasıyla gündeme gelmeleridir. Bir başka temel güçlük de levha dinamiği ve fasiyes oluşumunun birbirinden bağımsız oluşları nedeniyle yapılacak tablolarda sedimantolojik ve tektonik ölçütleri bağdaştırmadaki güçlüktür. Bu güçlük özellikle eski istiflerin farklı ortamlara yorulabilmelerinde kendini göstermektedir. Bu konuda Mitchell ve Reading (17) ve Reading (18) tektonik/fasiyes ilişkilerini,Gökçen (19) kıta ve okyanus kabukları üzerindeki çökelme ortamları ve fasiyeslerini gözden geçirmişler; Miall (20)' da tortul ortamları tektoniği de dikkate alarak yeniden sınıflamıştır. Bu makalede yaklaşan ve uzaklaşan levha hareketlerine bağlı oluşan önemli depolanma alanlarındaki istifler ve bunların sedimantolojik ölçütleri verilmeğe çalışılmıştır.

TEKTONİK,ORTAM VE TORTUL İSTİF İLİŞKİLERİ

Tektonik,havza ve istif birbirlerini denetleyen ve sebep-sonuç ilişkisi içindeki üç ayrı olgudur. Plaka tektoniği bunların beraberce değerlendirilmelerine imkan verir. Birbirine göre uzaklaşan,yaklaşan ve yanal olarak hareket eden levhaların bu hareketlerine bağlı olarak,levha içlerinde ve kenarlarında depolanma havzaları ortaya çıkar. Bu depolanma alanlarının özellikleri ve depolanan istifler küçük geometriler içinde benzer olabilirlerse de,bölgesel ölçekte aşağıdaki ana fasiyesleri sunarlar.

1- Uzaklaşan levhalar ve bunlara bağlı fasiyesler

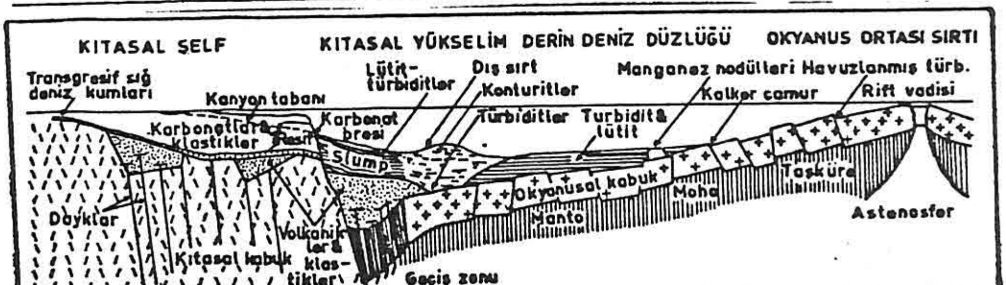
Deniz tabanı yayılması veya riftleşme ile tipik bu tür levha hareketleri gerek okyanusal kabuk,gerekse kıtasal kabuk üzerinde kalın istiflerle karakterize edilen çeşitli depolanma ortamları ortaya çıkarır.

a) Kıta-içi ortam ve karasal fasiyesleri: Kıta-içi riftleşme olaylarına bağlı olarak gelişen bu tür fasiyesler kalın alüvyal yelpaze ve örgülü akarsu tortullarıyla temsil edilirler. Bu tür depolanma havzalarına en iyi örnekler Doğu Afrika ve Baykal rift vadilerinden verilebilir. Ardalanma gösteren bu karasal tortullar grabenin yamaçlarından başlayarak asimetrik konumlu olarak izlenirler. Kalınlıklarının tersine yanal devamlılıkları fazla değildir. Alüvyal yelpazeler faylanma ile derin kanallarla yarılabilir ve ince tanelilerin egemen olduğu dış yelpazeler gelişebilir (21). Bazan geniş göller oluşabilir ve bu göllerde bazaltik bir temel üzerinde doğrudan evaporitik kayaçların yer aldığı gözlenebilir. Danakill çukurluğu bu tür evaporitik alanlara iyi bir örnektir (22). Buradaki evaporitik istifler gölün boşalımı olmadığından denizel kökenliler gibi kireçtaşı ve dolomitlerle başlayan dönemler göstermezler; tersine monoton ve kalın tuz yatakları halinde olup kenar bölgelerde yer alan kırıntılılara geçiş gösterirler.

Kıta içinde gelişen havzalar denizel fasiyeslere geçişli istifler de sunabilirler. Bunlar kalın olmaktan çok geniş yanal yayılıma sahip istifler olup,akarsu ve kıyı ovası tortulları olarak belirirler. Şelf üzerinde meydana gelen enine yarılmalar,denize yakın ve kıyı bölgelerde alüvyal yelpaze tortullarının meydana gelmesine yol açabilmektedir (23,24).

b) Denizel ortamlar ve fasiyesleri: Okyanus kabuğu üzerinde yer almak suretiyle okyanus ortası sırtlardan,kıta kabuğu üzerinde yer almak üzere Atlantik tipi kıta kenarlarına kadar çok geniş bir alana dağılırlar (şekil 1). Levha hareketlerinin bu tipinde tektonik etkilerin nispeten zayıf olduğu depolanma alanları özellikle sığ kıyı alanları,şelf,kıta yamacı ve derin deniz düzlükleridir. Her bölümün kendine özgü istifleri olmasına karşın kıta kenarlarında depolanma çok kalın ve tipiktir. Karbonat ve kırıntılıların bolluğuna karşın volkanik katkılar azdır. Çok tipik olan istifler şunlardır:

	Karbonat	Kırıntılı
Kıta düzü: (şelf)	platform kireçtaşları resifal topluluklar, karbonat düzlükleri	deltayik istifler
Kıta yamacı: (yokuş)	kalın yumrulu kireçtaşları	kanyon ve derin deniz kanal dolguları,denizaltı yelpazesinin bazı bölümleri,konturitler
Derin deniz düzlüğü:	karbonat ve kumtaşı türbiditler,pelajik kireçtaşları	yelpaze istifleri,pelajik tortullar,ince taneli türbiditler



Şekil 1. Uzaklaşan levhalar üzerindeki depolanma ortamları (Reading,1982'den).

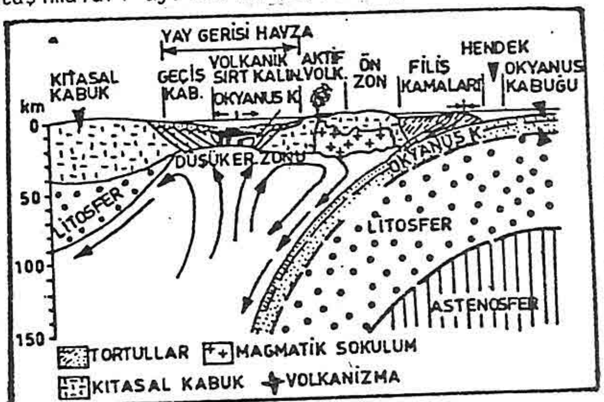
Genelde şelf ve kıta yamacı tortulları kıta kabuğu,derin deniz istifleri okyanus kabuğu üzerinde gelişirler. En önemli fasiyes özelliği büyük yanal devamlılık ve stratigrafik kalınlıklardır. Takonik tip,bu fasiyesler için iyi bir örnektir (25). Pasif veya Atlantik tip kıta kenarlarının sığ denizel veya şelf bölgelerinde platform tipi karbonatlar tanıtman litoloji oluştururlar. Bunun en iyi örneği Bernoulli ve Jenkyns (26)'in tanıttığı Alpin Akdeniz Jura'sında gözlenmekte olup,buralarda horst/graben sistemleriyle parçalanarak lokal havzalar ve denizaltı yükseltileri meydana gelmiştir. Aşırı kalanlık,yaygın dolomitleşme,pelajik oolitler,sığ ve derin deniz karbonatlarının yanal geçişleri,parçalanmanın olmadığı yerlerde kalın neptün daykları diğer tanıtman özelliklerdir (26,27,28). Bu alanların kırıntılı fasiyesleri karbonatlar kadar tipik değildir ve kalın gel-git istifler gözlenmektedir.

Riftleşmeye bağlı denizel havzaların kıta yamacı,kıta yokuşu ve derin deniz bölümlerinde kırıntılı fasiyesler çok belirgindir. Kıta yamaçlarında yumrulu kireçtaşları tanıtmandır (29). Şelften derin deniz düzlüklerine kadar uzanan ve türbit akıntılarla depolanan derin deniz yelpazeleri iyi bilinen istiflerdir. Pasif kıta kenarlarına yaslanan ve binlerce kilometre uzanımlı bir çok güncel yelpaze bilinmektedir (30,31,32,33). Eski yelpaze tortullarının yanal ve düşey fasiyes ilişkileri iyi bilinmektedir. Bunların bir çoğu bir kaç jeolojik çağı içine alan kalın serilerdir (34,25,35,36,37, 38,39,40). Kıta yamacı ve yelpaze tortullarının genel özellikleri önceki çalışmalarda dikkate alınarak yakın zamanda Stanley ve Kelling (41),Walker (42),Nilsen (43),Gökçen ve Kelling (39) ve Buck ve Bottjer (44) tarafından gözden geçirilmiş ve tartışılmıştır. Bunlar şelften başlayan ve kıta yamacını yaran büyük kanyon ve derin deniz kanalları yoluyla ve kütle akmaları yoluyla oluşmaktadır. Düşey kesitleri deltalara çok benzerlidir. Derin deniz düzlüklerinde ince taneli türbiditler olarak bulunmalarına karşın (45, 46,47),yamaç ve yamaç tabanında sık sık kayma/oturma yapılarıyla kesilmiş moloz akmalarının ve çeşitli kanal dolgularının yaygın olduğu kumlu filiş serileri olarak gözlenirler. Denizaltı yelpazelerinin ait fasiyeslerine ait tortul özellikleri için Normark (48),Nelson ve Nilsen (49) ve Whitaker (50) in karşılaştırmalı tablolarına bakılabilir.

Denizaltı yelpazelerinin yayılma alanı dışında kalan derin okyanus düzlükleri de çok ince taneli kırıntılılarla temsil edilirler ve laminalı yapılarıyla ayırdedilirler. Kökeni üzerinde tartışmalar varsa da Hess ve Cough (47) ile Champbell ve Clark (51) bunların çok ince taneli türbiditler olduklarını ve denizaltı yelpazelerinin distal bölümlerinden kaynaklanan ince taneli metaryalin çeşitli dip akıntılarıyla depolandığını belirtirler. Bu kesimlerde karbonat çökeli bulunmaz. Manganez nodülleri de bu alanları tanıtan karakteristik verilerdir.

2- Yaklaşan levhalar ve bunlara bağlı fasiyesler

Yaklaşan levhalar dalma/batma olaylarının meydana geldiği sınırlarda veya buralara yakın yerlerde özellikleri birbirlerine göre farklılanan havzaların meydana gelmesine yol açarlar. Levhaların okyanusal ve kıtasal kabuk taşımaları ayrıca bu çeşitliliği kontrol eder (şekil 2). Örneğin tortullaşma Pasifik tipi levha sınırlarında,dalma/batmanın meydana geldiği derin bir hendek ile yamaç ve kıta düzlüğü ve magmatik yay gerisindeki ensialik yay-ardı havzalarda yoğunlaşırken,okyanusal tipteki kabukların karşılasmasıyla bir dizi havza ada yaylarıyla kontrol edilir şekilde ortaya çıkar. Yitim olayının sonu olan kıta-kıta çarpışması ile meydana gelen kenet kuşakları (fosil yitim zonları) genellikle karasal,uzunlamasına geometriye sahip dağarası,dağeteği ve çevre havzaların oluşumuna yol açar. Yaklaşan levha hareketleri ile oluşan havzalar çeşitliliklerine karşın boyutları nispeten sınırlı olup fasiyesleri de yanal devamsızdır. Ofiyolit yerleşimi,volkanizma ve metamorfizma olayları tortul fasiyeslerle iç içedir. İyi bilinen havza ve fasiyesleri şunlardır:



Şekil 2. Yaklaşan levhalardaki ortamlar (Toksöz ve Bird,1977'den).

	Kenet kuşağı (fosil yitim kuşağı)	Okyanusal ve kıtasal levha yaklaşımı (yitim zonu)	Okyanusal-okyanusal levha yaklaşımı (yitim zonu)
Havza:	Dağarası,çevresel kıta düzlükleri	Dağarası,kıyı ovası kıta yamacı,düzü ve hendek	Ensimatik yay-hendek ilişkili havzalar
Fasiyes:	Alüvyal ve deltayik istifler,evaporit, sabka ve molas fasiyesleri	Alüvyal yelp.,akarsu tortulları,resif,filiş volkkanik filiş	Resif,volkanojenik filiş,pelajik tortullar

a) Kenet kuşakları (sütür zonları): Bu kuşaklar fosil yitim zonlarını temsil ederler. Fasiyeslerin çoğunluğu karasal olup ofiyolitik melanj ve değişik okyanusal tortullar üzerinde gelişen havzalardır. Buralarda evaporit ve sabka tipi tortullarla molas fasiyesleri tipiktir. Zagros'lar boyunca İran körfezi evaporitleri (52,16) ile Himalaya'lar eteklerindeki Siwalik grubu (53) belirgin örneklerdir. Bu havzalarda ortaya çıkan molas fasiyesi ardalanmalı depolanmış ve 1-35 m arasında yukarı incelmeli istifler halinde görülürler. Çarpışma sonrasında meydana gelen serbestlemeler ve genişleme tektoniği bir takım grabenlerin ve dağ-eteği havzaların oluşmasına yol açar. Alüvyal yelpazeler bu havzalarda tipiktir.

b) Okyanusal-kıtasal levha yaklaşım kuşakları: Pasifik tipi kıta kenarlarının oluşumunu sağlayan bu tip levha hareketlerinde,yiten ve üstleyen levhalarda tektonik ve volkanik etkinliklerin yoğun olduğu bir dizi depolanma havzası meydana gelir. Bunlar magmatik yay-gerisi karasal veya denizel ortamlar,yay-önü karasal fasiyesler,şelf,kıta yamacı ve hendekten oluşan depolanma alanlarıdır. Yay-gerisi karasal ortamlardaki tortullar diğer yerlerdeki benzerlerinden farklı değildir. Yalnızca buralarda çokça volkanik katkı beklenir. Yay-önü alüvyal yelpazelerde volkanik katkılar daha sınırlı olup bunlar sığ denizel fasiyeslere geçerler. Hendekte çoğunlukla kıta yamacına paralel gelişen türbidit yelpazeleri ofiyolitli melanj oluşumlarıyla katkılanır. Bu kesim tortulları önemli oranlarda volkanik katkı içermezler. Şelfte meydana gelebilecek tansiyon etkisi birbirlerinden ayrı ve paralel uzanan alt çökelme alanlarının oluşumuna yol açabilir. Başka bir deyişle istiflerin yanal devamlılığı Atlantik tipi kıta kenarlarına göre daha sınırlıdır. Bu havzalar kara kökenli malzemenin derinlere ulaşmasını engelleyebilecekleri gibi (54,17) platformun bu şekilde parçalanmasıyla da derinlere büyük bloklar aktarılabilir. Yiten levhanın üst üste bindirmeler halindeki yığışım prizmalarını meydana getirmesi de bu havzaların tipik özelliğidir.

Bu grup içinde magmatik yay-gerisi ortamlar özel bir yer tutarlar. Yitimin kıta kenarından başlayarak yaklaşık 250 km kıta içerisinde meydana getireceği tansiyon etkisi bir takım yay-gerisi havzaların açılmasını sonuçlar (55). Bu tür bölgeler riftleşme merkezinin devamlı değişmesi yüzünden zaman içerisinde bir seri havza meydana getirirler. Volkanik katkılı sedimantasyonla karakterize edilen bu havzalardan her yeni meydana gelen aktif kıta kenarına yakın yer alır (54). Oldukça büyük kalınlıklara ulaşan volkanik katkılı türbidit istifleri bu havzaların önemli karakterlerindendir (Gökten,1986).

c) İki okyanusal kökenli levhanın yaklaşmasına bağlı havzalar: Bu şekildeki havzalar hem yiten hem de üstleyen levhanın okyanusal karakterde olduğu yerlerde meydana gelirler. Mariana ve Kermadec-Tonga hendekleri dolaylarında yer alan havzalar bu tipin örnekleridir. Hendekte melanj yerleşimi ve pelajik tortullaşma gelişirken yay-arası ve yay-gerisi kuşaklarda yoğun volkanik malzeme ile pelajik tortullaşma egemendir. Kara kökenli malzeme aktarımının zayıf olduğu bu tip havzalarda volkanik oluşumlar üzerinde yükselen resifal kireçtaşlarıyla çevrede bunlardan aktarılan karbonat kırıntılıların çökelimlerine de rastlanır.

3- Yanal levha hareketlerine bağlı havzalar

Birbirlerine göre yanal olarak yer değiştiren levhalara bağlı transform ve doğrultu atımlı faylarla boyuna havzalar gelişir. Okyanus tabanlarında yer alan bir çok kırık kuşağı ile kıta kabuğunda gelişenlerden Kuzey Anadolu ve San Andreas fay zonu çevresindekiler iyi bilinen örneklerdir. Bu tip havzalardaki istiflerin genel karakteristikleri bölgesel yanal devamsızlık, büyük kalınlıklara ulaşan hızlı depolanma,sık sık uyumsuzluk yüzeyleriyle belli olan yükselme ve aşınmalar ile metamorfizma ve volkanizmanın yokluğudur (17). Bu havzalardan doğrultu atımlı faylanmaya bağlı olan çek-ayır (Pull-apart) ile sıradağ-havza (Basin and range) tipindekiler genellikle karasal ortamlar olup istifleri ekseri gölsel,deltayik ve akarsu tortullarından kuruludur. Doğrultu atıma bağlı havzalarda alüvyal yelpaze ve yelpaze deltaları çok tipiktir (Hornelen basin:57,58,59;Hazar gölü:60,61;Burdur gölü havzası:62). Doğrultu atımlı faylara bağlı denizel havzalar da bilinmektedir ki küçük boyutlu olanlarına Jamaika'daki Yallahs havzası bir örnektir (63,64). Kaliforniya kıyılarının batısında Pasifik okyanusu içinde birbirinden adalar oluşturan eski tortullarla ayrılmış uzunlamasına havzalar da kökensel olarak San Andreas fayına bağlı yapısal özelliklerdir (18). Türbit akıntılar,tane akmaları,kayma-oturma yapıları,pelajik ve ince taneli terrijen malzeme çökelimi bu havzaları karakterize eden unsurlardır. Okyanus tabanlarında yer alan ve okyanus ortası sırtlarını öteleyen transform faylar da ince ve çok uzun bir takım çökelme ortamlarıdır. Diyapirik serpantinit yerleşmelerinin görüldüğü bu havzalar kıtadan kaynaklanan türbit akıntılarının ince kanallar içerisinde çok uzun mesafelere taşınmasını sağlarlar (65,66).

GENELLEME

Genel jeoloji çalışmalarında amaç paleocoğrafya ile evrimi saptamak olduğundan doğru bir yargı için çökelmenin olduğu havzanın tipini ve onu doğuran tektonik mekanizmayı kestirmek gerekir. Bu da istiflerin doğru yorumlarıyla elde edilebilir. Tektonizma ve sedimantasyon birbirine girmiş iki olgu olduğundan bunları birbirinden ayrı düşünmek imkansızdır. Bu etkileşimin güncel havzalardan çıkarsanan sonuçları eski havzalarda yapılacak doğru fasiyes analizlerinin tektonik modeli de ortaya çıkarabileceğini göstermektedir. Aslında basen analizlerinin önemi de böyle bir tümevarımın sağlanmasından kaynaklanır.

Tektonik kontrolun ne olduğunu ortaya koymak için fasiyes analizi ve istif özelliklerinin açıklanması gerekir. Ancak çoğu zaman eksik veri ve bunların sistematik biçimde toplanmayışı tümevarımı güçleştirmektedir. Ek tablo 1 ve 2 de üzerinde durulması gerekli özellikler gösterilmeğe çalışılmıştır. Gerek kıtasal,gerekse okyanusal kabuk üzerinde gelişen istifler için, istif geometrisi,yanal ve düşey depolanma özellikleri,tipik tortul yapılar, volkanizma,metamorfizma ve fasiyes çeşitliliği en önemli ayırtman kriterleri oluştururlar. Litoloji,renk,mineralojik bileşim,yönlü fabrik vb. ortamın beslenme biçimini ve geometrisini ortaya koyacak verilerdir. Ancak bunlar ortamların konumlarına göre çeşitlenebilirler. Bu çeşitliliği vurgulamak için ayırıcı kriterler her bir ortam için var-yok,seyrek,tipik şeklinde simgelerle tablo üzerinde işaretlenmiştir. Bu ayırıcı ölçütlerin ve bulunuşlarının lokal farklılıklar gösterebileceği tabiidir.

Buraya kadar vurgulanmağa çalışıldığı gibi ortam ile depolanma türü ve bunların zaman içerisinde oluşturduğu tortul istifler,tektonizmanın kontrolundadır. Tektonik kontrolun tipi ve oluşturduğu tortul havzanın özellikleri,tortul istiflerden toplanacak sistematik verilerle ortaya koymak mümkündür.

İSTİF ÖZELLİKLERİ / ORTAMLAR		KITA İÇİ ORTAMLAR														
		DAĞAR.	ÖRGÜLÜ AK.	MENDERESLİ AKARSU					GÖL	ÇÖL			BUZUL	İÇ DENİZ		
		Al. yelp.	Kanal	Yan set	Kan.set	Taş.ova	Akmaz g.	Bataklık		Vadi	İç göl	Çöl ova.		Lagün	Haliç	Deniz
Litoloji – Kırıntılılar	Breş,kong.	K	K	S	Y	E	E	-	Y	S	E	E	K	E	S	Y
	Kuv.kumt.	E	-	-	-	S	E	-	S	Y	S	Y	S	E	S	Y
	Grovak	-	-	-	-	-	E	-	-	-	-	-	-	-	-	S
	Arkoz	-	-	-	-	-	E	-	S	-	-	S	E	E	E	Y
	Volk.kumt.	S	E	S	-	S	S	E	Y	Y	Y	Y	S	S	S	Y
	Silttaşı	S	S	Y	S	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Çamurtaşı	K	Y	Y	E	K	K	K	K	S	Y	E	Y	K	Y	Y
	Kiltaşı	Y	Y	Y	E	Y	Y	K	K	S	Y	-	Y	K	Y	Y
Litoloji – Karbonatlar	Kalkarenit	-	-	-	-	-	-	-	Y	-	Y	-	-	K	Y	Y
	Oolitikkçt.	-	-	-	-	-	-	-	S	-	Y	-	-	Y	Y	Y
	Resif kçt.	-	-	-	-	-	-	-	E	-	S	-	-	Y	Y	Y
	Stromatolit	-	-	-	-	E	E	E	Y	-	Y	-	-	Y	Y	Y
	Karb.çam.	-	-	-	-	S	Y	E	K	-	Y	-	-	K	K	Y
	Dolomit	-	-	-	-	-	S	E	Y	-	Y	-	-	K	Y	Y
Litoloji	Jips-anidrit	-	-	E	-	S	Y	S	Y	E	K	E	E	K	Y	Y
	Radyolarit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S
	Kömür	E	-	E	E	Y	Y	K	Y	-	E	-	S	Y	Y	S
Seçilmiş sedimantolojik ölçütler	Renk	Kırm.kah	kırm.kah	kırm.kah	gri	gri	gri	gri,siyah	gri	kırmızı	açık	kırmızı	gri,kah.	sarımsı	gri,siyah	açık
Çapt.	Büy.ölçekli	S	K	S	K	S	S	-	S	Y	S	K	K	S	S	S
	Küç.ölçekli	Y	K	Y	K	Y	S	S	Y	Y	Y	K	K	Y	Y	K
	Paralel	Y	Y	Y	Y	Y	Y	S	K	Y	Y	K	K	Y	Y	K
	Masif	K	Y	S	Y	E	-	-	Y	Y	S	S	K	S	S	S
	Kayma-otur.	S	S	S	S	S	E	S	Y	S	S	Y	K	S	S	Y
Derece.	Normal	Y	K	Y	K	Y	Y	Y	Y	Y	Y	K	Y	Y	Y	K
	Belirsiz	Y	Y	Y	Y	S	S	Y	Y	Y	Y	K	Y	Y	S	Y
	Ters	Y	E	E	E	E	E	-	S	S	S	S	Y	S	E	S
	Rip.laminas.	S	Y	E	S	K	Y	Y	Y	S	Y	K	Y	K	Y	K
	Par.laminas.	Y	S	K	S	K	K	K	K	Y	K	K	K	K	K	K
	Taban yapısı	E	E	-	S	S	-	-	S	E	S	E	S	S	S	Y
	Kuruma çat.	S	S	Y	S	K	K	K	Y	E	K	Y	E	Y	Y	S
	Canlı izleri	E	-	E	E	E	Y	S	Y	E	S	S	E	K	K	Y
Fosil	Hayvan	E	E	E	E	S	Y	S	Y	-	Y	S	E	K	K	K
	Bitki	Y	E	Y	Y	K	Y	K	K	E	Y	E	S	K	K	K
	Geometri	Mercek	Mercek	Mercek	Mercek	Devamlı	Mercek	Devamlı	Mer.dev	Mercek	Mercek	Devamlı	Mer.dev	Mercek	Mercek	Devamlı
Değişim	Silisleşme	-	-	-	-	-	-	-	K	E	S	Y	S	Y	Y	Y
	Dolomitleşme	-	-	-	-	-	S	S	Y	-	K	-	-	K	Y	Y
	Otijenik min.	E	E	-	-	-	S	Y	Y	-	Y	S	S	K	Y	Y
	Çimentolan.	S	S	S	S	S	S	Y	Y	S	Y	Y	Y	K	Y	Y
İstif	Ritmik istif	Y	Y	Y	Y	K	Y	K	Y	S	Y	Y	K	K	Y	Y
	Siklik dep.	Y	Y	Y	Y	Y	S	S	S	S	S	S	Y	S	S	Y
	Tektonik kont.	K	S	S	S	Y	Y	S	Y	S	S	S	Y	S	S	Y
	Volk.katkı	E	E	E	E	E	S	-	K	-	S	E	E	E	E	Y

Tablo 1. Kıta içi ortamlarda istif ölçütleri.(K:Karakteristik,S:Seyrek,E:Ender,Y:Yaygın.)

İSTİF ÖZELLİKL. \ ORTAMLAR			UZAKLAŞAN LEVHALARDAKİ ORTAMLAR							YAKINLAŞAN LEVHALARDAKI ORTAMLAR								YANAL HAR. LEV. ORT.		
			KARAS.	GEÇİŞ		DENİZEL				YAY ÖNÜ				YAY GERİSİ				KARASAL		DENİZ.
			Rift vad.	Kıyı	Delta	Self	Yamaç	Abisal	Sırt ek.	Self	Yamaç	Hendek	Abisal	Kıyı	Self	Yamaç	Abisal	Çekayır	Dağ et.	Dön. fayı
Litoloji	Kırıntılılar	Breş, kong.	K	Y	Y	Y	Y	S	E	Y	Y	S	E	Y	S	Y	Y	Y	K	Y
		Kuv. kumt.	S	Y	Y	Y	Y	Y	E	Y	Y	Y	Y	Y	S	Y	–	Y	Y	Y
		Grovak	E	E	E	S	Y	Y	S	S	Y	Y	Y	S	S	S	–	Y	S	S
		Arkoz	E	E	E	S	Y	Y	S	S	Y	Y	Y	Y	Y	Y	–	S	S	E
		Volk. kumt.	Y	Y	Y	Y	Y	S	Y	Y	Y	Y	S	K	K	Y	K	E	S	S
		Silttaşı	Y	Y	Y	Y	Y	Y	S	Y	Y	Y	K	Y	Y	Y	Y	Y	Y	Y
		Çamurtaşı	K	Y	Y	Y	Y	Y	–	Y	Y	Y	K	Y	Y	Y	Y	K	K	Y
		Kiltaşı	Y	Y	Y	Y	Y	K	–	Y	Y	Y	K	Y	Y	Y	Y	Y	Y	Y
	Karbonatlar	Kalk-arenit	E	S	–	K	Y	Y	E	K	Y	S	Y	Y	Y	Y	K	S	E	Y
		Oolitik kct.	E	S	–	K	S	–	E	K	E	–	–	Y	S	E	–	S	E	–
		Resif kçt.	E	S	–	K	E	–	S	K	S	–	–	Y	S	S	K	S	S	–
		Stromatolit	E	S	–	K	E	–	–	K	–	–	–	S	S	S	–	Y	S	–
		Karb. çamur	Y	Y	–	K	Y	K	E	K	Y	K	K	Y	Y	Y	–	Y	S	–
		Dolomit	E	S	–	K	E	–	–	K	E	–	–	S	Y	S	–	S	E	–
	Jips-anidrit		S	S	E	Y	E	–	–	Y	–	–	–	S	S	–	–	Y	K	–
	Radyolarit		–	–	–	S	Y	Y	K	S	S	K	Y	E	S	Y	–	S	E	–
	Kömür		S	S	S	S	–	–	–	S	–	–	–	E	–	–	–	Y	K	–
Sedimantolojik ölçütler	Renk		Kır, kahve	Değişken	Gri	Gri	Gri	K. gri, si.	Si., gri	Gri, bey.	Gri	Gri, si.	K. gri, si.	Değişken	Gri, bey.	Gri, kır, yeş.	K. gri, si.	Değişken	Değişken	Gri, si.
	Çapt.	Büy. ölçekli	K	Y	Y	Y	S	E	E	Y	S	–	–	Y	S	S	E	Y	K	Y
		Küç. ölçekli	K	K	K	K	Y	S	S	K	Y	–	S	Y	Y	Y	S	K	K	–
	Paralel		Y	K	K	K	Y	Y	Y	K	Y	Y	Y	K	Y	Y	Y	Y	Y	–
	Masif		K	Y	Y	Y	K	Y	–	Y	K	E	Y	K	Y	Y	Y	Y	K	–
	Kayma-otur.		K	Y	Y	Y	K	Y	S	Y	K	Y	Y	Y	Y	K	K	Y	Y	–
	Derece.	Normal	Y	Y	K	K	Y	Y	Y	K	Y	Y	K	K	Y	Y	Y	K	K	K
		Belirsiz	Y	Y	Y	Y	K	Y	Y	Y	Y	Y	K	Y	Y	Y	–	Y	Y	–
		Ters	K	S	S	S	K	S	S	S	K	E	Y	Y	S	Y	–	Y	Y	–
	Rip. laminas.		Y	Y	K	K	Y	K	S	K	Y	Y	Y	Y	Y	Y	K	K	Y	–
	Par. laminas.		K	Y	K	K	Y	K	Y	K	Y	K	K	K	Y	Y	K	K	K	–
	Taban yapısı		S	Y	S	Y	K	K	Y	Y	K	K	K	Y	Y	Y	K	K	Y	–
	Kuruma çat.		Y	S	S	S	–	–	–	S	–	–	–	E	E	–	–	Y	K	–
	Canlı izleri		S	Y	S	Y	Y	K	E	Y	Y	S	Y	Y	Y	Y	–	Y	Y	–
	Fosil	Hayvan	S	Y	Y	K	Y	K	S	K	Y	Y	K	Y	K	Y	Y	Y	S	Y
		Bitki	Y	Y	Y	K	Y	K	S	K	Y	S	Y	K	Y	Y	–	Y	K	Y
	Geometri		Mercek	Mercek	Mercek	Devamlı	Dev. mer.	Devamlı	Mer. dev.	Devamlı	Dev. mer.	Mer. dev.	Devamlı	Mer. dev.	Devamlı	Dev. mer.	Devamlı	Mercek	Mercek	Mer. dev.
Değişim	Silisleşme		Y	S	S	Y	S	S	K	Y	S	S	S	S	Y	S	K	Y	Y	–
	Dolomitleşme		E	S	–	Y	S	–	–	Y	–	–	–	Y	Y	S	–	S	S	–
	Otijenik min.		S	S	S	Y	Y	S	Y	Y	S	S	S	Y	Y	Y	S	Y	S	–
	Çimentolan.		Y	Y	Y	Y	Y	K	Y	Y	Y	Y	Y	Y	Y	Y	E	Y	S	E
İstif	Ritmik dep.		S	Y	S	Y	Y	K	Y	Y	Y	K	K	Y	Y	S	K	Y	Y	K
	Siklik dep.		Y	Y	K	K	K	S	S	K	S	S	S	K	K	Y	–	K	K	–
	Tektonik kont.		K	K	K	K	K	Y	Y	K	K	K	K	K	K	Y	K	K	K	K
	Volk. katkı		Y	S	S	S	S	E	K	S	E	E	E	K	K	Y	K	E	E	E

Tablo 2. Uzaklaşan, yakınlaşan ve yanal hareketli levhalardaki ortamlar ve istif ölçütleri. (K: Karakteristik, S: Seyrek, E: Ender, Y: Yaygın)

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YERBİLİMCİNİN SESİ EYLÜL 1987 Sayı 14-15
GEOSOUND SEPTEMBER No

GEOTHERMAL ACTIVITY IN TURKEY

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SUMMARY: Turkey is located on the Alpine tectonic belt. There are many grabens, widespread acidic volcanism, hydrothermal alteration zones, fumeroles and a lot of hot springs with temperatures over 100°C due to this young tectonic activity. The available data indicates that Turkey has an important geothermal energy potential. The initial geothermal energy studies were carried out in 1960's by MTA research groups. The first economic geothermal field of Turkey was discovered at Denizli-Kızıldere in 1968. In this a geothermal power plant of 20.4 MW capacity came in operation in February 1984. High enthalpy Aydın-Germencik (232°C), Çanakkale-Tuzla (174°C) and Kütahya-Simav (158°C) geothermal fields were discovered in 1982. In addition, some fields at Eastern Anatolia like Bitlis-Nemrut which were affected by young volcanism are promising for dry steam production.

Non-electirical uses of geothermal energy in Turkey has also begun in 1982. In İzmir-Balçova and Afyon geothermal fields have been encountered. For this reason down-hole heat exchanger system was tested in both fields and succesfull results were obtained. Thus, today the potential of both fields are being used for domestic heating. Geothermal energy field studies are in progress in order to explore new high and low enthalpy fields in addition to the above mentioned areas. Utilization of geothermal energy is very important for Turkey since half of the energy consumed in this country comes from imported petroleum.

TÜRKİYE'DEKİ JEOTERMAL ETKİNLİK

ÖZET: Türkiye Alpin tektonik kuşağı üzerinde yer almaktadır.

Bu tektonik kuşağı bağımlı olarak birçok graben, geniş yayılımlı asidik volkanizma, hidrotermal ayrışma zonları, fümeroller ve 100°C'nin üzerindeki ısıda bir çok sıcak noktalar vardır. Belirlenen verilere göre Türkiye önemli bir jeotermal enerji potansiyeline sahip bulunmaktadır. Türkiye'deki jeotermal enerji ile ilgili çalışmalar 1960 yıllarında MTA araştırma grupları tarafından yapılmıştır. Türkiye'nin ilk ekonomik jeotermal sahası 1968'de Denizli_Kızıldere'de bulunmuştur. Bu jeotermal saha 20.4 MW kapasiteli olup Şubat 1984 yılında üretime başlamıştır. Yüksek entalpili jeotermal sahaları 1982'de Aydın-Germencik (232°C), Çanakkale_Tuzla (174°C) ve Kütahya_Simav (158°C)'de bulunmuştur. Bunların yanısıra Doğu Anadolu'da genç volkanizmanın etkilediği kuru buhar ürünü Bitlis_Nemrut gibi jeotermal alanlar saptanmıştır.

Elektrik üretiminde kullanılmayan jeotermal enerji 1982'de üretilmeye başlanmıştır. Bu enerjiyle ilgili olarak İzmir-Balçova ve Afyon jeotermal alanları belirlenmiştir. Bu nedenle hir iki alanda da kuyu dibi ısı değiştirici sistemi denenmiş ve başarılı sonuçlar elde edilmiştir. Böylece bugün her iki alanın potansiyeli binaların ısıtımında kullanıma başlanmıştır. Yukarıda bahsedilen bölgelere ilaveten, yeni yüksek ve düşük entalpili alanları saptamak için jeotermal enerji alanındaki çalışmalar sürdürülmektedir. Türkiye'nin enerji ihtiyacının % 50'si ithal petrol ile karşılandığından jeotermal enerji kullanımı Türkiye için çok önemlidir.

INTRODUCTION

Geothermal energy is rather a new concept for Turkey. Besides the continuous increase in demand for energy, the limited fossil energy resources of the country, as coal, oil and natural gas, have promped the Mineral Research Exploration General Directorate of Turkey (M.T.A), to undertake the exploration of new energy recources. Geological and geophsical studies followed the initial research work started in 1962 (1). The first geothermal fluid was discovered in 1963 by a shallow borehole drilled at İzmir-Balçova but no use was made out of that 124°C fluid at that time because of rapid scaling effect. Due to the prospectoreous results of geological, geophysical, geomorphological and geochemical works, test studies and drilling activities at various depths were carried out in many promising fields, especially in Western and Central Anatolia.

The first geothermal field, suitable for generation of electricity . was explored in Denizli-Kızıldere, as a result of the work carried out in cooperation with the United Nations Development Programme (U N D P). The 20.4 MWe power plant was installed in this field by Turkish Electricity Authority and started electricity production in February 1984. Aydın-Germencik and Çanakkale-Tuzla fields were discovered in 1982. On the other hand domestic heating via İzmir-Balçova and Afyon geothermal fields came into application in the same year.

A total of 23523 m shallow gradient holes and 34578 m of deep boreholes have been drilled since 1962. Geothermal energy exploration activities are continuous implemented by MTA.

GEOTHERMAL ENERGY POTENTIAL OF TURKEY

Turkey is located on the Alpine-Himalayan orogenic belt and has numerous grabens developed under the effect of young tectonic movements, widespread acidic volcanic activities, hydrothermal alterations, fumeroles and more than 600 hot water springs with temperatures exceeding 100°C. This data indicates that Turkey is located on a geothermal energy belt and has an important potential of geothermal energy (Figure 1).

The work done up to date is not sufficient for an exact evalution and calculation of the net potential of the country. Depending on the data obtained during the last 20 years, a potantial of 4500 MW electrical energy can be estimated in high entalpy fields. In addition to this, 31000 thermal MW

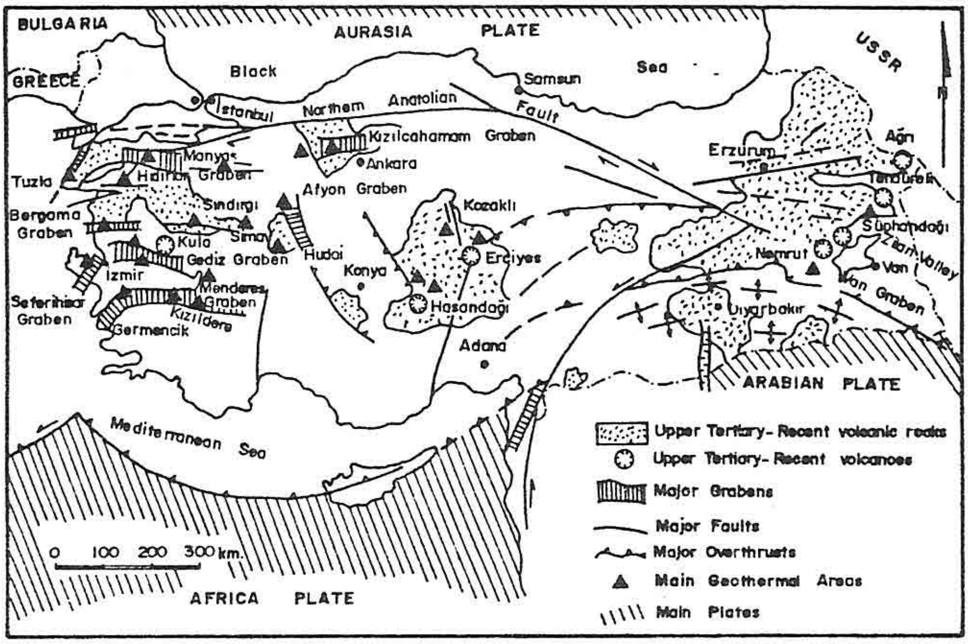

Figure - I : General tectonic and volcanic features of Turkey

geothermal potential is expected for the direct use of heat discharge such as domestic and greenhouse heating and industrial uses etc. Furthermore, if the "hot dry rock" projects which are planned for the coming years give positive results, the geothermal energy production in Turkey, with no doubt, will increase.

MAIN HIGH ENTALPY GEOTHERMAL FIELDS

Denizli-Kızıldere Geothermal Field

The first economical geothermal field of Turkey was discovered at Denizli-Kızıldere field in 1968. This field is located in Western Anatolia, at the eastern part of the Büyük Menderes Graben which a high geothermal energy potential

(Figure 2). After geological, geophysical, geochemical surveys and 108 shallow gradient boreholes, implemented by the inputs of a UNDP project for this field, the first deep well resulted with the exploration of high temperature geothermal fluids suitable for electricity production. 17 deep holes were drilled in the area with a total depth of 9909 m and two reservoirs were explored. The first reservoir consist of lacustrine limestone in sedimentary rocks of Pliocene age. It has a geothermal fluid of 198°C temperature and its depth is nearly 400 m. The second reservoir's depth varies between 450-1100 meters and has a temperature of 212°C. It consists of Paleozoic marbles, schists and quartzites (2, 3). A total of approximately 1600 t/hr geothermal fluid is obtained from six wells in the Kızıldere geothermal field (Figure 3). Approximately 10-12 percent of the produced fluid consists of steam, which is being utilized in the generation of electricity by the Turkish Electricity Company (T E K).

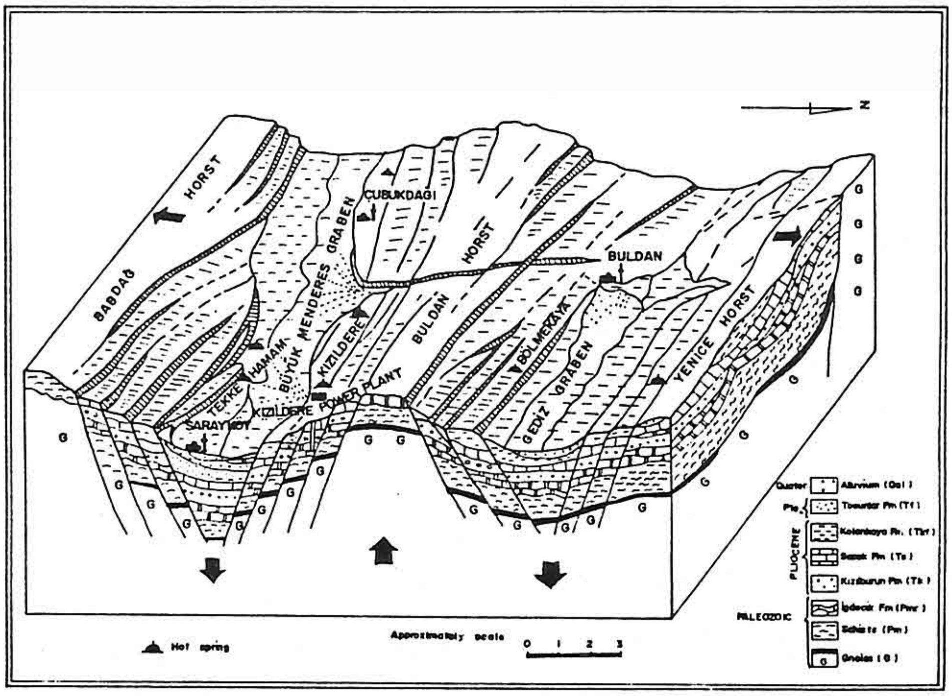

Figure-2 : Block diagram of the Sarayköy - Buldan area. (S. Simşek, 1982)

Turkey's first commercial geothermal power plant, installed in the Denizli-Kızıldere area, started operation on February 11, 1984. Capacity of the plant is 20.4 MWe and its net contribution to an interconnected system is 17.8 MWe (4). Total annual production period of the single-flash cycletype power plant is 7000 hours; maintenance and mechanical cleaning of wells and of equipment take approximately 1760 hours per year. Cost of electricity produced by the plant is about 0.025-0.030 $ / kWh. Additional 6 wells will be drilled in near future for regular utilization. As a result, electric generation from geothermal energy seems more advantageous than electric power produced from fossil fuels (5). A plant started production of Carbondioxide in 1986 with a capacity of 120 tons/day in Denizli.

The fluid which is seperated from the steam has a volume of 1450 t/hr and has a temperature of about 140°C. At this temperature, a small amount of steam can still be obtained by means of a second separator. The remaining fluid (100°C) has a thermal potential of 100 MWt and could be used to heat greenhouses covering an area of 50 ha (500.000 m^2). At present tests for heating the greenhouses covering 4500 m^2 gave satisfactory results. An area of 1 million m^2 has been expropriated by the Ministry of Agriculture and Forestry (M A F) for the development of greenhouse agriculture. Due to its chemical properties, the waste geothermal fluid is also used by Sarayköy Textile Industries for whitening purposes. The whitness and brightness of the textile products make them a high-demand item in the foreign market. Since this region has a high potential for tourism, it seems reasonable to develop healt and touristic resorts. These resorts will also serve as health and recreation centers.

The envisaged utilization of geothermal energy in Denizli-Kızıldere field is given on Figure 3. An appraisal of the available data (from TEK and MAF) shows that the contribution from all of the planned programs and from the ones mentioned above to the economy of the country will be significant. Electric generation will be worth $45X10^9$ TL and greenhouse agricultune will be worth $10X10^9$ TL (1984 prices). Should other utilization be taken into account, the total contribution to the economy of the country will reach $60X10^9$ TL.

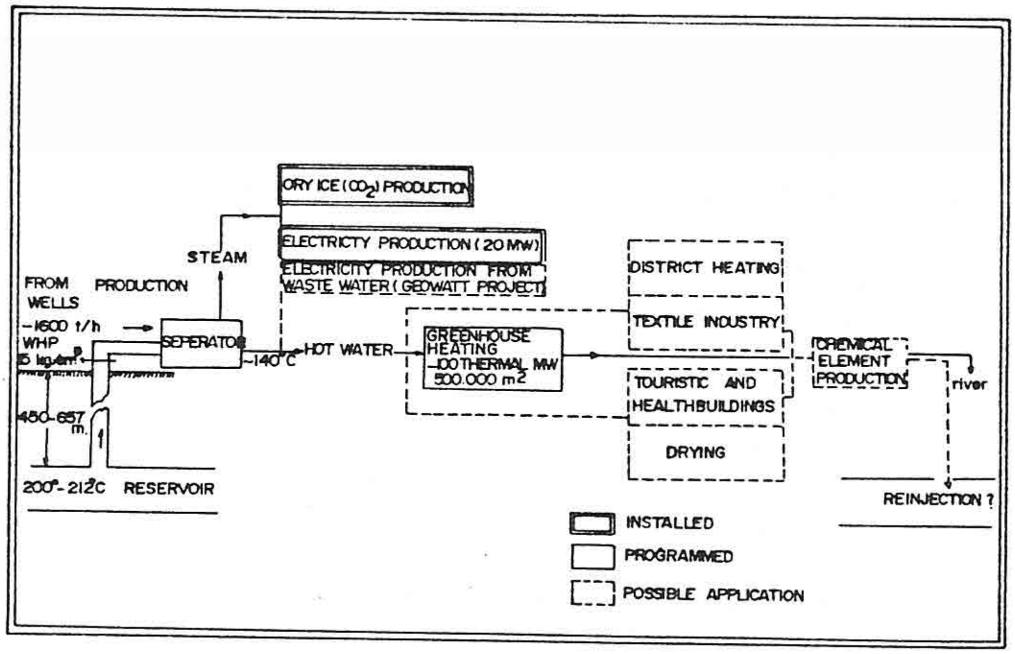

Figure 3 : Envisaged utilisation of geothermal energy in Denizli - Kızıldere field (Ş. Şimşek, 1985)

Aydın-Germencik Geothermal Field

This field is located at the western part of the Büyük Menderes Graben on the West Anatolia. Geological, geophysical and geochemical studies have indicated that this field has an important potential (Figure 4-5). The first exploratory hole in the area was drilled in 1982. Two reservoirs have been explored in this field. The first one is in this field in Neogene basal conglomerates, the other one is in metamorphic rocks containing gneisses, schists, quartzites and marbles of Poleozoic age. Up to data 8 wells have been drilled with depths changing between 285-2398 m. The fourth one, ÖB-4 well

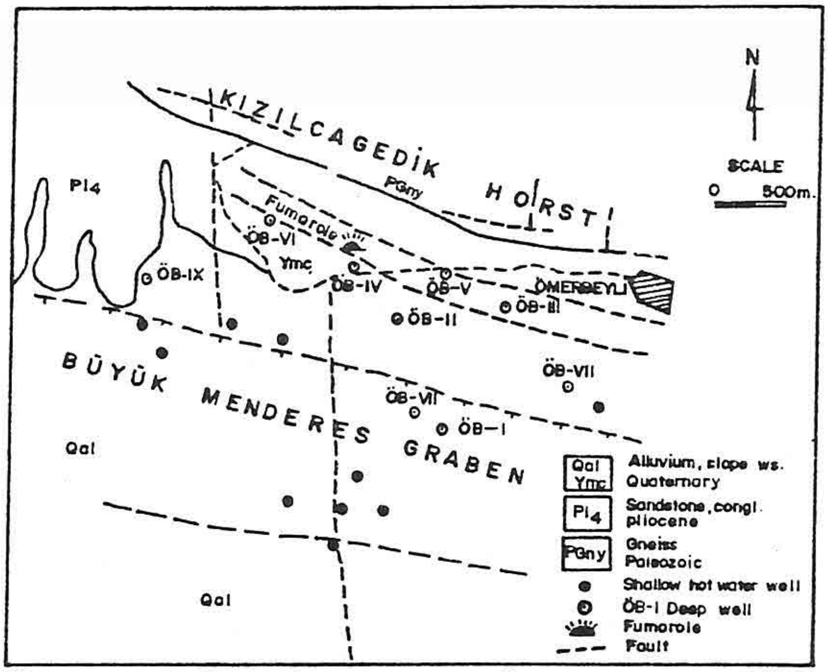

Figure: 4-Geologic map of the Germencik-Ömerbeyli Geothermal Field (Ş. Şimşek, 1984)

(285 m) is one of the shallowest geothermal wells in world. The temperatures of reservoirs are in between 200°C-231°C. According to shortterm tests, the production rate is changing between 130-425 t/hr and the steam ratio is approximately 13-20 % (6). The collected data indicates that the field has important geothermal potential for production of electricity, disposed hot water can be used for domestic heating, greenhouse heating, drying, canning textile industry cooling and for touristic and balneological purposes.

Çanakkale-Tuzla Geothermal Field

It is located in Northwestern Anatolia, 80 km south of Çanakkale city and 5 km to the Aegean Sea. Important and promising results were obtained from the geological, geophsical, geochemical studies and gradient drillings in previous years. The first well of 814 m depth was drilled in 1982. In this

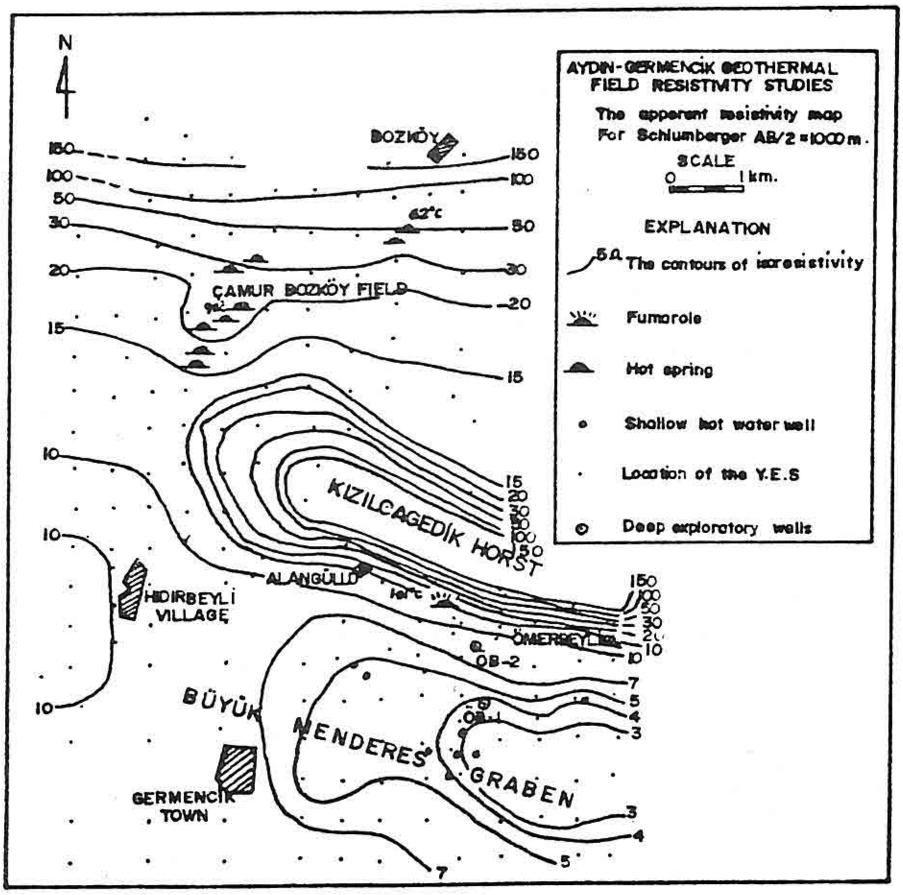

Figure: 5-Apparent resistivity map of Germencik Geothermal Fields (H. Şahin, 1981)

well, steam and hot water mixture was recovered from the first reservoirs at depths between 333-553 m in volcanic rocks. Production rate of the well is measured as 130 t/hr, temperature 173°C and steam ratio is 13 %. Expected second rezervoir of marbles and metamorphic rocks encountered at 759 m but could not be tested. Deep drilling operations will be continued to explore higher temperature reservoirs in the field. This field is extremely suitable for agricultural uses (heating greenhouses, drying etc.), besides electiricity production. In addition to this, geothermal fluid can be used for salt production because of its chemical properties (Table 1). The waste water disposal will not be a problem due to the closeness to the Aegean Sea.

Table - I - Chemical composition of hot water collected from some geothermal field's in Turkey.
(S. Simşek, E. Şamilgil and M.F. Akkuş, 1981)

NAMES OF FIELDS	pH	MEASURED TEMP. °C	T.DS mg/lt	CONCENTRATION OF DISCHARGED WATER (In ppm)											
				Na^+	K^+	NH_4^+	Ca^{++}	Mg^{++}	B	HCO_3^-	$CO_3^=$	$SO_4^=$	Cl	Li	SiO_2
Kızıldere x DENIZLİ (Second reservoir)	8,9	212	5020	1400	148	3,6	2,2	0,0	28	2117	336	714	122	-	550
Germencik x AYDIN (Second reservoir)	6,3	232	4400	1335	45	3,8	6,4	1,0	45	1324	246	37	1586	8	305
Ömer - Gecek x AFYON	7.4	106	4500	1510	116	5,4	143	10	9.1	952	180	487	1790	-	125
Balçova x İZMIR	8,7	124	1230	380	29	1,03	12	7	2,8	567	6	174	192	1,6	145
Seferihisar x İZMIR (First reservoir)	7,5	137	19938	6400	650	5,55	425	129	17	88	0.0	323	1/348	15.4	140
Tuzla x CANAKKALE (First reservoir)	7.0	173	70000	22250	2125	2,66	5715	101	35	55	0.0	176	44140	74	123
Kızılcahamam x ANKARA	7.6	105	2072	670	66	1.3	41	42	8.3	1512	0-0	122	243		112

(x Drill - holes)

İzmir-Seferihisar Geothermal Field

This field is located 40 km southwest of the İzmir city. Geological, geophyical, geochemical studies, gradient and deep drilling operations conducted in the area indicated that the field has an important geothermal energy potential suitable for electrical energy generation as well as for greenhouse heating and building facilities for balneological and touristic purposes. The first reservoir was encountered between 70-720 m at deep drilling operation which reached 1417 m dept. This well was abandoned because of the tecnical difficulties. In this well, fluid temperature from first reservoir is 145°C.

Nemrut-Zilan-Süphan-Tendürek Geothermal Fields

These fields are located on the north of Lake Van in Eastern Anatolia. Geological and geochemical studies have already been completed. According to young volcanic activity in the area and geochemical data,"Dry-Steam" production is expected from these fields.

Nevşehir-Acıgöl Geothermal Field

It is located in the Central Anatolia. The geological magnetic, and geophysical (magnetic gravity and resistivity) surveys have indicated the presence of an active heat source composed of young extrusives at a shallow depth. Consequently, studies directed to "Hot-Dry-Rock" project are planned in this area in the near future.

MAIN LOW ENTHALPY FIELDS

Non-electrical uses have been continuing in some low enthalpy geothermal fields in Turkey for 10 years. These fields, which have low enthalpy and high scaling characteristics, are being utilized and operated for domestic heating purposes. Non-electrical uses in different fields may be summerized as fallows:

Balçova-İzmir Geothermal Field

The first geothermal energy well was drilled in this field in 1963 and yielded a mixture of hot water and steam of 124°C temperature at a depth of 40 meters. Because of rapid scaling problem. the well became in.efficient in a short period, thus, no-use was made at that time (7). The first application of down-hole heat exchanger system in Turkey took place at this field in 1982, in order to avoid the scaling. The first well used for this purpose has a depth of 100 meters and bottom-hole temperature of 115°C. With this new application; heat transferred to fresh water circulated through "U" shaped pipes which are placed in the well (Figure 6). The temperature

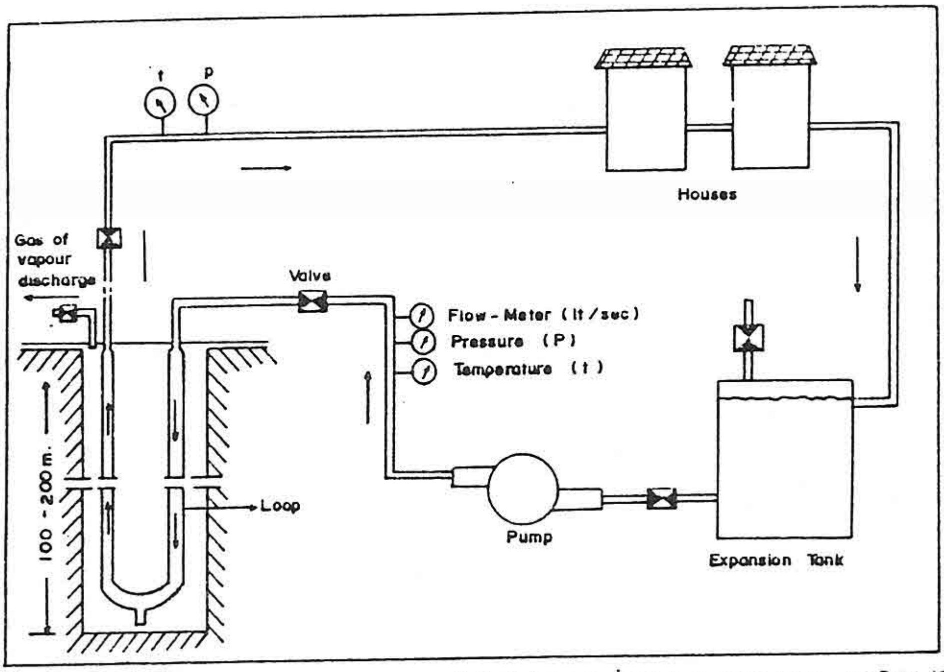

Figure : 6 . Down- hole heat exchanger system applied at Balçova - İzmir and Afyon area (T. Polat, 1984)

of clean circulating water in the system varies in between 50-95^{o}C depending on the external effects and flow rate. Today, the touristical spa-hotels and its recreational facilities with 250 room capacity in Balçova are heated by a single well. Some units of İzmir-Dokuz Eylül University are also heated by the other three wells. The total present production potential is about $4.5X10^{6}$ Kcal/h by 9 wells drilled up to now in the field. The economical comparison of geothermal energy to lignite and fuel-oil for Balçova-İzmir Area is given on Table 2.

Studies are continuing to predict the total potential of the field for the purpose of domestic heating of some parts of İzmir City by geothermal energy. In the mean time the greenhouses in this district are already planned for heating with geothermal energy. For the Hotel in Balçova, absorbtion refrigeration unit cooling by geothermal energy using amonia is under contruction.

Table - 2. The economical comparison of geothermal energy to lignite and fuel - oil for Balçova (İzmir) and Ömer - Gecek - (Afyon) area. (T. Polat, 1984)

Field Name	Heat Capacity	Equivalent Amount of Lignite	Equivalent Amount of Fuel-Oil	Amount of Lignite Saved in a year	The Cost of Lignite Saved in a year	Amount of Fuel-Oil Saved in a year	The Cost of Fuel-Oil Saved in a year
	Kcal/hour	kg/hour	kg/hour	tons	TL. and U.S. $	tons	TL. and U.S. $
Balçova (İzmir)	45x106	1125	469	1350	14.175.000 T.L. or $ 51629	563	58 552.000 T.L. or $ 142327
Ömer Gecek (Afyon)	2,8x106	700	292	2016	21.168 000 T.L. or $ 51629	841	87 464 000 T.L. or $ 213327

1- Equivalent Heat Capacities are considered as below:
Lignite: 4000 Kcal/kg and Fuel-Oil 9600 Kcal/kg

2- The average usage in a year is considered as follows:
In Balçova-İzmir Area: 10 hour/day and 4 Months.
In Ömer-Gecek-Afyon Area 16 hour/day and 6 Months

Ömer-Gecek-Afyon Geothermal Gield

This is another field where a rapid scaling is in effect. The temperature of geothermal fluid is around 98^{o}C at the average depth 120-200 meters. In order to avoid the scaling effect, lown-hole and well-head heat exchanger systems have been tested successfully. Down-hole heat exchanger system is now in use. The temperature of fresh water circulated in the system varies in the range of 58-95^{o}C depending on external effects and flow rate. Greenhouses on an area of 2.0X10^{3} sq meters have already been constructed and economically operated for 3 years and new additionals are planned up to the total area of 100X10^{3} sq meters. The geothermal energy is also used at the spa-hotel in the area for heating of swimming pool and restaurant, and other facilities are plannad to be heated in near future as well. The firld is still at the stage of development and new additional wells will be drilled. The total heat potential of 2.8X10^{6} Kcal/h is produced from 3 wells in the field today. The economical comparison of geothermal energy to lignite and fuel-oil for Afyon-Ömer-Gecek Area is given on Table 2. In addition to above mentioned utilization, $1.0X10^3$ sq meters in Çanakkale-Kestanbol, $6.5X10^5$ sq meters in Balıkesir-Havran and $3.0X10^3$ sq meters greenhouses in Denizli-Tekkehamam are being heated by this natural source. Balıkesir-Gönen, Afyon-Sandıklı and Eskişehir Spa-hotels are making use of these recourses as well.

OTHER PROSPECTING GEOTHERMAL AREAS

Main prospecting geothermal areas are; Aydın-Salavatlı, Nevşehir-Kozaklı, Ankara-Kızılcahamam-Ayaş-Çubuk, Manisa-Salihli-Alaşehir, Denizli-Tekkehamam-Karahayıt-Pamukkale-Yenice, Kayseri, İzmir-Dikili-Bergama, Balıkesir-Sındırgı-Gönen-Havran, Kütahya-Simav, Çanakkale-Kestanbol, Afyon-Sandıklı and Erzurum-Ilıca-Pasinler Geothermal Fields. Geological, geophysical and geochemical surface surveys have already been completed. Among these, Aydın-Salatlı, İzmir-Dikili-Bergama, Kütahya-Simav, Balıkesir-Sındırgı, Çanakkale-Hıdırlar, Ankara-Kızılcahamam, Bitlis-Nemrut and Erzurum-Ilıca Geothermal Fields are at the stage of drilling operation. Also, agricultural and space heating uses have already been successfully operated in Denizli-Kızıldere, İzmir-Balçova, Afyon-Ömer-Sandıklı, Çanakkale-Kestanbol, Balıkesir-Gönen-Havran, Kütahya-Simav Geothermal Fields.

THE ADVANTAGES OF GEOTHERMAL ENERGY IN TURKEY

There are many advantages of geothermal energy in Turkey as:

a) Geothermal energy is an important resource in bridging the gap between the energy supply and demand of Turkey,

b) Cost of geothermal energy both in generation of electri_ city and heating seems to be cheaper than other resources,

c) Geothermal energy is one of the renewable energy resources as solar, hydraulic and wind energy. Therefore geothermal energy plants are uncomparably advantageous than the plants making use of fossil resources as coal, oil, natural gas, bituminous shale, nuclear, etc.,

d) The distrubition of geothermal fields in the country, indicates a camformity to the energy demand in Turkey. Mainly high enthalpy geothermal fields are located in West and Northwest Anatolia where is a shortage of electrical energy. On the other hand in Central and Eastern Anatolia where energy for heating is a necessity, there are geothermal fields of low enthalpy, suitable for heating purposes ,

e) National techonology is competent enough for the applications other than generation of electricity,

f) Geothermal power plants are simpler to construct and install and this fact necessitates shorter periods than others to get them into national energy production network.

CONCLUSION

Geothermal energy is very important for Turkey since shortages have increased rapidly and half the energy used in Turkey is provided by imported petroleum. Electricity production and heating costs from geothermal energy seem to be cheaper than from other resources. By the construction of integrated facilities in the geothermal fields, geothermal energy will be the most economic energy source for Turkey.

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HABERLER NEWS

KONGRE CONGRESS

KURULTAY MEETING

K.T.M.M.O.B.'DEN HABERLER

K.T.M.M.O.B.'nin 1987 yılında yapılan ve yapılması düşünülen etkinlik ve faaliyetlerini kısaca şöyle özetlemek mümkündür.

1. K.T.M.M.O.B.'ne bağlı 10 oda ve 2 vize bürosunu aynı çatı altında barındırmanın güçlüğü karşısında yeni binanın inşaatı 1987 yılı başında başlamıştır. Yıl sonunda bitirilmesi planlanan yeni bina ile birlik ve oda çalışmalarını rahatlacak yeni bir mekana kavuşabileceğimizi tahmin etmekteyiz.

2. 2-5.Haziran 1987 tarihlerinde bir "Çevre Simpozyumu" düzenlenmiştir. K.K.T.C. Cumhurbaşkanı Sn.Rauf DENKTAŞ'ın açılış konuşmasını yaptığı sempozyumda 30 bildiri sunulup tartışılmıştır. Ana konularının;
   a) Doğal kaynakların korunması
   b) Mesarya ovasının çölleşmesinin önlenmesi
   c) Güzelyurt bölgesi yer altı suyundaki tuzlanmanın kontrol altına alınması, olan sempozyumun bildirilerinin bir kitap halinde yayınlanması çalışmaları sürdürülmektedir.

3. Maden, Metallurji ve Jeoloji Mühendisleri Odasından sonra Mimarlar Odası, ardından da Ziraat Mühendisleri Odasının periyodik olarak yayınlanacak yayın organları çıkmaya başlamıştır.

4. Dünya konut yılı olarak 1987 yılının tesbit edildiği bu yılda, birliğimiz 7-11 Aralık 1987 tarihlerinde "Yapı ve Konut Kongresi" adı altında bir kongre düzenliyecektir. Yapı malzemeleri, sosyal ve toplu konut yapımları ve şehirleşmenin getirdiği sorunların tartışılacağı kongrede ayrıca teknik geziler ve film gösterileri de gerçekleştirilecektir.

5. K.K.T.C. M.M.J.M.O ile Çukurova Üniversitesi Fen Bilimleri Enstitüsü Jeoloji Mühendisliği Anabilim Dalında master tezi hazırlayan bir üyemizin Karpas'daki mangan zuhurlarının tespiti konusunda yaptığı çalışmalar halen devam etmektedir.

42.TÜRKİYE JEOLOJİ KURULTAYI

42nd Geological Congress of Turkey/ 15-19 Şubat 1988/February 15-19, 1988-ANKARA.

Kurultaya son başvuru tarihi 15 Kasım 1987, Application to attend congress before: 15 Nov. 1987.

Kurultay Yazışma Adresi/For correspondence: 42.Türkiye Jeoloji Kurultayı Yürütme Kurulu Başkanlığı P.K. 507 Kızılay-ANKARA.

☆

NEOTEKTONİK EGE BASENİNİN YAPISAL VE SEDİMANTER EVRİMİ

Structural and Sedimentary Evolutions of the Neotectonic Aegean Basins

5-6 Nisan 1988/April 5-6 1988 İNGİLTERE/U.K.

Yazışma Adresi/For Correspendence: Mr.Richard Collier/Dr.Mike Leeder, Dept.of Eart Sciences, The University Leeds LS2 9JT,ENGLAND.

☆

4.ULUSLARARASI KONFERANS SERİSİ UZAKTAN ALGILAMADA OBJELERİN SPEKTRAL BELİRTİLERİ

4 th Intertanional Colloquium Spectral Signatures of Objects in Remote Sensing

18-22 Ocak, 1988/January 18-22,1988

Yazıyma Adresi/For Correspendence

Colloque Signatures Spectrales Centre Paul Langevin, Aussois 73500-Modane (FRANCE)

☆

NATO JEOMAGNETİZMA VE PALEOMAGNETİZMA İLERİ ÇALIŞMA ENSTİTÜSÜ

Nato Advanced Study Institute on Geomagnetism and Paleomagnetism

7-22 Nisan 1988/April 7-22 1988

Londra (İNGİLTERE)

Yazışma Adresi/For Correspondence:

Anne Colding Dept.of Geophysics and Flanetary Physics School of Physics The University Newcastle Upan Tyne NE 1 7 RA ENGLAND

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BOKSİT ALÜMİNYUM VE ALÜMİNYUMLU KİL ICSOBA VI ULUSLARARASI KONGRE

VI.International Congress of ICSOBA International Committee for the Study of bouxsite, alumina and aluminium clay

11-20 Mayıs, 1988/May 11-20,1988
Yazışma Adresi/For correspondence:
Prof.A.J.Melfi Institute Astronomico e Geofisico Caixa Postal 30.625. 01051 Sao-Paulo, BRAZIL

☆

TÜRKİYE 6.KÖMÜR KONGRESİ
The Sixth Coal Congress of Turkey
23-27 Mayıs 1988/May 23-27,1988
(Zonguldak)
Yazışma Adresi/For correspondence:
TMMOB Maden Mühendisleri Odası Zonguldak Şubesi,Türkiye 6.Kömür Kongresi Yürütme Kurulu P.K.41 Zonguldak/The Zonguldak Branch of the Chamber of Mining Engineers The Executive Committe's of The Sixth Coal Congress of Turkey P.K.41 Zonguldak-TURKEY

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ULUSLARARASI SEDİMANTOLOGLAR BİRLİĞİ ULUSLARARASI SEDİMANTER MEDEN YATAKLARI SİMPOZYUMU
Intertanitonal Association of Sedimentologists International Symposium on Sedimentology Related to Mineral Deposits
30 Temmuz-4 Ağustos 1988/Juli 30-Agust 4, 1988
Yazışma Adresi/For correspondence:
Dr.Wang Shousong IAS Symposium on the Sedimentology of Mineral Deposits c/o Institute of Geology,Academia Sinica B.O.Box 634 Beijing, CHINA

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BELÇİKA SEDİMANTOLOGLAR BİRLİĞİ 9'NCU IAS BÖLGESEL TOPLANTI
The Belgium Sedimentological Group 9th IAS Regional Meeting Leuven, BELÇİKA
12-14 Eylül-1988/Septemper 12-14,1988
Yazışma adresi/For correspondence
Secretary: 9th IAS Regional Meeting Redingenstraat 16 B-3000 Leuven,BELGIUM

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ESKİ YERLEŞİM ALANLARININ, ABİDELERİN VE ÇALIŞMALARIN KORUNMASINDA MÜHENDİSLİK JEOLOJİSİ SİMPOZYUMU
Engineering Geology as Related to the study, preservation and protection of ancient works, monuments and historical sites
19-23 Eylül,1988/September,19-23,1988
Atina,YUNANİSTAN
Yazışma Adresi/For correspondence