LINEAMENTS MAP OF TURKEY FROM LANDSAT IMAGERY AND SELECTING TARGET AREAS FOR MINERAL EXPLORATION, RELATIONSHIP OF REGIONAL LINEAMENTS TO EARTHQUAKE EPICENTERS, MINERAL WATERS AND HOT SPRINGS

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ABSTRACT . — Landsat coverage country wide have been interpreted and a map of lineaments has been prepared. Circular features which are the surface expressions of deep or near surface intrusions have been carefully mapped in order to investigate their relationship (if any) to known mineralizations. From the outset it was postulated that the mineralizations are located at the intersections of lineaments, especially in the vicinity of circular features. To test this hypothesis known mineralizations were placed on this map. It is noted that the metallic mineral deposits can be grouped into ten regions, and out of these, two regions need to be explored more intensively. In some regions selected, locations of possible mineralizations were determined. Earthquake epicenters, mineral water sources and hot spring locations were placed on the lineaments map. It is seen that the hot springs and earthquake epicenters are located on regional fault systems.

INTRODUCTION

Geological remote sensing techniques are employed to minimize costs and maximize results of ground-based geological investigations. Prediction of subsurface geological relationships from analysis of remotely sensed data is dependent upon the expertise of the data analyst who evaluates variations in electromagnetic energy emanating from the Earth's surface and extrapolates to the subsurface using these surficial attributes and . predictive, conceptual models.

Although remote sensing is but another tool in the study of terrain and exploration for mineral resources, it is a great advantage in synoptic coverage; of being able to view large areas and see a geomorphic province, or to trace a major fault for hundreds of kilometers in very few frames of space photography or imagery.

The objective of this study is to identify landforms, faults, fractures, folds and major rock types; to ascertain where possible the processes by which these features were formed; and potray these features on a map and display their relationship to known mineralizations. From these relationships identify target areas for mineral exploration.

METHOD OF INTERPRETATION

Landsat imagery in four bands were used: 1:1 000 000 scale mosaic of Turkey in band 7 was made and a general interpretation was completed. In some areas that was thought to be worthy of further interpretation additive colour viewer, density slicers were used. With the additive colour viewer 1:1 000 000 and 1:500 000 scale colour composites were made for interpretation. Locally at 1:250 000 and other scales black and white imagery were used for further detailed studies. 1:500 000 scale Geological Map of Turkey was used extensively to compare the results of the interpretation.

IDENTIFICATION OF LINEAMENTS AND CIRCULAR FEATURES

Joints, breakage planes along which no visible movement has occurred are the rock structures which are most numerous type fracture, and play an important role in the breakdown of rocks.

Faults are second in frequency of occurrence among fractures in the rocks. Unconsolidated material, including soil and alluvium, also is cut by faults. They are exteremely important in terrain and mineral-studies and relatively easy to identify on imagery. Major faults may extend for ten to hundreds of kilometers, but segments of their surface traces may be concealed. The synoptic view of space imagery permits correlation of the exposed segments of individual faults of fault systems.

Many major ore deposits are localized at the intersections of large structural features, especially where these intersections are the loci for the emplacement of granitic igneous bodies. Some fractures are postulated to cut deep into the crust and even into the mantle, and to have served as zones of weaknesses along which igneous rocks have been injected and (or) as conduits for hydrothermal fluids carrying metals and other constituents of igneous rocks (Badgley, 1959, 1962, 1965; Butler, 1933; Mayo, 1958; Schmitt, 1966; Turneaure, 1955; Wisser, 1959, 1960).

Circular features are formed by intrusive igneous rocks of domelike masses (laccoliths, stocks, bosses). It is generally recognized that a great many primary mineral deposits are concentrated in and around these masses.

Analysis were performed in several scales. First the photolinears were mapped on an overlay from 1:500 000 scale, band 7 mosaic (Fig. 1). Some areas were checked with colour composit in 1:1 000 000 and 1:500 000 scales. In areas where larger scale needs, up to 1:250 000 scales were used for interpretation. Following the mapping in severel scales, known mineralizations were located on the map of lineaments (Fig. 2). On the same map of lineaments earthquake epicenters and hot springs were placed (Fig. 3). The objective of mapping at different scales was to determine the target areas at regional and local scale, to evaluate the target areas and to determine the relationship between the distribution of lineaments and circular features and metallic mineral deposits, earthquake epicenters, hot springs and mineral waters.

Linear features indicating local structures

These features are clearly discernible on aerial photographs, but are poorly seen in satellite imagery. They are generally 10 km or less in length, and their study is best accomplished through aerial photo interpretation as a direct adjuct to field mapping. These linear features indicate the form and position of individual folds, faults, joints, veins, lithologic contacts and other features that may lead to the location of individual ore bodies. In general they reflect only immediate surface and near-surface conditions, and are poor guides to concealed deposits. The only discernible pattern in these linear features is the pattern of the structure of structure with which they are associated.

These lineaments have not been considered in the interpretation of the imageries.

Linear features indicating regional structural regimes

These are linear features generally mapped in studies of space photography. They are mostly from 10 to 200 km in length although in some areas they are longer, and some may be parts of much longer linear features of more fundamental significance.

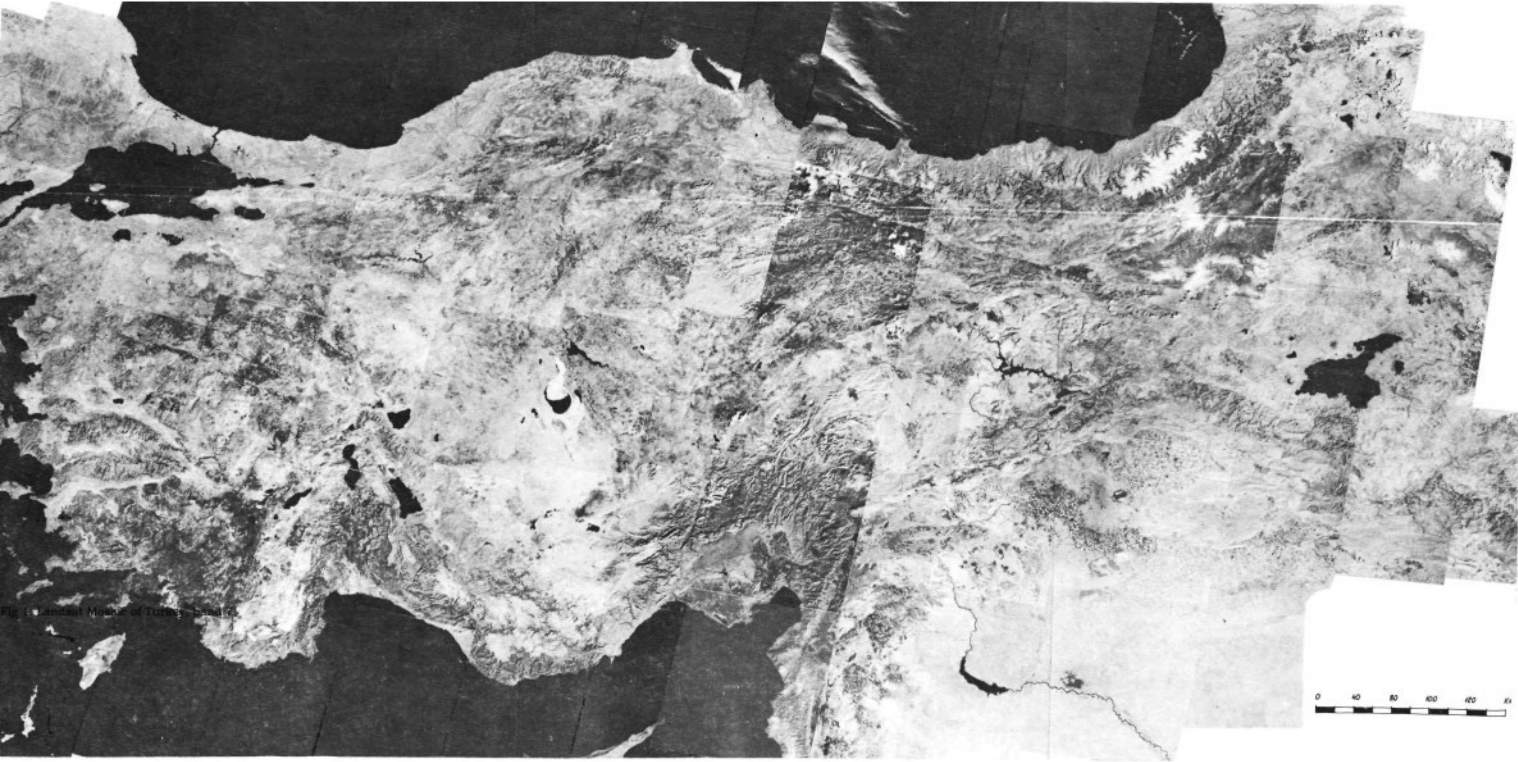

Fig. 1. Landsat Mosaic of Turkey, band 7.

Fig. 2 - Lineaments map of Turkey and mineral deposits.

Fig. 3 - Lineaments map of Turkey and earthquake epicenters, hot springs, thermal mineral water springs and mineral waters.

Linear features of regional structural regimes indicate the general geometry of folds, faults, and other structures that characterize a foldbelt, or the joints and other structural patterns.

A regional pattern is commonly observed in linear features indicating regional structural regimes. This pattern, however, is determined by the internal character of the tectonic element, and is commonly different in adjacent or nearby tectonic elements of differing structural style.

These linear features are useful in defining target areas, local settings in which ore bodies may be concentrated, and which merit more detailed study in the field. A strong positive spatial correlation of mineral districts with these linear features has been noted in many areas particularly in Adana-Kayseri (Mansurlu) region, Eastern Black Sea, Biga peninsula and Hasançelebi-Divriği (Sivas) area the correlation is noticible. A high percentage of the known mineralizations occur within 1-5 km of linear features.

Linear features indicating crustal tectonic elements

Linears that indicate crustal tectonic elements are more than 200 km long, and generally are 1000 km or more in length. They commonly mark all or parts of the boundaries of regional structural elements, or zones separating areas within these elements in which local or regional patterns of type or trend of structures are divergent. On the other hand, they may traverse the entire extent of a regional structural element, or transgress the boundaries between elements having structural regimes of differing types, with little major change in the surface geology.

These linear features occur as alignments that are combinations of surface geologic structures, linear valleys or ridges, and linear changes in tonal contrast marking differences in soil type, moisture, or vegetation. Most are broad and diffuse, some being poorly identifiable for short stretches along their length. Parts of the trace of many of these linear features coincide with the trace of major known faults.

Because of the great length of these linear features, they are most effectively studied on mosaics of Landsat imagery. Identification of these features on meteorologic images is even easier.

Circular features

Circular features may be considered as a special case in the study of linear features. They are identified by the same kind of features as others which are morphology and tonal contrast. They seem to be concentrated in certain regions according to tectonic setting. For example, Niğde-Mansurlu area, Bitlis Massif, Eastern Black Sea region, Northwestern Anatolia. Some circular features occur on or near major linear features, and some seem disrupted by such features. Some others have little or no relation to long linear features.

The geologic identity of circular features tens of kilometers or less can generally be determined by the surface geology, or inferred by the tectonic settings. In Black Sea region some circular features can be related to volcanic centers. Those in Niğde-Mansurlu, NW Anatolia and Bitlis Massif area may be related to intrusive rocks.

The known affinity of mineral deposits for volcanic necks, pipes, ring dike complexes, caldera, impact craters and nearcircular porphyritic intrusives makes the study of these, important for mineral exploration.

Circular features on Landsat images are expressed as circular, elliptical or concentric and radial fractures (fig. 4).

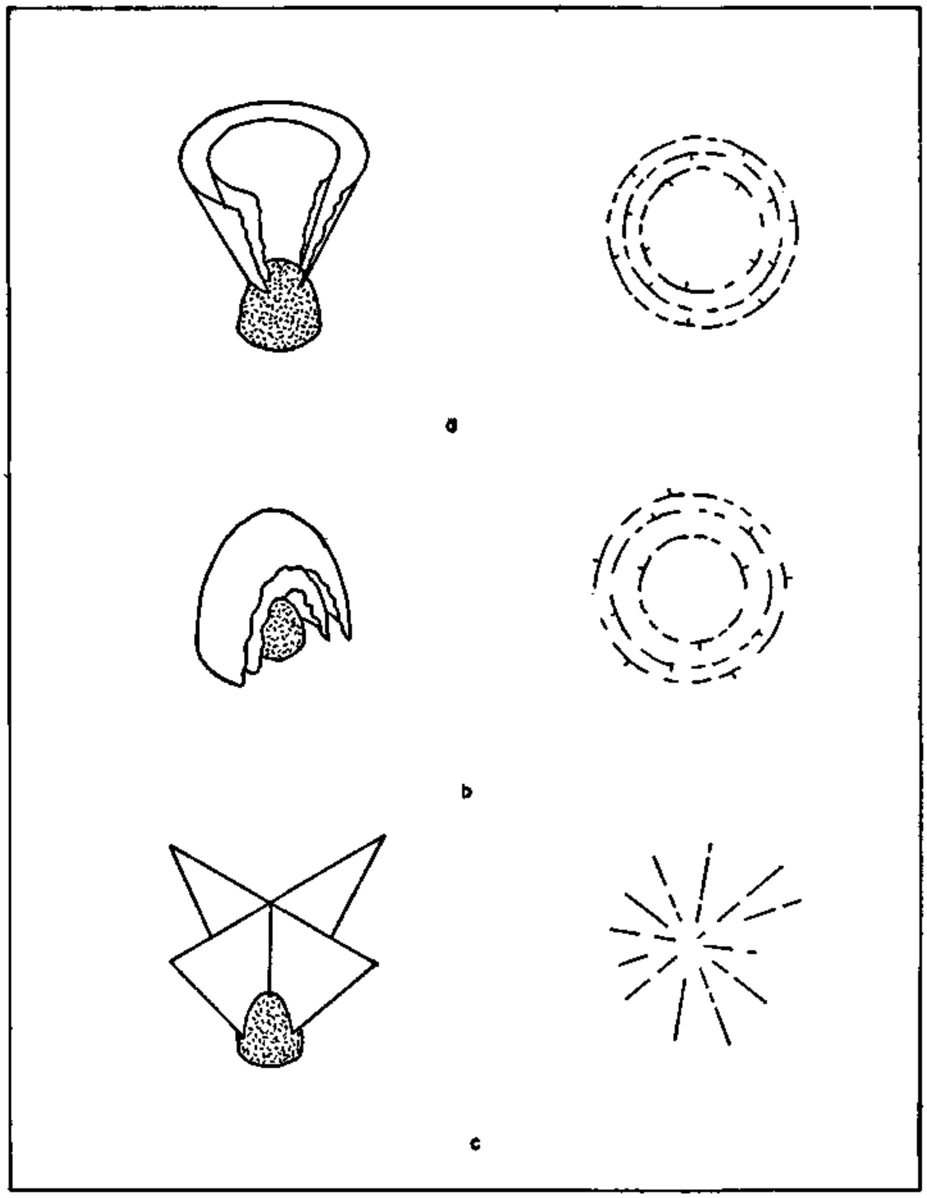

Fig. 4 - Types of fractures in domal structures and plan view.
a - Conical fracture and plan view; b - Domal fracture and plan view; c - Radial fracture and plan view.

Koide and Battacharji (1975) have suggested an exact solution of three-dimensional theory of elasticity in an infinite elastic rock medium around magma reservoirs of various aspect rations and the criteria of rock fracturing (Fig. 5). Theoretical analysis suggest the conditions and regions of formation of dominant radial fractures, dominant concentric fractures or combination of radial and concentric fractures and central subsidence (or graben) in domal uplift related to intrusions of magma bodies of vavious shapes and sizes.

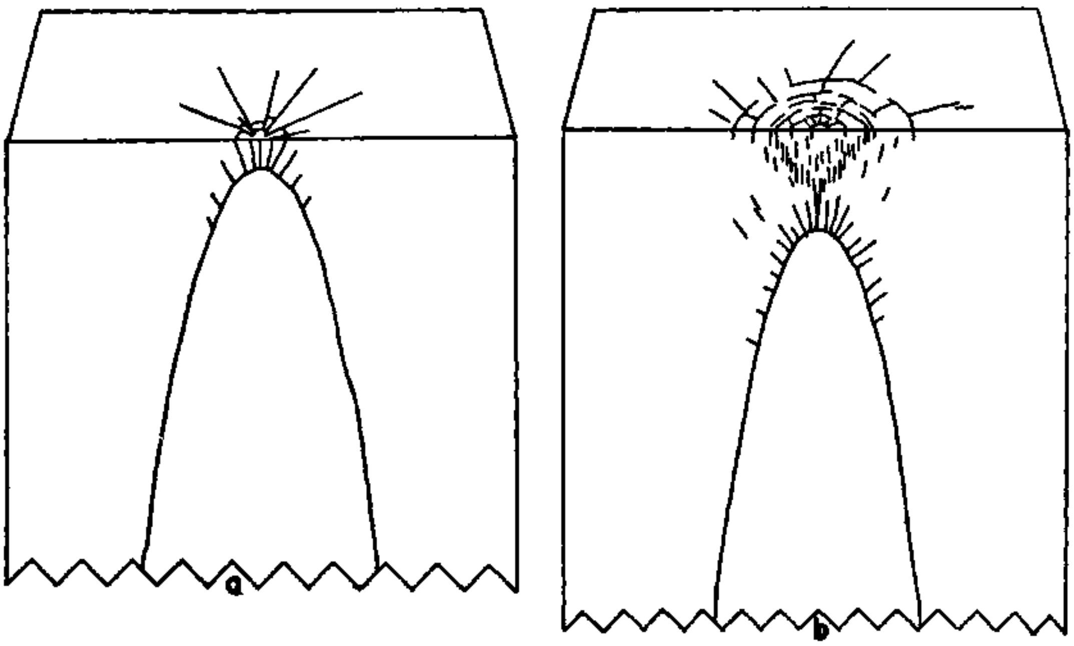

Fig. 5 - Possible development of fracture patterns around a vertically elongated magma reservoir due to increasing hydrothermal pressure (Koide and Bhattacharji, 1975).
a - Magma and hydrothermal pressure (low); b - Magma and hydrothermal pressure (high).

Estimation of stress distribution around spheroidal and prolate magma bodies suggests development of possible zonal distribution of fractures from the periphery of the magma outward in the order of continuous tension fracture zone, brittle fault zone, ductile fault zone followed by no fault zone. Brittle fault and continuous terision fracture zones provide excellent sites for ore mineral localization.

Drainage patterns are important guides to identify circular features in the space imageries (Fig. 6). Ease of identification of the drainage patterns depends on the degree of erosion.

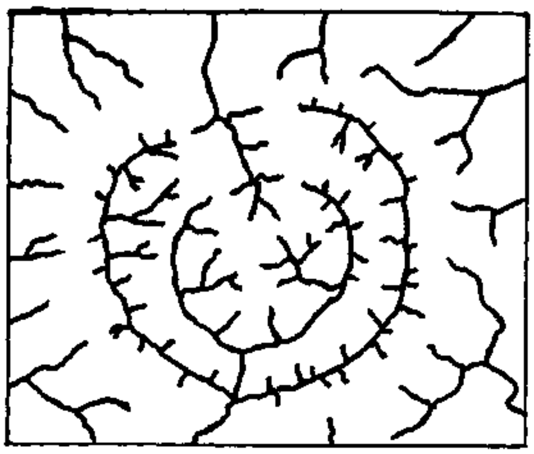

Fig. 6 - Drainage system of a domal structure due to mature erosion.

TARGET AREAS

The map of lineaments and circular features revealed 190 areas that may be the targets for mineral exploration. These target areas are seen to group into ten regions. Metallic mineral deposits which were taken into consideration were Fe, Cu, Pb/Zn, Mn and Hg. In Figure 2 it can be seen clearly that the concentration of known mineralizations are directly related to lineaments and circular features. Ovalıoğlu (1973) made statistical analysis of various data and informations to determine potential areas for Cu-Pb-Zn. Results of that investigation are similar to that of the Landsat analysis. The Landsat investigations showed that two additional regions are potential areas for exploration.

Out of the ten regions, south east and north of Turkey seem not to have been explored as much as the other regions. Having evaluated the target areas at regional scale, each target region was examined to determine possible location of mineralizations. In one region, north of Adana (south of Turkey). Iron deposits were found to be located at the intersection of lineaments trending NW-SE and NE-SW (Fig. 7). Location of mineralizations were found to be within the boundary of a circular feature with a radius of 9-10 km, which may be an indication of a granitic intrusion at depth. Field checks have shown that the mineralizing fluids followed the lineaments trending NE-SW, and depositions occurred at the intersections with NW-SE trending lineaments. If the intersections are lithologically and structurally favorable, economic deposits are found.

LINEAMENTS AND EARTHQUAKE EPICENTERS

Earthquakes between 1913 and 1970 were taken and grouped according to Richter scale into three magnitudes; 3-4.9, 5-6.9, and above 7 and according to depth 0-70 m more than 70 m. (Earthquake epicenters were taken from an unpublished map compiled by A. Boray.) Along the North Anatolian Fault in three groups of Richter scale earthquakes are noticible. To the west, around Bolu, this fault splits and one branch continues through Adapazarı and south of Tekirdağ to the west (Fig. 3). The branch going south westerly from Bolu, passing south of İznik lake and Bandırma continues in the south-west direction between Bandirma and gulf of Edremit, earthquake epicenters indicate the direction of faulting, eventhough the line of fault is not very clear in the imageries. The lineaments and the earthquake epicenters indicate that the fault does not follow a line.

In the vicinity of south of Kastamonu, a branch of the North Anatolian Fault continuing to NW is clearly seen. To support this view, earthquake epicenters are noted to group on this line. Further east another branch is seen to go north-west, but there are only two earthquake epicenters on this line. These two branches suggest that the North Anatolian Fault, before following a curved path may have followed these straight lines.

Around Erzincan the North Anatolian Fault splits into three and continues in the north-east direction. On the two northerly branches, no earthquakes have been recorded. On the southerly one going in Erzurum-Karaköse direction, a line of earthquake epicenters are noticible. On the imageries no evidence has been found for strike-slip faulting.

From the North Anatolian Fault, between Erzincan-Karlıova another branch goes in the north east direction. After the point of intersection with the East Anatolian Fault, in Karlıova, the fault zone continues in the direction of lake Van. In this part it is not a line but a zone of parallel faults. On this zone earthquake epicenters correlate with the fault lines. Here, there is no evidence of strike-slip faulting.

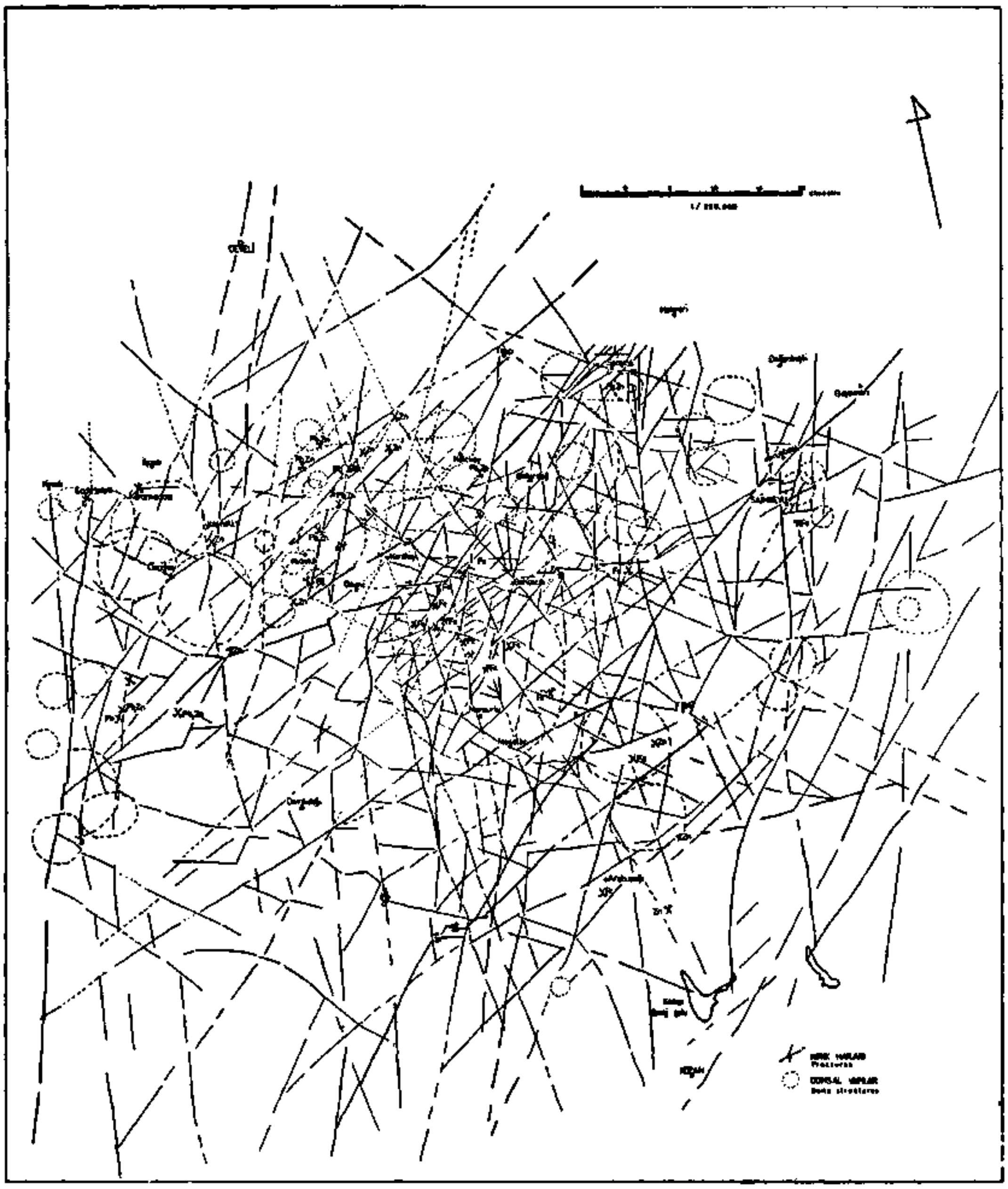

Fig. 7 - Relationship between lineaments, circular features and mineralizations in Adana-Kayseri-Mansurlu area.

A portion of the East Anatolian Fault, which is nearby Karlıova south of Hazar Gölü (lake) and in the south passes through Hatay and south of Kahramanmaraş, is traced without any difficulty. Earthquake foci are densely concentrated in the circumference of Hazar Gölü (Arpat and Şaroğlu, 1975).

In the north Aegean region a large area in a zone between Afyonkarahisar and Balıkesir is traversed by parallel fault systems and a number of earthquake epicenters are found to be arrenged in this zone. In addition to this, the earthquake epicenters in the Aegean region reveal a distribution without any parallelism to fault zones.

Those regional lineaments in Central Anatolia indicating a NE-SW and dominantly NW-SE trend and in the west of Tuz Gölü they have NW-SE and NE-SW trend. On the contrary as advanced to the north those lineaments, in the NW-SE trend tend to curve to the east.

Space images indicate that there is a close relationship between young fault systems and earthquakes. Other than those regional fracture systems, continuous lineaments which transect Anatolia in the N-S, NE-SW and NW-SE directions are noticible. In eastern Turkey, those lineaments are initiated from Arabic block and advanced to the north by intersecting the north Anatolian Fault. Those lineaments could be interpreted as quite young, deep fracture systems with little movements.

LINEAMENTS AND MINERAL WATERS, THERMAL SPRINGS

Relationship of regional faults to earthquakes is revealed and indicating parallelism particularly with thermal springs. On the other hand mineral waters and thermal mineral water springs are in good agreement with smaller fracture systems (Fig. 3).

In the Aegean Region, it is noticed that mineral water thermal mineral and thermal springs are in close relationship with grabens.

RESULTS AND SUGGESTIONS

As a consequence of this study it is found that ore mineralization in Turkey is concentrated into ten major regions. By conducting more detailed study for each region, exploration areas could be reduced into smaller groups and also possible ore deposits could be verified. It is also noticed that target areas are directly related to photo lineaments and circular features. If remote sensing techniques are utilized with geophysical, geochemical, and geological data the success rate will undoubtfully increase.

Relationship of earthquake foci and thermal springs with regional fault zones are determined which has revealed that those zones are particularly in harmony with young fault systems.

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