STATISTICAL PROSPECTION OF EPIGENETIC ORE DEPOSITS

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Since statistical and computer methods are nowadays finding manifold fields of application it is logical that they should also be used in mineral prospection. This article shows how these methods can be applied to advantage in Turkish mineral prospection. A long list of pertinent references will enable the interested reader to delve more deeply into the subject.

It seems reasonable to expect that the geometry of veins and replacement bodies in a mining district should provide a clue to a better evaluation of suspected mineral trends and, if they exist, lead to new discoveries. For this purpose data compiling of known occurrences is suggested for interpolation and extrapolation into adjacent currently nonproductive areas. This research project is mainly concerned with application of statistical methods and computers for the discovery of the quickest and most rational way of estimating possibilities for hidden ores.

As is well known, fractures are commonly loci of veins and replacement deposits and some, although not containing ore themselves, represent significant structural trends with which ore is associated. For example, NW fractures are preferentially mineralized and NE ones are barren at Göynük and Dereköy antimony mines (Aral, 1970), whereas intersection of N-S/NW-SE and E-W/NE-SW fracture lines exert a control at Hopa-Murgul Cu-pyrite-and Zn-bearing ore deposits (Kraeff, 1963). On the other hand, the Pb-Zn-Gu mineralized area from Trabzon to Hopa is related to NW trending structure (Sawa & Hamamcıoğlu, 1971). A statistical study of the literature by Landwehr (1967) revealed that in the preponderant number of the meso- and hypothermal occurrences in western United States, the mineralized fractures, and dikes, and often the larger igneous masses, strike northeasterly.

Statistical analysis of the factors controlling localization of known epigenetic ore deposits as a guide to the discovery of hidden ore bodies was applied in 1963 in the Colorado Mineral Belt, U.S.A., which measures some 1500 sq miles (Ayler, 1963). Compilation of orientations of strike and dip of ore-bearing faults, fractures and joints, as well as their spacing in a given mining district, may lead to determination the tectonic controls of mineralization. And, of course, other controls such as lithology of host rocks, associated intrusives, hot-springs, etc. lend themselves to similar analysis. This may be carried out by a questionnaire, prepared according to a coding system, which covers all items that might be of interest in exploration studies of a mineralized region. Statistical analysis will not only provide a better understanding of metallogenic problems of that area but will enable estimates to be made of the possibility of finding new ore bodies.

A research project, initiated by Visiting Prof. A.K. Snelgrove, along these lines is underway at Middle East Technical University. This study is made up of three parts: A questionnaire, tectonic elements and empirical net.

The first part is a questionnaire covering many important items about each occurrence (Table 1). The main purpose of the questionnaire is to collect significant information in simplest form and store it in a «bank». Any sort of statistical analysis could be made using the data collected in the *«Data Bank»*. Information collected from other sources than the questionnaire may be stored in the same way too, for example, the data collected by Remote Sensing studies. It is believed that besides its numerous statistical benefits, the questionnaire will also help the field geologist to orient himself during his work and know the aspects which have priority. Some questionnaires had previously been prepared in M.T.A. Institute, but they were not sufficiently detailed for statistical purposes.

The second part involves defining the ore-bearing tectonic elements by computer and evaluating them by means of statistical analysis. A *coding form* and a computer program were prepared for this purpose (Tables 2 and 3). In the coding form the geologist should note the *number* of ore-bearing faults, fractures and joints *observed in the field* according to their orientations. In the coding form, strike is recorded to the nearest 10 degrees in groups from north to east and north to west. Eighteen strike-rows are needed for this purpose (such as N 00-10°E, N 21-30°W etc.). Dips corresponding to each strike are defined in four intervals as 00-20°, 21-50°, 51-70°, 71-90°N and S. The coding form is so arranged that the geologist can note the number of mineralized faults, fractures and joints on one sheet of paper. One coding form is made for each mine and 18 data cards are needed to be punched for each mine, each corresponding to a strike-row. The program, which is a computer application of 18 X 24 matrix, is so arranged that every dip interval of one coding form is added to the corresponding dip intervals of the subsequent coding forms. By this program, if sufficient data are given, it is possible in a few minutes to find the number and trend of mineralized structures, for instance N 81-90°E/71-90°N trending faults, or fractures or joints in a region or in the whole of Turkey. The output is similar to a normal input coding form, but more (four) digital spacings have been saved since many observations from different mines are added. An example was processed in M.E.T.U. Computing Center : Three coding forms are used as an input and 54 data cards punched, and for each dip interval 1 is inserted. The output was as expected (Table 4). The program is so arranged that time spent and data cards punched are minimized; the strike-rows which have no value written in dip intervals do not need to be punched.

The coding form and program may be modified to find the general trend of planar structures (bedding, schistosity, joints) of different rock types (Table 5). The stored data evidently will serve to indicate the general characteristics of each rock type on regional and country scales.

The data collected from questionnaires can be interpreted and presented by means of graphs, lists and histograms which may also be prepared by computer. For this purpose Table 6 shows a computer application to some statistical analysis formulas (Fang, Robinson, Ohya, 1971). It is believed that if properly used, extended, and evaluated, compiled statistical data should provide useful tools to us for determining relative favorability of prospecting areas within and near the total area studied. The studies most probably will lead to discovery of some relationship among ore deposits, host-rock, intrusives and structural controls that have not yet been defined. Many additional sorts of studies can be made with the suggested coding system. If more complete and recent data could be obtained, other potentially useful applications could be made. If the questionnaires are applied to reports which have already been written, it will serve to re-evaluate them and make the information in them more useful. The collected data will be particularly important in the immediate future. For example, it is believed that the stored material will be useful in solving metallogenic problems related to the newly developing concept of Global Tectonics.

The last part deals with computerizing mineral prospection data made by the new method, «*Empirical Net*» and describes the further studies planned to minimize unfavorable factors.

Mineral discovery by chance was at one time the only «method» available to the prospector. By this method it was possible only to find obvious ore deposits which were exposed at the surface. More recently, refined techniques and new exploration methods have been developed which make possible the discovery of hidden ore-bodies. Now is the time for aplication of computers. A new approach being developed at M.E.T.U. is to apply computer techniques to mineral exploration.

One of the most exciting prospection methods proposed in recent years is construction of an empirical net as a guide to the discovery of hidden ore-bodies. Empirical net consists of lines of stress-trajectories drawn equidistantly parallel to ore-bearing major lineaments and mineral belts. The most attractive feature of this method is its ready adaptability to processing.

The theoretical basis for constructing an empirical prospecting net is given in papers of Varnes (1962) and Kutina-Pokorny-Vesela (1967). Basically the method depends on the theory of «plasticity in plain strain», proposed by von Mises (1925) which states that the shear fracture (fault) patterns in an isotropic (homogeneous) medium show systematic sets of trends. The most common distribution of fractures and associated ore veins is classified by Kutina *et al.* (1967) as follows:

1. In the form of two sets of equidistant planes, one set being commonly more or much more distinctly developed than the other,

2. In the form of curved surfaces, which may also appear in two sets, but the distances between them are not equal, and

3. In more complex forms.

There are many factors affecting the number, set, spacing and trend of the lineaments. For example, inhomogeneity of the upper part of the Earth's crust, in which the search for ore deposits is being done, considerably influences the stress distribution and has an important effect upon the localization of faults and fractures. Nevertheless, it is significant that, in spite of this serious factor, at places faults repeat themselves at equal intervals, so that the principle of equidistances may at times be successfully applied even in an anisotropic medium. Several examples of equidistant distribution of faults are known. The studies of Varnes (1962), Jung (1965), Kutina *et al.* (1967), and Kutina (1969) may be mentioned in this respect. In Figure 1 the equidistant distribution of NNE-trending faults in Czechoslovakia is shown. A statistical study made by air photographs in Wizard Lake-Alberta revealed that four sets of fractures trending WNW, NNE, NNW, and ENE are distributed regularly and symmetrically (Blanchet, 1957) (Fig. 2).

One of the main purposes of constructing an empirical net is to find the intersection points of different sets of mineralized lineaments which are presumably the most favorable places for prospecting new mineralized zones. This approach is emphasized by Badgley (1965). According to him, many mineralized districts (such as Bagdad district, Arizona, Central City area in the Front Range mineral belt, Colorado, and Silver Plume, Boulder Creek) lie close to areas of intersection of major faults. He believes that favorable ore-hunting districts can be outlined by systematic fracture-intensity studies of a detailed nature. Empirical plotting of four sets (E-W, N-S, NE-SW, NW-SE) of equidistantly spaced shear stress trajectories was done by Kutina (1969), based on regularities in distribution of three sets of actual faults and ore veins in the continental area and on the landward prolongation of the big fracture zones of the northeastern Pacific (Mendicino, Pioneer, Murray, etc.) (Fig. 3). The intersection points of four systems of trajectories are proposed as the favorable prospecting places for unknown hydrothermal deposits in the Cordilleran part of the United States.

A program was prepared to plot empirical net by means of computer in M.E.T.U. (Table 7). The program is so prepared that it gives the coordinates of

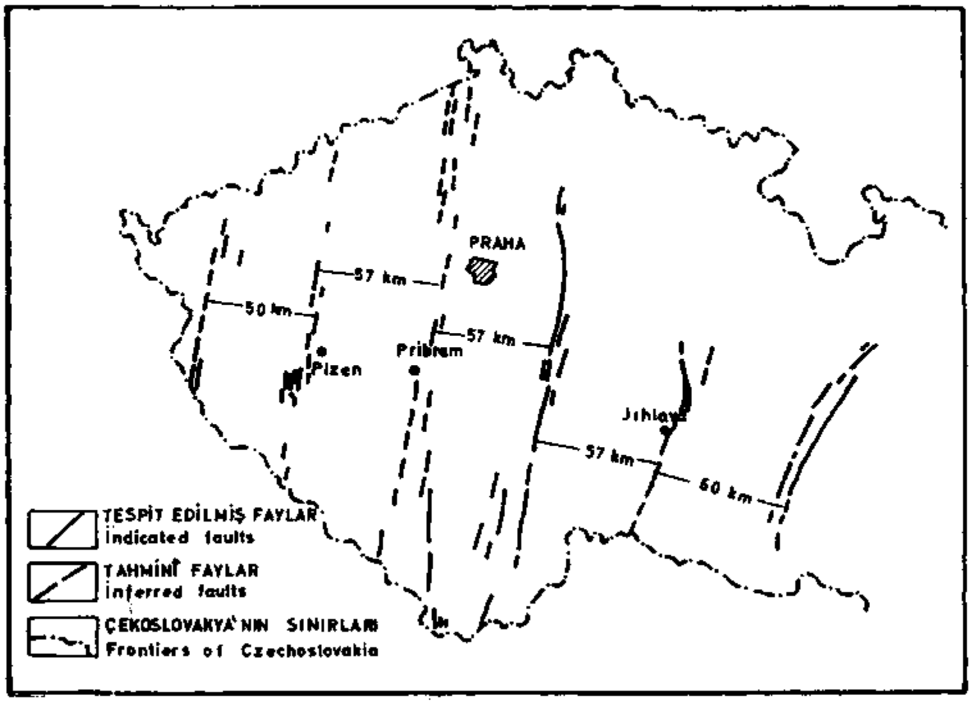

Fig. 1 - Equidistant distribution of faults of «Rhine Strike» in the Czechoslovakia part of the Bohemian Massif (Kutina-Pokorny-Vesela, 1967).

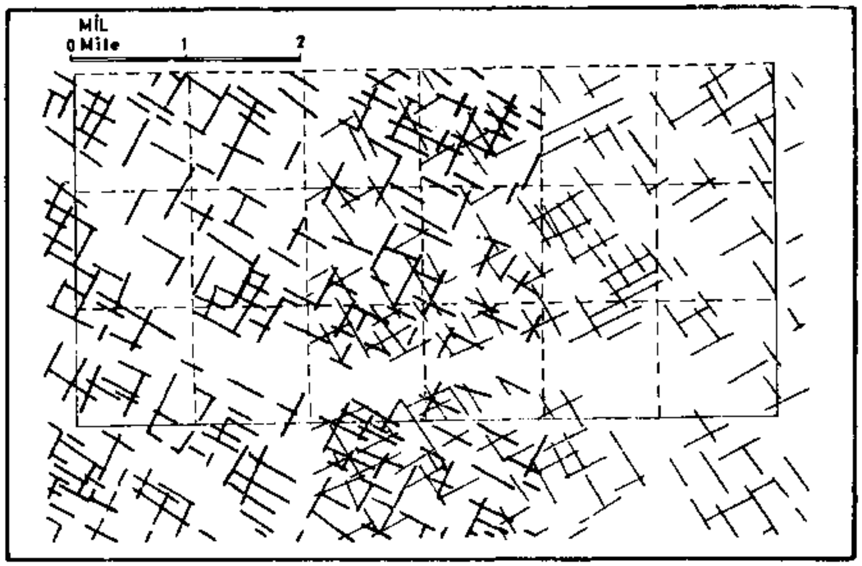

Fig. 2 - Systematic and regular distribution of fractures determined from air photos in Wizard Lake district, Canada (Blanchet, 1957).

the points of intersections of equidistantly spaced sets of numerous lines trending in several directions. These points of intersections are also shown in output as a graph (Table 8). These points of intersections have been easily transferred to topographic maps since their coordinates are known. Table 8 shows the graphical representation of four sets of mutually intersecting faults, trending N 64°W, N 45°E, N-S, and E-W. As the program is processed, the machine finds the coordinates of the points of intersections of first two sets of lines and keeps them in the memory to compare the vertical distance between these points with a third group of lines. If this distance is zero or equal to a pre-determined distance «d» it will be either kept in memory to compare with another set of lines or it will be printed as a graph.

The main reason for application of computer programming in the empirical net method is to evaluate large amount of various data in the shortest time. By computer application several empirical nets may be constructed for faults, mountain range and river trends, mineralized fracture-joint systems, seismic and volcanic activity lines, hydrothermal alteration zones, geochemical and geophysical anomaly trends, and geographic distribution of known mines. It is believed that comparison of these graphs will suggest some points favorable for mineral prospection.

In order to estimate most favorable places by the empirical net method the data given should be strictly correct. The distance between lines of sets and their trends must be precisely determined by statistical analysis. In country-scale empirical net studies, it should be noted that lines of trajectories may be curved, not straight, and another program should be prepared for this purpose. Some modifications should also be made in the present program, in the case where stress trajectories are not equidistantly spaced.

For maximum utility, the data storage must be supplemented by a well-organized store which must also publish the statistical results frequently. Only by

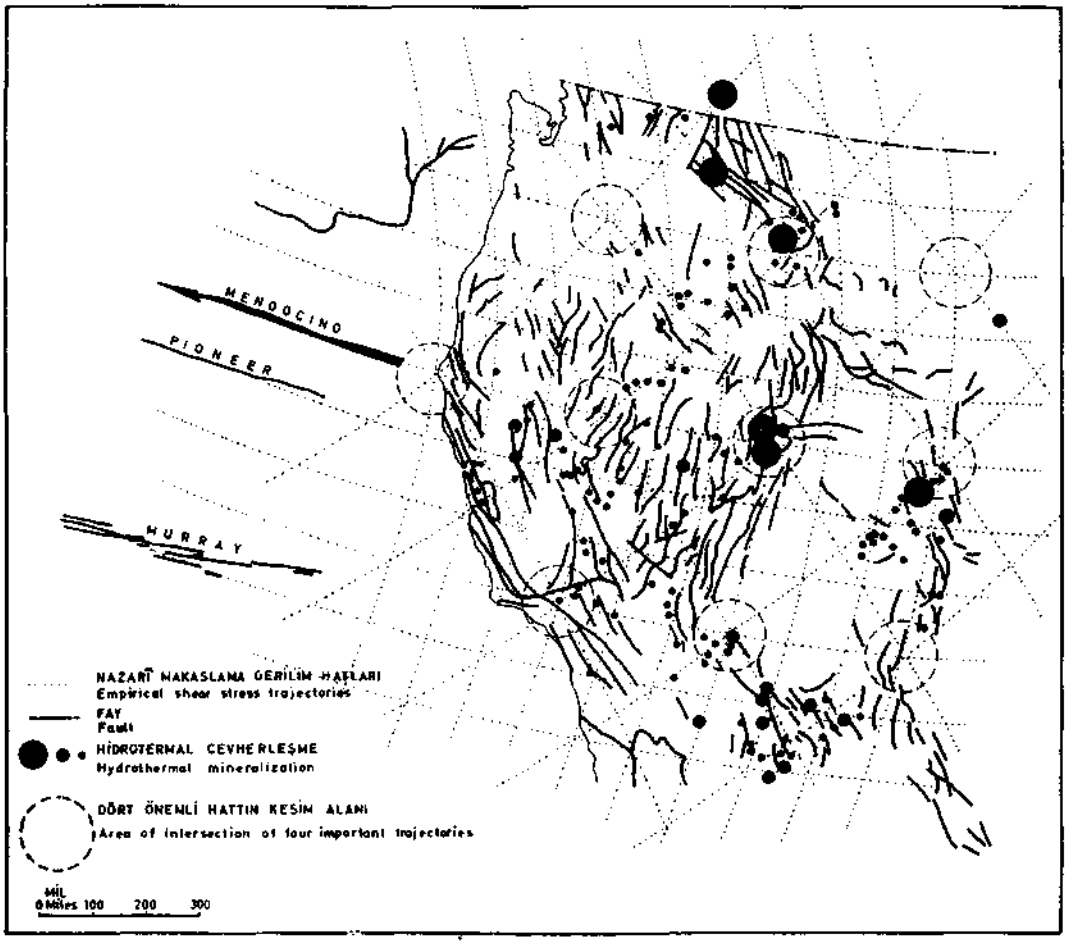

Fig. 3 - Empirical prospecting net for hydrothermal ore deposits in the western United States (Kutina, 1969).

these means will the researches made in universities and other institutions have a strong and safe base.

It is hoped that the recommended questionnaire or a more detailed one will find application in Turkey. For this purpose it is suggested that well-mineralized regions such as Biga Peninsula, Pontids, and Menderes and Kırşehir Massifs should be given priority and then should be extended to all of Turkey.

In conclusion we tender our thanks to Prof. A.K. Snelgrove and Dr. Tuncel Yegülalp who encouraged the study and we also thank Hikmet Saka who prepared the computer program shown in Table 2 at M.E.T.U. Department of Computing Sciences.

Manuscript received April 12, 1971

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Table - 1

Statistical prospection for epigenetic ore deposits

Part 1

Note: Please leave empty if the answer is not known and add (?) if uncertain. Estimate amount of error in your answer indicating in parenthesis (%) at the end of each answer.

1. Name and position of respondent:

2. If you compile these data from others report — Your name and position:

3. a. Name of occurrence:
   b. Location: City: Town: Village:
   c. Label map, 1 : 100,000 scale:
   d. Coordinates at 1 : 100,000 longitude: ( )
   and latitude: ( )
   e. No. of map (1 : 25,000) occurrence located:
   f. Scale (s) of map used:
   g. Field work by respondent: beginning ( ) and end ( ).
   h. Size of area mapped:
   i. Position of discoverer: ( ) %
   j. Date of discovery: ( ) %

4. a. Name and age of ore (s): ( ) %
   b. Name and age of host rock (s) ( ) %
   c. Is there lithological control in mineralization?
   Yes ( ) No ( ) Probably ( )
   d. Size of mineralized area:

	Proved		Estimated
Width :	( ) %	Width :	( ) %
Length :	( ) %	Length :	( ) %
Depth :	( ) %	Depth :	( ) %

   e. General trend of mineralized area:

5. Answer followings according to Altan Gümüş's classification in «Metallogeny of Turkey»:
   a. Metallogenic province of occurrence: ( ) %
   b. Metallogenic Epoch of occurrence: ( ) %
   c. Tectonic unit of occurrence: ( ) %

6. Massif in which occurrence is included: ( ) %

	I. Determined in field		II. Determined in laboratory
7. a. Primary ore minerals:	( ) %		( ) %
b. Secondary ore minerals:	( ) %		( ) %
c. Trace elements:	( ) %		( ) %
d. Gangue minerals:	( ) %		( ) %
e. Placers (if any):	( ) %		( ) %

8. Nearest intrusive rock related to mineralization:
   a. Lithology: ( ) %
   b. Age: ( ) %
   c. Distance to occurrence (give direction): ( ) %
   d. Outcrop pattern: ( ) %
   e. General trend of outcrop: ( ) %
   f. Contact metamorphic minerals: ( ) %

9. Extrusive rock (s) in/and near mineralized area:
   a. Lithologies: ( ) %
   b. Age (s): ( ) %
   c. Distance to nearest extrusive rock (give direction): ( ) %

10. Distance to nearest hot-spring :

Table - 1 (continued)

	I. Dike (s)		II. Sill (s)
11. a. Lithology:	( ) %		( ) %
b. Age:	( ) %		( ) %
c. General trend:	( ) %		( ) %
d. Shortest spacing between them:	( ) %		( ) %
e. Host rock they traverse:	( ) %		( ) %

12. a. Hydrothermally altered area (sq km) and coordinates of the end points at 1 : 100,000 scale map:
b. Intensity of alteration: High ( ) Moderate ( ) Low ( ) None ( )
c. General trend of alteration: ( ) %

13. Major faults related to mineralization:
a. Strike and dip: ( ) %
b. Displacement:
c. Nature: Vertical ( ) Reverse ( ) Normal ( ) Strike-slip ( ) Overthrust ( ) ( ) %

14. Mineralization along mentioned major fault (s)?
Yes ( ) No ( )

15. a. Mineralized fault or fracture branching from major fault mentioned?
Yes ( ) No ( ) ( ) %
b. If yes, general trends of strike and dip: ( ) %

16. a. Mineralized fault parallel to the major fault mentioned? Yes ( ) No ( ) ( ) %
b. If yes, nearest and further distance between two parallel faults: ( ) %
c. Number of parallel faults and fractures: ( ) %

17. Nearest and further distance between two ore-bearing parallel joints: ( ) %

18. Major faults, not related to mineralization, but characteristic for region:
a. Strike and dip: ( ) %
b. Displacement (s): ' ( ) %
c. Nature (s): (see 13 c.) ( ) %
d. Nearest and further distance between these two parallel faults (if any): ( ) %

19. a. General trend if folded structure: ( ) %
b. Direction and amount of plunge: ( ) %
c. Mineralization in folded structure?
Yes ( ) No ( ) ( ) %

20. a. Is mineralization in folded structure related to faults traversing it?
Yes ( ) No ( ) Not clear ( ) ( ) %
b. If yes, their strike and dip: ( ) %

21. Major vein and replacement body:
a. General trend: ( ) %
b. This mineralized zone is a fault plane?
Yes ( ) No ( ) ( ) %
c. This mineralized zone is a fracture line?
Yes ( ) No ( ) ( ) %
d. Width: ( ) %
e. Length: ( ) %
f. Thickness: ( ) %
g. Proved depth: ( ) %
h. Continuity: ( ) %

22. Topographic indication of mineralization: ( ) %

23. Practical clues for unprofessional people:

Table - 1 (continued)

Part 1a

1. a. Coordinates of geochemically sampled area (on 1 : 100,000-scale map) :
   b. Geochemically sampled area :
   c. Number of samples taken :
   d. Your coding number : from .... to ....
   e. Depth of samples taken (cm) : ( ) %
   f. Elements asked to be determined :
   g. Method of analysis asked to be applied :

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2. Kind of geochemical sample taken (circle correct answer (s)):

a. Soil	: 1. Laterite	2. Residual	3. Transported	4. Humus	
b. Sediment	: 1. Stream sand	2. Beach sand			
c. Rock	: 1. Outcrop	2. Core	3. Transported		
d. Water	: 1. Stream	2. Hot-spring	3. Spring	4. Well	5. Lake
e. Plant	: 1. Leaf	2. Branch	3. Root	4. Bark	5. Trunk

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3. a. Any toxic change is observed in mineralized area?
   Yes ( ) No ( ) No idea ( ) ( ) %
   b. If yes, write their names :

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4. Name plants observed in mineralized area : ( ) %

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5. a. Flight lines and numbers of air photos :
   b. Area mapped by air photos :

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6. Geophysical method applied (circle correct answer (s)) :
   a. Gravity
   b. Magnetic
   c. Seismic
   d. Electrical
   e. Telluric
   f. SP
   g. Resistivity
   h. Radioactive
   i. Airborne magnetic
   j. Airborne radioactive

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7. a. Number of geophysical traverses :
   b. Length of geophysical traverses :
   c. Coordinates of end points of traverses (1 : 100,000) :
   d. Distance between traverses :

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8. Drilling in and near area :
   a. Total amount :
   b. Number :
   c. Kind :
   d. Core diameter :
   e. Coordinates of drilling points :
   f. Total amount of ore cut :
   g. Average grade : ( ) %
   h. Average core efficiency :
   More than 80 % ( ) 80-50 % ( ) less than 50 % ( ) ( ) %

Part 1b

Circle correct answer (s) in following questions from 1 to 18 :

1. Nature of ore-bearing faults are generally : ( ) %
   A. Vertical B. Reverse & thrust C. Normal D. Strike-slip E. Overthrust

Table - 1 (continued)

2. Type of ore-bearing faults are generally: ( ) %
A. En echelon B. Horsetail C. Radial and peripheral D. Transverse E. Step and ladder

3. Mineralization is generally restricted to: ( ) %
A. Inclined portions of fault planes.
B. Vertical portions of fault planes.
C. Open-spaces of strike-slip faults.
D. Fracture zones.
E. Crush zones.

4. Mineralization is generally restricted to: ( ) %
A. Lower contact of unconformably overlying impermeable rock.
B. Contact of different lithologies.
C. Bedding planes.
D. Schistosity planes.
E. Joints.

5. Mineralization is generally restricted to: ( ) %
A. Tectonic breccia and/or mylonite zones.
B. Solution cavities.
C. Shear zones.
D. Fault planes along bedding.
E. Space between pebbles and sand-size grains of the rock.

6. Minerals of wall-rock alteration: ( ) %
A. Feldspar B. Clay minerals C. Silica D. Chlorite E. Epidote

7. Minerals of wall-rock alteration: ( ) %
A. Carbonates B. Sericite C. Biotite D. Alunite E. Pyrophyllite

8. Minerals of wall-rock alteration:
A. Uralite B. Pyrite C. Fluorite D. Silicate E. Serpentine

9. Occurrence is restricted to: ( ) %
A. Horst zone B. Graben zone C. Crest of an anticline D. Flank of an anticline or syncline
E. Trough of a syncline

10. Occurrence is restricted to: ( ) %
A. Crest of an overturned anticline.
B. Trough of an overturned syncline.
C. Flank of an overturned anticline or syncline.
D. Crest of an anticline thrusted nearby syncline.
E. Trough of a syncline thrusted nearby anticline.

11. Reason of termination of mineralized vein or replacement body is due to: ( ) %
A. Displacement of the ore by a new fault.
B. Diminishing of the favorable lineament.
C. Ending of the wall-rock alteration.
D. Entering into unfavorable rock type.
E. Ending of the favorable folded structure.

12. Cavity filling type ore is in the form of: ( ) %
A. Discontinuous pockets and rosettes.
B. Vein.
C. Stockwork.
D. Lenses.
E. Crustified veins and geode fillings exhibiting comb structure.

13. Replacement type ore is: ( ) %
A. A massive body originated by replacement of host rock.
B. Disseminated or impregnated into the host rock.
C. Originated by replacement of the walls of faults or fractures.
D. In the form of replacement of pre-existing minerals.
E. Originated by selective replacement of bedding planes of host rock.

Table - 1 (continued)

14. General trend of ore-bearing faults and fractures are in accordance with: ( ) %
    A. Geochemical anomalies.
    B. Geophysical anomalies.
    C. Seismic activity lines.
    D. Old volcanic activity lines.
    E. Drainage pattern.
15. General trend of ore-bearing faults and fractures are in accordance with: ( ) %
    A. General trend of schistosity.
    B. General trend of bedding.
    C. General trend of hydrothermal alteration.
    D. Axis of folded structure.
    E. Trend of intrusive bodies.
16. Tectonism after mineralization is: ( ) %
    A. Evidently observed.
    B. Suspected.
    C. Not recognized.

Part 1c

1. Write your opinion briefly about the following:
   a. Genesis: ( ) %
   b. Paragenesis: ( ) %
   c. Ore-mineral zoning: ( ) %
   d. Supergene enrichment: ( ) %
2. According to laboratory studies:
   a. Genesis: ( ) %
   b. Paragenesis: ( ) %
   c. Ore- mineral zoning: ( ) %
3. Coding number of geochemically anomalous samples:
4. Geophysically anomalous traverses or station numbers:

Part 1d

1. a. Number of trenches:
   b. General trend of trenches:
2. Economically extractable metals: ( ) %
3. Date of begining (/ /197) and end (/ /197) of production.
4. a. Open work carried out till now: ton ( ) %
   b. Underground work carried out till now: ton ( ) %
5. Your sampling method:
6. Mining method (s) applied:
7. If there is no exploitation, mining method you suggest:
8. According to you, the mining method applied is:
   Best ( ) Good ( ) Wrong ( ) Very wrong ( )
8. If following type (s) of working (s) are present in occurrence, their:

	Number	Length	Slope & direction
a. Shaft:			
b. Inclined shaft:			
c. Adit:			

Table - 1 (continued)

d. Level :
e. Cross-cut :
f. Raise :
g. Winze :
h. Stope : Size (m^3) :

---

9. Average grade : Estimated (%) ( ) %; Proved (%) ( ) %

10. Reserves : Proved (ton) ( ) %; Probable (ton) ( ) %; Possible (ton) ( ) %

11. Indicate by (+) if the effect of the following for the value of the occurrence is positive, and if not by (—) :

a. Size of area mineralized	( )	( ) %
b. Depth of mineralization	( )	( ) %
c. Grade	( )	( ) %
d. Marketing factors	( )	( ) %
e. Transportation charges	( )	( ) %
f. Energy resources	( )	( ) %
g. Availability of laborer	( )	( ) %
h. Subsurface water	( )	( ) %
i. Natural conditions	( )	( ) %
j. Investment	( )	( ) %
k. Social conditions	( )	( ) %

Part 1d-References

1. Samples given for determination or analysis :
   a. No. and designation of thin sections :
   b. No. and designation of polished sections :
   c. No. and designation of paleontological sections :
   d. No. and designation of samples for chemical analysis :
   e. No. and sign of samples for X-ray analysis :
   f. Other determinations and analysis : (geochronological):

Note : Indicate if determinations or analyses were made somewhere else than in M.T.A. Institute, T.T.L. Dept.

2. No. of report to which the results of above-mentioned determinations and analysis are annexed :

3. Geochemical log numbers and number of report to which they are annexed :

4. Geophysical log numbers and number of report to which they annexed :

5. Drilling log numbers and number of report to which they are annexed :

6. If you compiled these answers from other reports, reference no. of those reports :

7. Other references :

8. Please, make any additions that you wish to see in this questionnaire :

Prepared by : Halil ARAL, 25/3/1971

Table - 2

Coding form for statistical compilation of ore-bearing lineaments

NAME OF OCCURRENCE :

STATISTICAL PROSPECTION OF EPIGENETIC ORE DEPOSITS (Part II)

Strike ↓ ↓ ↓	*MINERALIZED FAULT OBSERVATIONS*								*MINERALIZED FRACTURE OBSERVATIONS*								*MINERALIZED JOINT OBSERVATIONS*							
Amount of dip →	*00-20°*		*21-50°*		*51-70°*		*71-90°*		*00-20°*		*21-50°*		*51-70°*		*71-90°*		*00-20°*		*21-50°*		*51-70°*		*71-90°*	
Direction of dip →	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*
→ for IBM →	10 11	13 14	16 17	19 20	22 23	25 26	28 29	31 32	34 35	37 38	40 41	43 44	46 47	49 50	52 53	55 56	58 59	61 62	64 65	67 68	70 71	73 74	76 77	79 80
N 00 - 10 E																								
N 11 - 20 E																								
N 21 - 30 E																								
N 31 - 40 E																								
N 41 - 50 E																								
N 51 - 60 E																								
N 61 - 70 E																								
N 71 - 80 E																								
N 81 - 90 E																								
N 00 - 10 W																								
N 11 - 20 W																								
N 21 - 30 W																								
N 31 - 40 W																								
N 41 - 50 W																								
N 51 - 60 W																								
N 61 - 70 W																								
N 71 - 80 W																								
N 81 - 90 W																								
→ for IBM →	10 11	13 14	16 17	19 20	22 23	25 26	28 29	31 32	34 35	37 38	40 41	43 44	46 47	49 50	52 53	55 56	58 59	61 62	64 65	67 68	70 71	73 74	76 77	79 80

N=north, S=south

Note : Write the number of ore-bearing faults, fractures and joints observed in the field according to their orientations.

Table - 3

Computer program for statistical prospection of epigenetic ore deposits

```
                    DOS FORTRAN IV 360N-FO-479 3-0 MAINPGM
      C        EPİJENETİK CEVHER YATAKLARININ İSTATİSTİKSEL PROSPEKSİYONU
      C           LİSAN    : FORTRAN 4
      C           MAKİNE : IBM 360/40
      DIMENSION STRIKE (2), DIP (24), IOTDIP (18, 24), LINE (130)
      REAL LINE, IKI
      INTEGER DIP
      DO 10 I = 1,18
      DO 10 J = 1,24
10    IOTDIP (I, J) = 0
11    READ (1, 12, END = 20) (STRIKE (I), I = 1,2), (DIP (J), J = 1,24)
12    FORMAT (2 A 4, 24I3)
      IF (STRIKE (2). EQ.  BIR) I STRK =  1
      IF (STRIKE (2). EQ.  IKI) I STRK =  2
      IF (STRIKE (2). EQ.   UC) I STRK =  3
      IF (STRIKE (2). EQ. DOR) I STRK =  4
      IF (STRIKE (2). EQ.  BES) I STRK =  5
      IF (STRIKE (2). EQ.  ALT) I STRK =  6
      IF (STRIKE (2). EQ.  YED) I STRK =  7
      IF (STRIKE (2). EQ.  SEK) I STRK =  8
      IF (STRIKE (2). EQ. DOK) I STRK =  9
      IF (STRIKE (2). EQ.   ON) I STRK = 10
      IF (STRIKE (2). EQ.  OBI) I STRK = 11
      IF (STRIKE (2). EQ.  OIK) I STRK = 12
      IF (STRIKE (2). EQ. OUC) I STRK = 13
      IF (STRIKE (2). EQ. ODO) I STRK = 14
      IF (STRIKE (2). EQ.  OBE) I STRK = 15
      IF (STRIKE (2). EQ.  OAL) I STRK = 16
      IF (STRIKE (2). EQ.  OYE) I STRK = 17
      IF (STRIKE (2). EQ.  OSE) I STRK = 18
      DO 13 I = 1,24
13    IOTDIP (ISTRK, I) = IOTDIP (I STRK, I) + DIP (I)
      GO TO 11
20    DO 14 I = 1,130
14    LINE (I) = DESH
      WRITE (3,15) (LINE (I), I = 1, 120), (LINE (I) I = 1, 129), (LINE (I), I = 1, 129), $ ((IOTDIP
      (I, J), J = 1,24), I = 1,18)
15    FORMAT (1H1, / /, T15,'        CEVHERLİ   FAY   ADEDİ        , 'T54, 'CEVHER
    * LI     KIRIK     ADEDİ        , 'T94',        CEVHERLİ    EKLEM  ADEDİ
    * I '/ T11, 120 A1 / T14, '00 10', T24, '11 40', T34, '41 70', T44, '71 90', T54, '00 10', T64,
    * '11 40', T74, '41 70', T84, '71 90', T94, '00 10', T104, '11 40', T114. '41 70', T124, '71 90'/
    * T2, 129 A1, /, T3, 'DOĞRULTU', T14, 'N S N S N S N S N S N S N S N S N S N S N S
    * N S', /, T2, 129 A1, /, T3, 'NOO 1OE', T11, 24I5, / / T3, 'N11 2OE', T11, 24I5, / /, T3,
    * 'N21 30E', T11, 24I5 / / T3, 'N31 40E', T11, 24I5, / /, T3, 'N41 50E', T11, 24I5, / / T3,
    * 'N51 60E', T11, 24I5, / /, T3, 'N61 70E', T11, 24I5 / /, T3, 'N71 80E', T11, 24I5, / /, T3,
    * 'N81 90E', T11, 24I5, / /, T3, 'N00 10W', T11, 24I5, / /, T3, 'N11 20W', T11, 24I5, / /, T3,
    * 'N21 30W', T11, 24I5, / /, T3, 'N31 40W', T11, 24I5, / / T3, 'N41 50W', T11, 24I5, / /, T3,
    * 'N51 60W', T11, 24I5, / /, T3, 'N61 70W', T11, 24I5, / / T3, 'N71 80W', T11, 24I5, / / T3,
    * 'N81 90W', T11, 24I5 / / )
      STOP
      DATA BIR, IKI, UC, DOR, BES, ALT, YED, SEK, DOK, ON, OBI, OIK, OUC, ODO, OBE,
    * OAL, OYE, OSE / '10E', '20E', '30E'; '40E', '50E', '60E', '70E', '80E', '90E', '10W', '20W',
    * '30W', '40W', '50W', '60W', '70W', '80W', '90W' /, DESH / '    ' /
      END
```

Table - 4

	Mineralized fault observations								*Mineralized fracture observations*								*Mineralized joint observations*							
Dip → → →	*00-10°*		*11-40°*		*41-70°*		*71-90°*		*00-10°*		*11-40°*		*41-70°*		*71-90°*		*00-10°*		*11-40°*		*41-70°*		*71-90°*	
Strike ↓ ↓ ↓	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*
N 00 10 E	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 11 20 E	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 21 30 E	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 31 40 E	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 41 50 E	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 51 60 E	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 61 70 E	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 71 80 E	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 81 90 E	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 00 10 W	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 11 20 W	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 21 30 W	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 31 40 W	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 41 50 W	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 51 60 W	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 61 70 W	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 71 80 W	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
N 81 90 W	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Table - 5

Coding form for statistical analysis of planar structures of different rock types

Name of respondent	*Locality :*								*Locality :*								*Locality :*							
	Lithology :								*Lithology :*								*Lithology :*							
	Age :								*Age :*								*Age :*							
Strike ↓ ↓ ↓	*Formation related :*								*Formation related :*								*Formation related :*							
	Number of bedding plane observations :								*Number of schistosity plane observations :*								*Number of joint observations :*							
Amount of dip →	*00-20°*		*21-50°*		*51-70°*		*71-90°*		*00-20°*		*21-50°*		*51-70°*		*71-90°*		*00-20°*		*21-50°*		*51-70°*		*71-90°*	
Direction of dip →	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*
→ for IBM →	10 11	13 14	16 17	19 20	22 23	25 26	28 29	31 32	34 35	37 38	40 41	43 44	46 47	49 50	52 53	55 56	58 59	61 62	64 65	67 68	70 71	73 74	76 77	79 80
N 00 - 10 E																								
N 11 - 20 E																								
N 21 - 30 E																								
N 31 - 40 E																								
N 41 - 50 E																								
N 51 - 60 E																								
N 61 - 70 E																								
N 71 - 80 E																								
N 81 - 90 E																								
N 00 - 10 W																								
N 11 - 20 W																								
N 21 - 30 W																								
N 31 - 40 W																								
N 41 - 50 W																								
N 51 - 60 W																								
N 61 - 70 W																								
N 71 - 80 W																								
N 81 - 90 W																								
→ for IBM →	10 11	13 14	16 17	19 20	22 23	25 26	28 29	31 32	34 35	37 38	40 41	43 44	46 47	49 50	52 53	55 56	58 59	61 62	64 65	67 68	70 71	73 74	76 77	79 80

Table - 6

```
DOS FORTRAN IV 360 N-FO-479 3-0              MAINPGM
          C    PROGRAM TO CALCULATE (1) MEAN, (2) MEDIAN,
          C    (3) RANGE, (4) STANDARD DEVIATION,
          C
          C    (5) VARIANCE, (6) COEF. OF VARIANCE, AND (7) SKEWNESS, AND TO PLOT
          C    A HISTOGRAM.
          C
          C    INPUT CONSISTS OF...
          C    (CARD 1) NUMBER OF OBSERVATIONS AND  NUMBER OF GROUPS DESIRED.
          C    (15, F 10.0)
          C    (CARD 2) VARIABLE FORMAT CARD FOR THE SET OF DATA. (80A1)
          C
          C    (CARD 3) DATA CARDS IN ANY  FORMAT SPECIFIED  ABOVE. MAXIMUM OF
          C    200. (FMT)
               DIMENSION FMT (80), X (200), POINT (20), NFREQ (200)
               DIMENSION A (9), AGP (120, 60), INFQ (30), AN (10)
               DATA Q1, Q2, Q3, Q4, Q5/1HI, 1H—, 1H+, 1HX, 1H /
               DATA A/1HF, 1HR, 1HE, 1HQ, 1HU, 1HE, 1HN, 1HC, 1HY /
               DATA AN/1H0, 1H1, 1H2, 1H3, 1H4, 1H5, 1H6, 1H7, 1H8, 1H9 /
               READ (1, 1) N, WIDTH
             1 FORMAT (I5, 5X, F 10.0)
               READ (1, 2) FMT
             2 FORMAT (80A1)
               READ (1, FMT) (X (I), I=1, N)
          C    SORT IN ASCENDING ORDER
               L=N—1
               DO 50 J=1, L
               L1=L—J+1
               DO 50 I=1, L1
               IF (X (I). LE . X (I+1)) GO TO 50
               SAVE=X (I)
               X (I)=X (I+1)
               X (I+1)=SAVE
            50 CONTINUE
          C    CALCULATE THE MEAN
          C
               X SUM=O.
               DO 60 I=1, N
            60 X SUM=X SUM+X (I)
               AK=N
               AMEAN=XSUM/AK
          C    CALCULATE THE MEDIAN
               IF (MOD (N, 2). EQ.0) GO TO 70
               J=(N+1)/2
               AMED=X (J)
            70 J=(N+1)/2
               K=(N+2)/2
               AMED=(X (J)+X (K))/2.
          C
          C    CALCULATE THE RANGE
               RANGE=X (N)—×(1)
               ANGE=X (N)
               NCELL=ANGE/WIDTH
               IF (CRANGE. LT. ANGE) NCELL=NCELL+1
               ANGE=FLOAT (NCELL)* WIDTH
```

Table - 6 (continued)

```
C       CALCULATE VAR. AND ST. DEV.
        SS=0.0
        DO 80 I=1, N
     80 SS=SS+ (X (I)—AMEAN)**2
        VAR=SS/(AK—1.)
        SD=SQRT (VAR)
C
C       CALCULATE THE COEF. OF VAR.
        COEFV=SD/AMEAN
C
C       CALCULATE SKEWNESS
        SKW 1=0.
        DO 90 I=1, N
     90 SKW 1=SKW 1+ (X (I)—AMEAN)**3
        SKW 2=AK* (SQRT ((AK—1.)/AK)* SD)**3
        SKW=SKW 1/SKW2
C
C       TO OBTAIN FREQUENCY
        POINT (I)=0.
C
        DO 100 I=1, NCELL
    100 NFREQ (I)=0
        K=NCELL+1
        POINT (1)=0.
        DO 110 M=2, K
    110 POINT (M)=POINT (M—1)+WIDTH
        DO 120 I=1, N
        DO 120 M=2, K
        IF (X (I). GE. POINT (M—1). AND. X (I). LT. POINT (M))
      * NFREQ (M—1)=NFREQ (M—1)+1
    120 CONTINUE
C
C       DESCRIPTIVE STATISTICS
C
        WRITE (3,3) N, (X (I), I=1, N)
      3 FORMAT (1H0,//15//(1H, 10F10.2/))
        WRITE (3,4) AMEAN, AMED, RANGE
      4 FORMAT (1H1,/////20 X,               5 HMEAN=, F 13. 5,7 X, 7 HMEDIAN=, F13
      1. 5,7 X, 6 HRANGE=, F 10.5)
        WRITE (3,5) SD, VAR, COEFV, SKW
      5 FORMAT (1H0, 10 X, 8 HST. DEV.=, F 7.5, 10 X, 9 HVARIANCE=, F 9.5,7 X,
      1 10 HC DEF. VAR.=, F 13.5,7 X, 9 HSKEWNESS=, F 7.3)
        WRITE (3,6)
      6 FORMAT (///10 X, 7 X, 5 HGROUP, 7 X, 9 HFREQUENCY/)
        WRITE (3,7) (POINT (M), POINT (M+1), NFREQ (M), M=1, NCELL)
      7 FORMAT (10 X, F 7.3,4 H...., F 7.3,16)
C
C       PLOT HISTOGRAM
C       NCELL MUST BE LESS THAN 100
        MAXFQ=NFREQ (1)
        DO 10 I=2, NCELL
        IF (NFREQ (I). GE. MAXFQ) MAXFQ=NFREQ (I)
     10 CONTINUE
        RGY=MAXFQ
        RGX=POINT (K)
        RCY=50./RGY
        RCX=100./RGX
        IWCOE=WIDTG* RCX
```

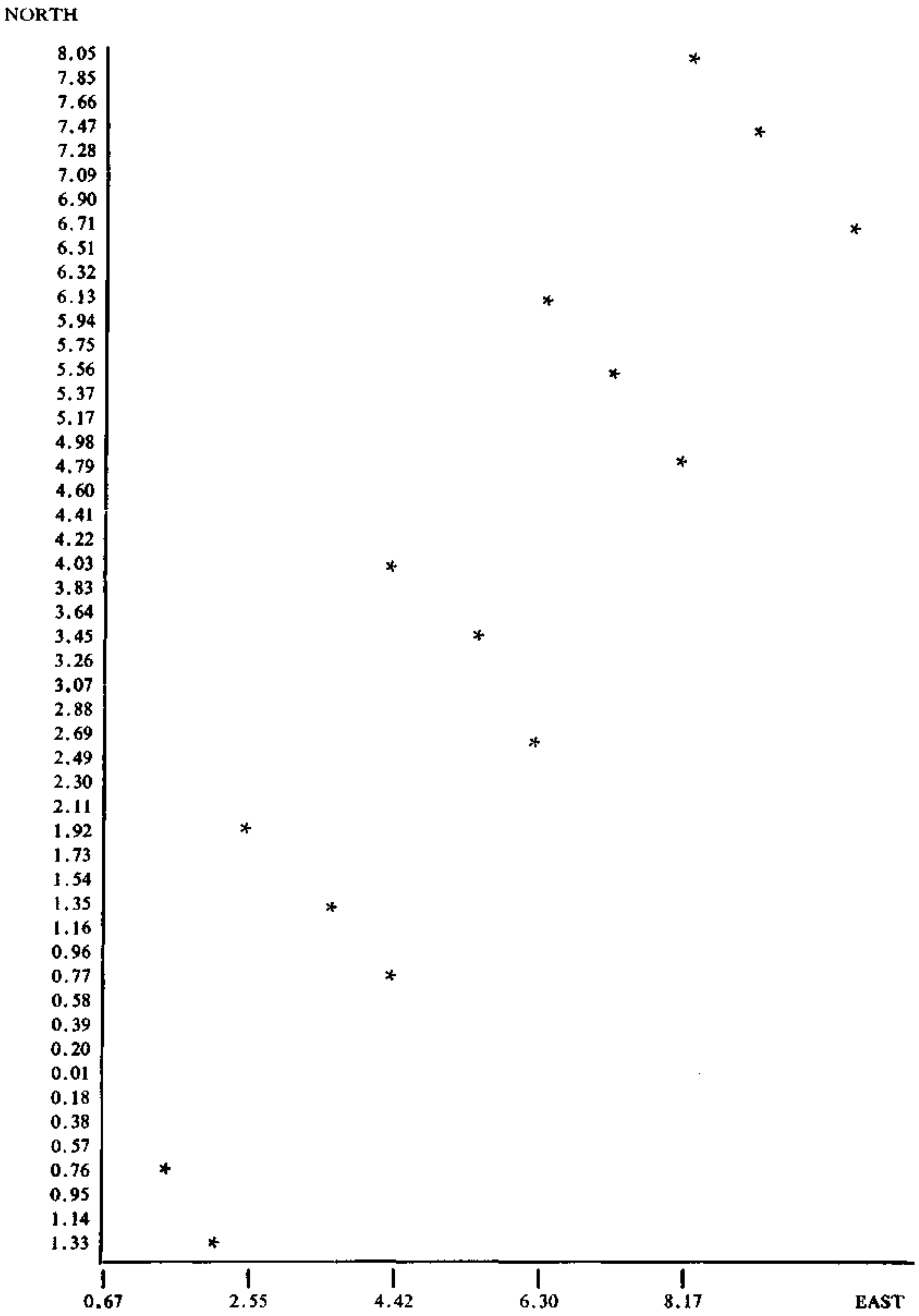
Table - 6 (continued)

```
   DO 11 I=1, NCELL
   INFQ (I)=FLOAT (NFREQ (I))* RCY+1
   IF (NFREQ (I). EQ.0) INFQ (I)=0
11 CONTINUE
   DO 21 I=1,120
   DO 21 J=1,60
21 AGP (I, J)=Q 5
   DO 12 I=1,50
   AGP (10, I)=Q 1
12 AGP (110, I)=Q 1
   J=1
   DO 23 I=1,50,5
   II=51—I
   AGP (10,II)=AN (J)
   AGP (110,II)=AN (J)
23 J=J+1
   DO 13 I=10,109
13 AGP (I,50)=Q 2
   I J=9
   DO 22 J=1, NCELL
   JJ=INFQ(J)
   JJ=50—JJ
   IF (JJ. LE.0) JJ=1
   KK=I WCOE+1
   DO 15 I=1, KK
   II=I+I J
15 AGP (II, JJ)=Q 4
22 I J=I J+I WCOE
   I=1
   L=10+I WCOE
   DO 16 II=L, 110, I WCOE
   KK=I+1
   J=MAX0 (INFQ (I), INFQ (KK))
   IF (J. LE.0) J=1
   DO 17 M=1, J
   MM=50—(M—1)
17 AGP (II, MM)=Q 4
16 I=I+1
   J=1
   DO 14 I=10,110, I WCOE
   N=J/11
   JJ=J
   JJ=JJ—10* N
   AGP (I, 50)=AN (JJ)
14 J=J+1
   I=1
   DO 18 N=16,33,2
   AGP (8, N)=A (I)
18 I=I+1
   WRITE (3,19) ((AGP (I, J), I=1, 120), J=1,60)
19 FORMAT (1H1/(5 X, 120 A1))
   WRITE (3,20) RGX, NCELL, WIDTH, MAXFQ
20 FORMAT (15X, 25 HRANGE OF X IS FROM 0. TO, F 10.5,10 H. GROUPS=, I3,
   119 H WIDTH OF GROUP IS, F 10.5,24 H. MAXIMUM FREQUENCY IS, I 3,1 H.)
   STOP
   END
```

Table - 7

```
                 DOS FORTRAN IV 360N F0 479 3 0   MAINPGM
C     EMPIRICAL PROSPECTION NET METODU İLE BİLİNMEYEN ZUHURLARIN
      TESPİTİ
C     MO = 3
      DIMENSION A (10), B (10, 30), C (10), D (10), M (10), X (30, 30), Y (30, 30),
    * KODE (30, 30), ORD (3), APS (3), TITLE (20), AA (1000), BB (1000), CC (1000)
      READ (1,9) MO, (M (I), I = 1, MO)
      DO 50 I = 1, MO
      READ (1, 10) A (I), B (I, 1), C (I)
      A (3) = 1. E + 20
   50 D (I) = C (I) *SQRT (1. + A (I) **2)
      WRITE (3, 10) (A (I), B (I, 1), C (I), D (I), I = 1, MO)
      DO 75 K = 1, MO
      ML = M (K)
      DO 75 I = 2, ML
   75 B (K, I) = B (K, 1) + (I — 1) *D (K)
      M1 = M (1)
      M2 = M (2)
      DO 100 I = 1, M1
      DO 100 J = 1, M2
      KODE (I, J) = 1
      X (I, J) = (B (2. J) B (1, I)) / (A (1) A (2) /
  100 Y (I, J) = (A (1) *B (2, J) A (2) + B (1, I)) / (A (1) A (2))
      WRITE (3, 10) ((X (I, J), Y (I, J), J = 1, M2), I = 1, M1)
   10 FORMAT (8 F 10. 3)
      READ (1, 10) BOY
    9 FORMAT (20I3)
      READ (1, 12) ORD, APS, STAR, TITLE
      DO 200 K = 3, MO
      DO 200  I = 1, M1
      DO 200  J = 1, M2
      IF (KODE (I, J)) 150, 200. 150
  150 ML = M (K)
      DO 250 L = 1, ML
      ORDI = A (K) + X (I, J) + B (K, L)
      IF (ORDI. GE. Y (I, J)) GO TO 275
  250 CONTINUE
  275 DIST1 = ABS (A (K) * X (I, J) Y (I, J) + B (K, L)) / SQRT (1. + A (K) **2)
      IF (L. EQ. 1) GO TO 300
      DIST 2 = ABS (A (K)* X (I, J) Y (I, J) + B (K, L 1)) / SQRT (1. + A (K) **2)
  300 IF (DIST 1 = BOY) 200, 200, 320
  320 IF (DIST 2 = BOY) 200. 200, 325
  325 KODE (I, J) = 0
  200 CONTINUE
   11 FORMAT (2I5, 3 F 10  3)
      K = 0
      DO 500 I = 1, M1
      DO 500 J = 1, M2
      IF (KODE (I, J)) 450, 500, 450
  450 K = K + 1
  315 WRITE (3, 11) I, J, X (I, J), Y (I, J)
      AA (K) = X (I, J)
      BB (K) = Y (I, J)
      CC (K) = STAR
  500 CONTINUE
      WRITE (3, 13) K
      CALL GRAPH (AA, BB, CC, K. ORD, APS, TITLE, 1, 0, 1, 1, 2, 1, 2)
   12 FORMAT (6 A4, A1/20 A4)
   13 FORMAT (5 X, 'K', I5)
      STOP
      DEBUG UNIT (3), SUBCHK
      END
```

Table - 8


NORTH
8.05
7.85
7.66
7.47
7.28
7.09
6.90
6.71
6.51
6.32
6.13
5.94
5.75
5.56
5.37
5.17
4.98
4.79
4.60
4.41
4.22
4.03
3.83
3.64
3.45
3.26
3.07
2.88
2.69
2.49
2.30
2.11
1.92
1.73
1.54
1.35
1.16
0.96
0.77
0.58
0.39
0.20
0.01
0.18
0.38
0.57
0.76
0.95
1.14
1.33
0.67
2.55
4.42
6.30
8.17
EAST

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