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GEOLOGY AND MINERAL DEPOSITS OF THE HEKIMHAN-HASANÇELEBI IRON DISTRICT, TURKEY

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ABSTRACT

An area of 210 sq km was investigated in the Hekimhan-Hasançelebi district of central Turkey as part of the Maden Tetkik ve Arama Institusü(MTA)-U. S. Geological Survey(USGS) mineral exploration and training project to explore for iron deposits and to provide on-the-job training for MTA geologists.

The rocks of the area are Cretaceous and Tertiary sedimentary and volcanic rocks intruded by syenite and a serpentinized mafic and ultramafic complex and overlain unconformably by late Tertiary basalt. The base of the section is a thick mafic volcanic-sedimentary sequence with diverse rocks that include conglomerate, sandstone, shale, tuff, limestone, and basalt. The upper part of the sequence is metasomatized near syenite contacts. The sequence is conformably overlain by trachyte and unconformably overlain by massive limestone. Overlying the limestone is a Tertiary sedimentary sequence which is dominantly conglomerate and sandstone with local limestone and volcanic rocks. This series is in turn overlain by olivine basalt.

Mineral deposits are associated with the two types of intrusive rocks. Hematite-magnetite in the Karakuz mine area and in the Bahçedami-Hasançelebi area is related to the syenite, and siderite in the Deveci mine area is possibly related to the mafic-ultramafic rocks. Significant iron resources are found only in the Karakuz and Deveci areas. In the Karakuz area

disseminations, veins, and replacements consisting of hematite and magnetite are present. Most of the material is low grade. In the Deveci mine area a large deposit of siderite apparently is a replacement of carbonate beds adjacent to serpentinized igneous rock. The upper part of the siderite deposit is weathered and enriched to a mixture of iron and manganese oxides of direct shipping ore grade.

Additional investigation of both the Karakuz and Deveci mine areas is recommended including:

1. A detailed gravity and magnetic survey of part of the Karakuz area.
2. Diamond drilling at both the Karakuz and Deveci areas.

INTRODUCTION

Location and access

The Hekimhan-Hasançelebi iron district is in central Turkey approximately 70 km northwest of Malatya and approximately 120 km southeast of Sivas. The investigated area, between lat 38°52'30" and 38°38'00" N. and long 38°00'00" and 37°45'00" E., is north of Hekimhan, trends east, and is 5-10 km wide by 22 km long. The village of Hasançelebi (fig. 1) is in the area. The Karakuz mine is 17 km northwest of Hekimhan, and the Deveci mine, 10 km north-northeast of Hekimhan.

Hekimhan is accessible throughout the year by railroad and from April to November by roads from Malatya and Sivas. Mine roads and cart tracks provide access to all parts of the area.

Purpose and scope of investigation

The investigation was conducted as part of the MTA-USGS mineral exploration and training project sponsored by the Government of Turkey and the Agency for International Development, U. S. Department of State The main objective was to attempt to increase the iron ore reserves of a mineral belt extending 75 km from the Otlukilise mine area on the west to the Deveci mine area on the east. This report describes investigations made in the western third of the mineral belt. The investigation also provided on-the-job training for MTA personnel.

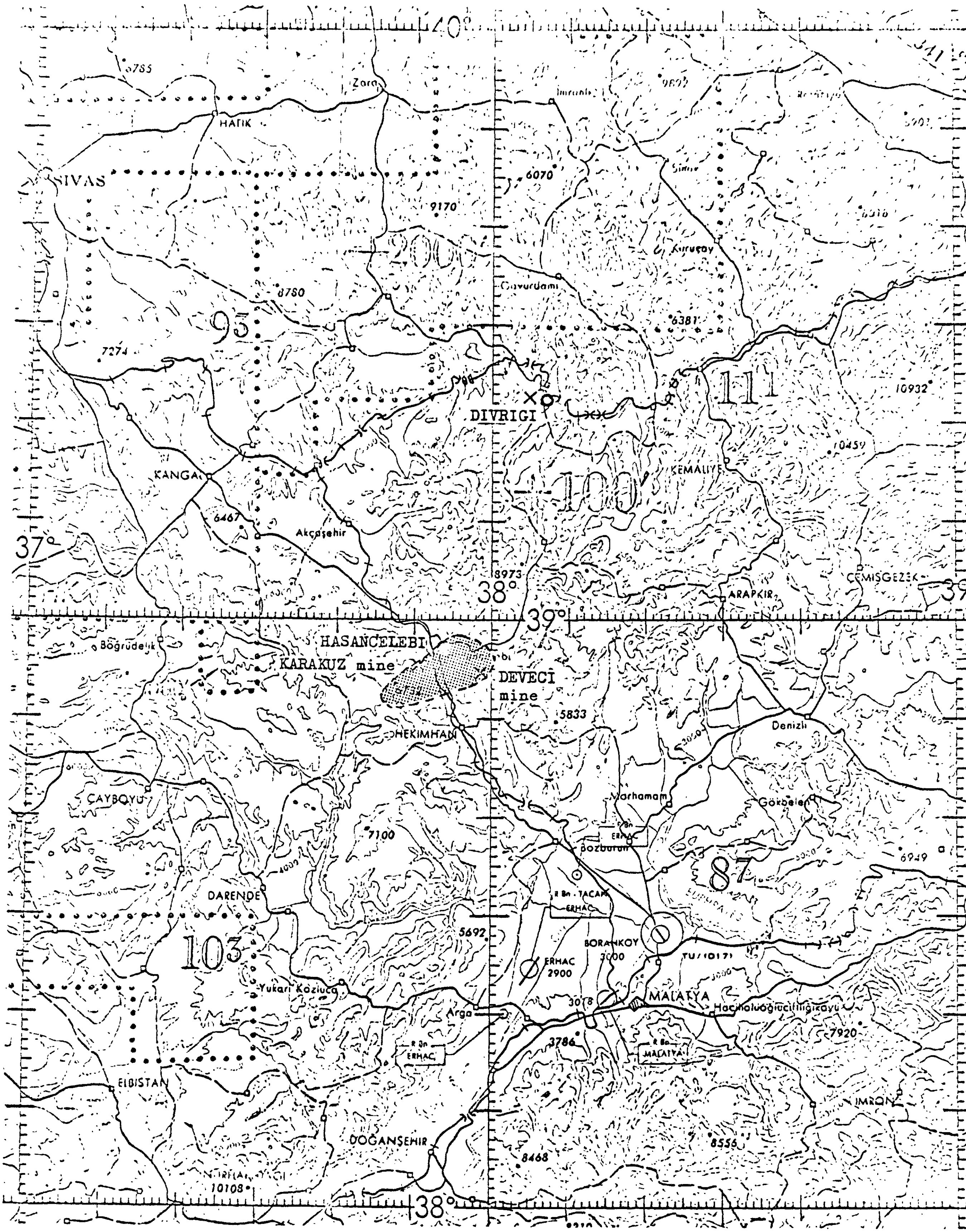

FIGURE 1. Index map showing the Hekimhan-Hasançelebi area, Turkey.

Fieldwork was done from September 16 to November 1, 1968, and from April 2 to September 26, 1969. Most of the time was spent in geologic mapping of the district at a scale of 1:25,000 and of the Karakuz and Deveci mine areas at a scale of 1:5,000. The mapping was supplemented by geophysical surveys, trenching, and diamond drilling. A preliminary report for the Karakuz mine area was completed in February 1969 (Jacobson and Boğaz, 1972).

Minerals

The region is economically important principally because of its iron deposits, though base metals and chromite are locally present. Iron is found as contact metasomatic magnetite deposits (Divrigi); magnetite-hematite replacement deposits (Karakuz); hydrothermal siderite deposits (Deveci); magnetite veins and disseminations (Bahçedami-Hasançelebi); and geothite-limonite weathering products of iron-bearing rocks (Deveci). Most of the iron deposits apparently are related to intrusions of serpentine and syenite.

Previous work

The geology and mineral deposits of the Hekimhan-Hasançelebi area have been the subject of repeated investigations for more than three decades. Among the earliest work is that of V. Kovenko (Kovenko, 1936 and 1938), who studied many of the iron deposits. Subsequently, the Karakuz and Deveci iron deposits were investigated in detail and extensively drilled during 1959-61 by a group of MTA geologists and mining engineers (Duransoy, 1960; Meer Mohr, 1961; Ozdogan, 1961; and Yilmaz, 1960). A comprehensive study of the geology and mineral deposits of the eastern half of the district was also conducted by E. Izdar (1963). In 1968 the Kirmizi Tepe area was investigated by G. Aytug (1969).

REGIONAL GEOLOGY

The Hekimhan-Hasançelebi district is in an area of Tertiary and Cretaceous sedimentary and volcanic rocks intruded by serpentinized mafic and ultramafic rocks (Baykal and Erentöz, 1966). North and east of the district the older rocks may be present under a cover of subhorizontal Tertiary volcanic rocks. The volcanic blanket extends north to the Divrigi iron district. Tertiary and Cretaceous rocks extending westward from the Hekimhan-Hasancelebi district were mapped during 1969 (G.W. Leo and others, in press and P.J. Barosh and others (1972). No rocks older than Cretaceous are present in the vicinity. The nearest pre-Mesozoic rocks are Permo-Carboniferous beds more than 30 km northwest of Hekimhan near Arapkir (Baykal and Erentöz, 1966).

Regional structures are not readily apparent.

The bedded rocks in the district reportedly are deformed in broad regional folds that trend east-northeast (Baykal and Erentöz, 1966, pl. 3). The axis of the Binboga anticline cuts the southeast corner of the district and passes through the Deveci mine area.

LAYERED ROCKS

Stratigraphic summary

All the rocks in the area investigated are Late Cretaceous or younger (table 1). They overlie the Cretaceous fossiliferous limestone (Campanian) exposed just south of the south boundary of the area (Izdar, 1963, pl. 1).

The mafic volcanic-sedimentary sequence is exposed over a large part of the area investigated (pl. 1). It has been subdivided into three units (table 1).

Table 1.--Stratigraphic summary of layered rocks

Age	Epoch	Character
QUATERNARY	Miocene-Pliocene (?)	Unconsolidated clay, sand, and gravel.
TERTIARY	Miocene-Pliocene(?)	Subhorizontal olivine basalt and very local interbedded tuff, andesite, and dacite.
	Eocene-Oligocene(?)	Sedimentary-volcanic sequence: 1. Upper unit: Subhorizontal conglomerate, sandstone, limestone, and chert. 2. Middle unit: Andesite. 3. Lower unit: Folded red beds with dominant conglomerate and sandstone and local shale and limestone. *Nummulites* in some limestone beds.
	Paleocene-Eocene(?)	Massive limestone, bedded limestone, and dolomitic limestone; very local gypsum.
MESOZOIC	Upper Cretaceous	Massive limestone and bedded limestone (mapped together with Tertiary limestone).
	Upper Cretaceous	Trachyte flows.
	Upper Cretaceous (Maestrichtian)	Mafic volcanic-sedimentary sequence: 1. Upper basalt unit: Columnar basalt, basalt pillow lava, tuff, and andesite. 2. Middle tuff unit: Tuff, shale, limestone with local sandstone, conglomerate, and mafic lava. Some limestone beds fossiliferous. 3. Lower conglomerate unit: Mafic conglomerate, tuffaceous sandstone, tuff, and mafic lava.
	Upper Cretaceous	Limestone with *Hippurites* fossils.

1. An upper unit consisting of basalt, tuff, and andesite.
2. A middle unit consisting of tuff, shale, limestone, and red sandstone, conglomerate and mafic lava.
3. A lower unit consisting of mafic conglomerate, tuff, tuffaceous sandstone, and mafic lava.

The boundary between the lower and middle units is clearly defined by a fossiliferous limestone bed of Maestrichtian age at the base of the middle unit exposed near Dere Köy (pl. 1) (MTA Paleontology Department, written commun., 1969). The boundary between the middle and upper units is not as clearly defined. It is gradational and has been mapped on the basis of a change from dominant tuffs to lavas. Metasomatized mafic rocks apparently are a metamorphic equivalent of the upper unit of the sequence.

The mafic volcanic-sedimentary sequence is conformably overlain by trachyte, exposed only at higher elevations (pl. 1) in parts of the district. Near Deveci, the sequence is unconformably overlain by limestone beds that are considered to be younger than the trachyte. In the only locality where the two formations are in contact the stratigraphic relationship is not clear.

The limestones have been mapped as a single unit (pl. 1) despite their considerable range in age, because they cannot be readily separated. They include: a) Upper Cretaceous massive limestone, platy bedded limestone, marly limestone and dolomite; and b) Paleocene and Eocene massive and bedded limestones (Izdar, 1963, p. 13).

The limestones are overlain by a Tertiary sedimentary-volcanic sequence equivalent to Izdar's "detritishe bunte serie" (Izdar, 1963, p. 15). In this report the sequence has been subdivided into 3 units (table 1).

1. An upper subhorizontal conglomerate unit, locally containing sandstone, limestone, and chert.

2. A middle volcanic unit composed of andesite lava.

3. A lower folded red-bed unit composed of conglomerate, sandstone, shale, and limestone.

This last unit is conformably overlain by olivine basalt.

Locally, unconsolidated clay, sand, and gravel of Quaternary age are present but were not mapped.

Mafic volcanic-sedimentary sequence Cretaceous

Areal distribution

The Cretaceous mafic volcanic-sedimentary sequence covers more than half the area mapped (pl. 1) and is a host rock for some iron deposits. It is present both north and south of an east-trending serpentinized belt in the center of the area (p. 15). In the eastern half of the area the sequence was mapped as a single unit and in the western half it was subdivided into lower, middle, and upper units. These rocks generally are exposed at lower altitudes and are covered by younger rocks at higher altitudes.

Stratigraphy and lithology

Lower conglomerate unit: The lower conglomerate unit consists mostly of subangular to subrounded pebbles and cobbles, mainly basalt and andesite, and lesser gabbro and dacite(?), in a sandy matrix. The source of the igneous material is unknown. The conglomerate commonly is well stratified and has graded bedding. Locally, the rock grades into conglomeratic sandstone.

Locally the conglomerate is interbedded with flow andesite and basalt and tuffaceous sandstone, tuff, tuff breccia, and agglomerate of intermediate to mafic composition.

Middle tuff unit: The middle unit includes a broad range of sedimentary and volcanic rocks, chiefly calcareous gray bedded tuff, tuffaceous sandstone, and tuff breccia, but also gray mudstone, gray shale, gray and maroon sandstone, gray and maroon conglomerate, lava flows, and bedded limestone. A basal limestone bed exposed near Dereköy (pl. 1) contains Radiolites and Orbignya aff. O. colliciate (Woodward). Higher in the section are several other limestone beds containing Pseudipolyconites, Hippurites, and Joufia reticulata (MTA Paleontology Section, written commun., 1969). Most of the lava flows are basalt and andesite, but a trachyte flow is also present in the sequence near the Deveci mine (pl. 3).

Upper basalt unit: The upper unit is thickest and best exposed in the northwestern part of the area (pl. 1) near Bahcedami. The basalt is typically equigranular and has medium- to coarse-grained, diabasic texture. The basalt is commonly interbedded with tuff and locally with andesite.

Metasomatised mafic rocks

In the northwestern quarter of the district an area totaling about 19 sq km is underlain by metasomatised mafic rocks which typically contain actinolite, soda-rich scapolite (marialite), albite, potassium feldspar, calcite, and analcite and in many places have unusually high concentrations of magnetite. The rocks probably originated by metamorphism and metasomatic alteration of basalts in the upper unit of the mafic volcanic-sedimentary sequence. Columnar jointed basalt 4 km southwest of Hasançelebi is clearly partly replaced by scapolite(and actinolite?). Numerous trachyte and syenite dikes cut the basalt and syenite stocks are nearby, which suggests that the metamorphism and metasomatism may be related to syenitic intrusions.

Possibly the most widely distributed of these rocks consists of actinolite crystals as much as 1 cm wide and 10 cm long surrounded by a magnetite ground mass. The larger actinolite crystals commonly form aggregates of fine fibers with interstitial calcite. A second type of metasomatised rock consists of aggregates of clinopyroxene-magnetite-calcite-epidote-chlorite cut by prismatic marialite. Elsewhere, prismatic marialite(?) pseudomorphs consist of granular aggregates of potassium feldspar, albite, or quartz, and subordinate analcite and clay (determined by X-ray diffraction). Samples from the lower part of a drill-hole near Hasançelebi (p. 36) consist of granular or clotted magnetite, chlorite, partly chloritized biotite, and potassium feldspar. The abundance of biotite and potassium feldspar at depth agrees with the concept that the metasomatism is related to syenite-trachyte intrusions. The relative abundance of the various mineral assemblages is not well known.

Age

The mafic volcanic-sedimentary series is Late Cretaceous. All fossils identified from limestone in the middle unit are Maestrichtian (N. Karacabey, MTA, written commun., 1969). The middle unit corresponds to Izdar's "flychartige" Upper Cretaceous series (Izdar, 1963, p. 11), and the lower unit corresponds to Izdar's Upper Cretaceous "Submarine volcanic-tuffaceous facies of ophiolite" (Izdar 1963, p. 26-27).

Trachyte (Cretaceous)

Areal distribution

Trachyte flows cap ridges in an east-west belt just north of the east-west serpentinized belt (pl. 1). Local outliers of trachyte are also present on hilltops to the north. The principal exposures are in the vicinity of Culhalli and the Karakuz mine.

Lithology

The trachyte is fairly uniform in composition but varies in grain size and texture. It is composed almost entirely of sanidine, is low in mafic minerals, and is without quartz.

Trachyte in the Karakuz mine area (pl. 1 and 2) is commonly vesicular, very fine grained, and has sparse sanidine phenocrysts. East of Karakuz and north of Dereköy a syenite intrusive progressively grades to a micro-syenite sill and from the sill to a trachyte flow.

Because of its tabular form we mapped the micro-syenite as trachyte in some areas. This geologic interpretation accounts for some of the differences between our map (pl. 1) and a previous map (Izdar, 1963, pl. 1).

Alteration and mineralization

The trachyte is generally unaltered and unmineralized except in the area which includes the Karakuz mine (pls. 1 and 2). In that area, 4.5 km long and 100-500 meters wide, the trachyte contains replacement veins and disseminated magnetite, hematite, and limonite. Although these rocks have an altered appearance megasophically, in thin sections they show little alteration. Locally, the trachyte contains secondary silica and tourmaline.

Age

The trachyte conformably overlies the Upper Cretaceous mafic volcanic-sedimentary sequence and is therefore believed to be Late Cretaceous in age.

Massive and bedded limestons (Cretaceous-Tertiary)

Several massive limestone units in the area in this report are grouped together because in general they could not be distinguished in the field, and because a complete limestone section is not present in the mapped area.

Areal distribution

Massive limestones were observed in three principal areas and in ridge-capping outliers. The three main areas are (pl. 1):

1. The northwest part of the mapped area.
2. The southeast part of the mapped area south of Deveci.
3. The eastern half of the east-west serpentinized belt where the limestone interfingers with serpentinized rocks.

Stratigraphy and lithology

The limestone, as studied by Izdar (1963, pl. 11-15) and summarized in table 2, includes dolomite, massive limestone, marly limestone, and platy-bedded limestone. These rocks range in age from Upper Cretaceous (Maestrichtian) to Eocene. The pre-Eocene limestone sequence consists of massive dense white limestone; bedded tan, locally dolomitic limestone; and massive yellow, partly sugary limestone. Locally, the sequence includes sandstone, siltstone, and fossiliferous limestone. Sample Z 348 contained _Gryphaea vesicularis_ Lam(?) of Albian-Danian age (MTA Paleontology Section, written commun., 1969).

The Eocene limestones are white and contain _Nummulities_. This unit is confined to the northwest corner of the mapped area (pl. 1).

The limestone that interfingers with the serpentinized rock north of Deveci (pl. 1) is dense, gray, red weathering, and commonly has a sugary texture. It may or may not be part of the above limestone section.

Age

The upper part of the limestone section has been dated as Eocene because of contained _Nummulities_ (Izdar, 1963, p. 14) and the lower part of the section is Maestrichtian, on the basis of fossil evidence (MTA Paleontology Section, oral commun., 1969). The Cretaceous-Tertiary boundary lies in the middle of the massive limestone section and cannot be positively defined.

Table 2.--Stratigraphy of limestone section.

(after Izdar, 1963, p. 13)

Age		Thickness (meters)	Description
TERTIARY	Eocene	150-200	Massive dolomitic limestone and limestone containing Nummulities.
	Paleocene	50-200	Massive cavernous limestone with local gypsum.
CRETACEOUS	Maestrichtian	60-100	"Platten" limestone and "bunite mergelkalke."
		50- 70	Yellow brecciated dolomite.

Tertiary sedimentary-volcanic rock sequence

The Tertiary sedimentary-volcanic rock sequence as defined in this report includes a lower folded red-bed unit, a middle volcanic unit, and an upper subhorizontal conglomerate unit. The sequence unconformably overlies older rocks in the area and is overlain by olivine basalt.

Areal distribution

The sequence exposed is a narrow belt extending northwest from the Deveci mine area to Hasançelebi (pl. 1), where it has not been subdivided during mapping. In the southwest corner of the area the lower part of the sequence is well exposed and conglomerate crops out in a small area in the northwestern corner.

Stratigraphy and lithology

Lower red bed unit: The red beds are dominantly red-brown conglomerate and conglomeratic sandstone. Rare red shale and very local white limestone beds also are present. The conglomerate is composed of rounded to subangular pebbles, cobbles, and local boulders in a matrix of coarse conglomeratic sandstone. The clastic fragments are derived from all the older volcanic, intrusive, and sedimentary formations in the district.

Middle andesite(?) unit: The red beds are unconformably overlain in the southwestern corner of the mapped area (pl. 1) by andesite derived from the Leylekdag volcanic center. This porphyritic andesite(?) consists of white plagioclase phenocrysts in a black fine-grained matrix and was not recognized elsewhere in the district.

Upper conglomerate unit: North of the Deveci mine area the red beds are overlain by coarse conglomerate in which sandstone, chert, and limestone are locally interbedded. The conglomerate is light gray and is composed of subrounded to rounded fragments in a sandstone matrix. The fragments are of diverse composition; mafic volcanic fragments are most common. Fractured gray chert beds are present only near Basak. The silica may be sedimentary, but more likely it represents silicification of another material.

The conglomerate shown in the northwest corner of plate 1 has been tentatively placed in this unit because it is believed to be of the same age, but it differs in composition from the other conglomerates in the unit. It is coarser and commonly consists of subrounded limestone cobbles in a sandy matrix.

Age

The sedimentary sequence corresponds to Izdar's "detritische bunte serie," dated as Eocene on the basis of fossil evidence (1963, p. 16).

Olivine basalt

Areal distribution and lithology

Subhorizontal basalt covers all older rocks north and east of the district and is well exposed in the northeast corner of the area mapped (pl. 1). The basalt is massive, black, and dense, and has very small olivine phenocrysts, only rarely visible in hand specimens. Locally, the basalt is interbedded with tuff, dacite, and andesite.

Age

The basalt overlies the Eocene sedimentary rocks and its age is therefore middle to late Tertiary-(Eocene-Pliocene).

INTRUSIVE ROCKS

Serpentine, peridotite, and gabbro

Areal distribution and lithology

A complex mixture of serpentinized mafic and ultramafic rocks forms a narrow east-west belt from the Deveci mine to the Karakuz mine (pl. 1). Elsewhere in the mapped area these rocks form local outliers. The largest outlier is at Kirmizi Tepe, in the northwest corner of the mapped area. In addition, two small gabbro intrusives are exposed 2 km southwest of Bahçedami. The rocks are chiefly serpentinite and partly serpentinized gabbro and peridotite.

The serpentinite is a fine-grained dark-green rock having typical greasy luster on fracture surfaces. The serpentinite commonly forms envelopes around partly serpentinized mafic and ultramafic rocks, which give the general appearance of a coarse breccia in a serpentine matrix.

The unserpentinized gabbro is an equigranular rock chiefly composed of plagioclase and augite. The peridotite is generally finer grained, has a sugary texture, and is somewhat variable in composition. The main constituents are olivine, augite, and actinolite.

The mafic and ultramafic rocks probably crystallized and cooled at great depth. Later the rocks probably were emplaced by tectonic movement accompanied by serpentinization.

Age

The mafic, ultramafic, and serpentinized rocks were intruded over an extended period. The presence of gabbro cobbles in the lowermost conglomerate of the Cretaceous mafic volcanic-sedimentary series represents the earliest noted evidence of these rocks. However, renewed movement of serpentinized rocks probably took place in Late Cretaceous time because such rock intrudes massive limestone of Cretaceous-Eocene age(?) and Upper Cretaceous mafic volcanic and sedimentary rocks. Evidence of intrusion into massive limestone is seen west of the Deveci mine where serpentinized rocks and limestone interfinger and locally have a gradational metamorphosed contact zone. Also, in that area, blocks of limestone are completely surrounded by serpentinized rock.

Syenite

Areal distribution and lithology

Intrusion of syenite(?)[1/] was accompanied by extrusion of trachyte and gradational syenitic to trachytic textures are common. As stated previously (p. 11), tabular micro-syenite which is probably a sill and grades into trachyte was mapped together with the trachyte. Syenite stocks are present in 3 localities (pl. 1):

1. At the Karaköy mine.
2. 1.5 km north of Dereköy.
3. 2.5 km north of Bahçedami.

[1/] No petrographic data available.

These are believed to represent a batholith which probably underlies much of the northern half of the area. The numerous trachyte porphyry dikes that cut the mafic volcanic-sedimentary sequence and the metasomatized rocks are probably off shoots of one or more subsurface bodies of syenite. The metasomatism probably was caused by the syenite(?).

The syenite in stocks is phaneritic and is composed almost entirely of feldspar, a high percentage of which is sanidine. Mafic mineral content is low. The dikes and sills are microsyenite porphyry to trachyte porphyry consisting of sanidine phenocrysts in a fine-grained feldspar matrix.

Metasomatism

The syenite intrusion probably caused the metasomatism of a large area of mafic volcanic rocks by providing heat and magmatic gases (chlorine, carbon dioxide, and sulfur dioxide). In Karakuz drill hole 69-1 (table 3), and perhaps elsewhere, contact metamorphism produced hornfels. The syenite intrusion apparently also caused a remobilization of iron in the mafic volcanic rocks to produce iron minerals (mostly magnetite), which were deposited in replacements, disseminations, and veins. At the Karakuz mine deposit magnetite veins have formed along the walls of trachyte porphyry dikes where they are in contact with mafic volcanic rocks (pl. 1).

Age

The syenite is probably the same age as the trachyte which overlies the Upper Cretaceous mafic volcanic-sedimentary sequence. The syenite was possibly intruded near the end of the Late Cretaceous, during a Laramide orogeny (Baykal and Erentöz, 1966, p. 87). In the area to the west (Leo, oral commun., 1969) the syenite also intrudes serpentine and the mafic volcanic-sedimentary sequence. The age of the syenite is thus not yet clearly established.

Diabase dikes

Diabase dikes are present in the eastern part of the area and represent the youngest intrusive activity. The dikes cut all the sedimentary and volcanic rocks including the upper conglomerate unit of the Tertiary sedimentary-volcanic series. The dikes are the probable feeders for the Tertiary olivine basalt.

STRUCTURE

Folds

Two periods of folding took place in the district. The older deformation affected the Cretaceous mafic volcanic-sedimentary sequence but not the massive limestone unconformably above it. Folds are gentle and fold axes trend east to east-northeast (pl. 1). Synclinal axes are evident south of the east-west serpentinized belt (pl. 1), and the serpentinized rocks apparently were intruded near an anticlinal axis. North of the serpentinized rocks the mafic volcanic-sedimentary sequence and the trachyte have a fairly uniform shallow northerly dip possibly representing part of a broad fold.

The second folding was local and affected only the Tertiary red beds. The folds are tighter near major faults, indicating that some folds may have been caused by drag along faults rather than directly by regional compression. An example is a tight fold just south of the Karakuz mine area.

Faults

Faults trend north, east, and northeast in the district. Only the most prominent and definite faults were mapped (pl. 1). A system of east-trending faults was mapped along the boundaries of the serpentinized belt. The faulting probably accompanied intrusion because the serpentinized rock has both fault and faulted intrusive contacts with the intruded rocks. Evidence for faulting is provided by breccia zones ranging in width from about one meter to one hundred meters. The widest breccia zone is well exposed where the northern contact of the serpentinized belt crosses the Hekimhan-Hasançelebi road.

A prominent north-south fault is present 2.5 km west of Deveci village (pl. 1). Both this fault and the east-west faults represent pre-Tertiary deformation. Later faulting which offsets east-west faults was inferred in the Karakuz mine area and is probably also present in the Deveci mine area (pls. 1, 2, and 3). This structural trend is believed to be an important ore control.

Joints and fractures

Most fractures lack clear evidence of shearing and were mapped as joints (pl. 1). Fractures and joints trend in all directions but tend to be concentrated in directions of north to N. 10° W., and east to N. 80° E. Similar trends were also found, statistically by Izdar (1963, p. 51).

GEOLOGIC HISTORY

The types of rock and structure leads us to the following chronologic interpretation of geologic history of the district:

1. Deposition of the mafic volcanic-sedimentary sequence.
2. Intrusion of syenite and extrusion of trachyte accompanied by local metasomatism of intruded rocks, including remobilization and redeposition of iron.
3. Folding and subsidence.
4. Deposition of limestone.
5. Intrusion of serpentinized rocks accompanied by folding and faulting, and by deposition of iron.

6. Deposition of red sedimentary rocks.

7. Extrusion of andesite, faulting, and deformation of red beds.

8. Deposition of conglomerate and other sedimentary rock.

9. Extrusion of olivine basalt.

10. Erosion, deposition of Quaternary sediments, and oxidation of siderite at the Deveci mine.

IRON MINES AND PROSPECTS

Distribution of iron minerals

Iron minerals in the Hekimhan-Hasançelebi district are present chiefly in two belts (pl. 1):

1. The east-west belt which includes both the Karakuz and Deveci mine areas.

2. A belt trending N. 80° E., from Bahçedami to Hasançelebi.

Outside of these belts iron oxides are concentrated in a few localities.

The iron minerals vary in different localities. At the Karakuz mine area, iron is mainly in the form of hematite and magnetite. Locally, at depth pyrite is disseminated. In the Deveci mine the near-surface minerals are chiefly goethite and limonite, with which manganese oxides are associated, whereas at depth siderite is the only iron mineral. In the Bahçedami-Hasançelebi belt, the dominant mineral is magnetite.

Karakuz mine area

The Karakuz mine area as referred to in this report is the area shown on plate 2, which includes the presently operating Karakuz mine (pl. 1, Fe3) and iron-bearing rocks over a distance of 4 km along strike (pl. 1 and 2), and all areas of geophysical anomalies shown on plate 4.

Geology

Lithology: The iron minerals are in trachyte and in underlying metasomatized mafic rocks. Trachyte in the center of the area (pl. 2) is impregnated with iron minerals. Such iron oxide-bearing trachyte has been mapped separately from unmineralized trachyte. The trachyte is a volcanic flow rock and has local vesicles and sanidine phenocrysts in a very fine grained sanidine-rich matrix. The mineralized trachyte also locally contains secondary silica, carbonate, or tourmaline.

The metasomatized mafic-volcanic rocks are soft green and white rocks which locally contain as much as 90 percent scapolite and commonly have considerable secondary calcite and iron oxides. The rocks are equivalent to mafic volcanic rocks exposed north of the mine area (pls. 1 and 2). The metasomatized rocks are intruded by syenite(?) which may be seen in highly altered outcrops only near the Karakuz mine itself (pl. 2). The syenite is believed to be part of a large stock which underlies the entire Karakuz area and evidently caused the metasomatism and remobilization of iron to form the iron deposits.

Serpentinized mafic rocks and Tertiary red beds are exposed south of the Karakuz mine area (pl. 2).

Structure: Mineral deposition was controlled in part by fractures that trend approximately N. 80° E. and N. 10° E., as demonstrated along the walls of the Karakuz mine open pit (Jacobson and Boğaz, 1972, pl. 2) and by trends of iron-bearing veins.

The altered and mineralized rock is bounded on the south by two major east-west faults (pl. 2), which are probably part of one fault which was offset by the northeast-trending fault near the center of plate 2. The faults are probably post mineral.

Iron deposits

General: In the Karakuz area, iron oxides form replacement deposits, disseminations, and veins, and are present in surface boulders.

The iron oxide may be sparsely disseminated or form slight to rich massive replacements of trachyte.

Karakuz mine replacement deposit: The Karakuz mine deposit consists of a massive central core of iron oxide containing more than 50 percent iron surrounded by trachyte partially replaced by iron oxides, and containing 30-50 percent iron. The core of the deposit is 70 to 80 meters long and 35 to 50 meters wide and averages 62 meters in depth, according to drill hole data (Meer Mohr, 1961, map 14289). The core of the deposit is direct shipping ore, now being mined. The low-grade envelope around it is potential ore, but would require beneficiation before shipment.

Replacement deposits west of the Karakuz mine: West of the mine (pl. 2) a series of iron-rich outcrops have been partly explored below the surface by drill holes (Meer Mohr, 1961, map 14289). These deposits are similar to that at the Karakuz mine, but are smaller and have a lower average iron content.

Veins: Hematite and magnetite in veins having quartz gangue are present in the area east and south of the Karakuz mine. The veins are both in trachyte and in metasomatized mafic volcanic rock. The veins range in length from a few to several hundred meters and in width from a few centimeters to 6 meters.

Iron-boulder fields: Two areas of sparse outcrop totalling 1.1 sq km (pl. 2) are covered by iron boulders and soil. Boulders have an average diameter of 20-30 centimeters and are composed of hematite, magnetite, and quartz. The boulder-soil zone has an estimated average thickness of 50 centimeters. The boulder fields are the product of soft weathered rocks cut by iron oxide-quartz veins.

Mineral exploration

Because of the widespread distribution of iron deposits, the Karakuz area is favorable for further mineral exploration. Magnetic surveys and drilling were done by MTA in 1959 and 1960. Additional work consisting of geologic mapping (pl. 2), supplementary magnetic survey, gravity survey, bulldozer trenching, and drilling was done during 1969 as part of the joint MTA-USGS project.

Magnetic surveys: Magnetic surveys showed that a weak magnetic anomaly having magnetic relief of more than 2000 gammas (pl. 4) is present along the entire 4 km length of the Karakuz area. The area contains nine local magnetic highs having magnetic relief of more than 8000 gammas. Most of the magnetic anomalies are within the iron boulder fields (pls. 2 and 4), thus are caused in part by magnetite in the boulders, but magnetite in disseminations, veins, and replacements also contributes to the anomalies. The form and amplitude of the anomalies supplemented by trenching and drilling data (holes G3 and 69-1) indicate few if any massive iron deposits.

Gravity survey: At the Karakuz mine hematite is the dominant iron mineral and no significant magnetic anomaly is present. A gravity survey was conducted in an effort to detect deposits similar to the Karakuz iron deposit. Gravity measurements were made along traverses trending N. 10° W.

and spaced 200 meters apart. Measurements were made at 50-meter intervals along the traverses and topographic corrections were made using a 1:25,000-scale topographic map. Because of the map scale, topographic corrections were not precise and there is an estimated maximum error of 2 milligals for each measurement.

The gravity contour map (pl. 4) shows no major gravity anomalies, but does contain anomalous areas near the east end. The 5- and 6-milligal contours reflect significant concentrations of dense material, possibly iron ore. The gravity anomalies are due in part to the blanket of iron boulders, because the 4-milligal contour on plate 4 corresponds approximately to the eastern area of iron boulders on plate 2.

Drilling: Diamond drill hole K69-1 was drilled south of the Karakuz mine to test for a possible iron deposit indicated by a magnetic anomaly (pl. 4) located near an intrusive contact of syenite. The hole was drilled to a depth of 115 meters in metasomatized mafic rock, silicified trachyte, and trachyte (table 3). The metasomatized mafic rock is partially replaced by magnetite from depths of 38 to 57 meters. The estimated average magnetite content is 40 percent and the average iron content determined by chemical analyses of the drill core (table 4) is 24 percent.

Trenching: Two bulldozer trenches were made in the eastern part of the area to evaluate the iron boulders and associated magnetic anomalies (pls. 2 and 4). One trench exposed a 6-meter wide magnetite-hematite vein and the second trench disclosed a series of magnetite-hematite veins, ½ to 1 meter thick, cutting metasomatized mafic rock.

Table 3.--Karakuz diamond drill hole 69-1 data.

Survey data

Topographic map (1:25,000-scale) coordinates: 392,644.16 and 307,586.03

Collar elevation: 1867.68 meters.

Bearing at collar: Due north.

Inclination at collar: 61°.

Inclination at 58 meters depth: 60°.

Geologic log

Interval (meters) From	To	Percent core recovery	
0	2.00	0	Hole collared in metasomatized mafic rock outcrop with disseminated limonite and hematite.
2.00	29.00	28	Green and white spotted metasomatized rock; disseminations and veinlets of iron oxides; green is partly metasomatized mafic rock; white is calcite and scapolite (secondary); iron oxides are disseminated hematite and magnetite in pods 1-30 mm thick, and in veinlets 0.5 to 3 cm wide; local quartz veinlets trend 30°-60° to core axis; brecciated zone with some clay from 13.5 to 16.5 meters; needle-shaped crystals (scapolite?) to one cm long, between 27.5 and 29.0 meters.
29.00	30.48	61	Metasomatized mafic rock as above but with an estimated 50 percent iron oxides.
30.48	38.00	46	Metasomatized mafic rock similar to above; prominent scapolite crystals to one cm long; from 35.1 to 37.0 meters; series of thin calcite stringers trend about 60° to core axis. Chlorite and garnet (in thin section).
38.00	57.00	91	Green, white, and black spotted metasomatized rock; green is partly metasomatized mafic rock; white is secondary calcite and scapolite(?); scapolite(?) crystals intermittently very prominent; black is magnetite as partial replacement, irregular pods, disseminations, and veinlets; magnetite content ranges from 10 to 70 percent, and averages about 40 percent; thin calcite and magnetite veinlets. Some garnet and chlorite (in thin section). Thin calcite and magnetite stringers 1-20 mm wide trend 30° to 65° to core axis; sparsely disseminated fine-grained pyrite throughout interval.

57.00	61.19	63	Green and white soft metasomatized mafic rocks; green is partly scapolitized mafic rock; white is scapolite and calcite; local scapolite(?) crystals $\frac{1}{2}$ cm long; sparse disseminated magnetite and pyrite; calcite stringer, $\frac{1}{2}$ mm thick, trend 27°-40° to core axis.
61.19	66.50	70	Rock same as in preceding interval but partly silicified; 10 cm interval at 61.2 m is 50 percent magnetite; few calcite or magnetite veinlets, $\frac{1}{2}$ to 2 cm thick, trend 40° to 70° to core axis.
66.50	67.70	74	Partly altered and iron oxide (limonite) stained brecciated metamorphic rock. Possible shear zone in rocks as above.
67.70	75.10	56	Partly altered and brecciated metasomatized mafic rock similar to above; limonite stain from 70.9 to 75.1 meters.
75.10	82.34	90	Silicified trachyte; very hard porphyritic and bedded rock; veinlets parallel to banding iron oxide and calcite veinlets to one cm wide trend 50° to 70° to core axis.
82.34	88.84	91	Silicified trachyte as above; rounded corners on feldspar phenocrysts; veinlets trend 50°-65° to core axis.
88.84	96.04	82	Partly silicified trachyte; little magnetite; iron oxide veinlets at 50°-60° to core axis.
96.04	99.60	65	Same as above interval.
99.60	102.35	65	Trachyte; sanidine phenocrysts in sanidine-quartz matrix; patches and stringers of calcite; traces of magnetite; limonitic stringers trend about 60° to core axis.
102.35	115.00	19	Trachyte; same as above but partly brecciated; poor core recovery.

Table 4.--Analytical data for samples from Karakuz drill hole 69-1.

Intervals (meters)		Laboratory analyses (percent)		
From	To	Fe	SiO_2	S
29.00	30.48	38.48	22.96	1.63
38.45	40.86	29.57	22.35	3.95
40.86	43.22	17.19	28.75	3.76
43.22	46.05	36.80	20.47	0.96
46.05	48.51	20.81	29.85	4.21
48.51	50.50	26.63	22.22	2.86
50.50	52.80	26.65	27.00	2.46
52.80	54.94	47.68	17.60	2.87
54.94	57.00	17.40	31.04	2.76

Deveci mine area

The Deveci mine area as referred to in this report includes the Karamağara Tepe, Kara Tepe, and Maden Tepe deposits (pl. 3). The area is nearly 6 km long and averages 1 km in width.

Geology

Lithology: The Deveci mine is in an area of Cretaceous sedimentary and volcanic rock and massive limestone intruded by serpentinized mafic and ultramafic rock (pl. 1). These rocks are unconformably overlain by Tertiary sedimentary rocks (pl. 3, northeast corner).

The middle unit of the Cretaceous sedimentary and volcanic rock is moderately well exposed in the southern half of the Deveci mine area (pl. 3). A generalized stratigraphic section is given in table 5.

Table 5.--Description of Cretaceous sedimentary-volcanic sequence in the Deveci mine area.

Upper part	Trachyte
Middle part (Maestrichtian)	Gray, red, and green shale; limestone and tuff with local sandstone; fossils in limestone J1160, J1167, J1168.
Lower part	Tuff, tuff breccia, tuffaceous sandstone and conglomerate.

The upper part of the section is a trachyte flow, the middle part is calcareous and is the host rock for the iron minerals in the Deveci mine, and the lower part is a detrital section.

The Deveci deposits are replacements of limestone in the middle unit; fossils are reported in the ore (Ruhi Özdoğan, oral commun., 1969).

Partly recrystallized, massive, gray, red-weathering limestone in the northwest corner of the mine area (pl. 3) probably is equivalent to the massive limestone mapped south of Deveci (pl. 1).

The above rocks are intruded by partly serpentinized gabbro and peridotite of the major east-west belt (pls. 1 and 3). Locally the serpentinized rocks underlie the iron deposits.

The serpentinized rock contains iron oxides near its contact with the Karamağara Tepe deposit. Contact-metamorphic effects in the intruded rocks are limited to apparently slight recrystallization of limestone.

Structure: The Cretaceous rocks in the mine area apparently are folded into the east-northeast-trending folds. An anticlinal axis crosses the Karamağara Tepe-Kara Tepe area and a synclinal axis passes through Maden Tepe (pl. 3). The serpentinized rock cuts across both folds (pl. 3, sections).

Faults that trend northeast to east-west offset the serpentinized rocks and thus are post-intrusion. Additional faults are probably present but were not observed owing to scarcity of outcrops in critical areas. Fractures parallel to the faults apparently controlled the deposition of ore.

Mineral deposits

The ore deposits consist of secondary iron oxide and manganese oxide minerals near the surface, and manganiferous siderite at depth. The oxide deposits are weathered products of the subsurface siderite. Iron content was enriched from 38 percent in siderite to 50 percent in the oxide deposits, and manganese content, from 3.8 percent in siderite to 5.1 percent in the oxide deposits (Izdar, 1963, p. 63).

Karamağara Tepe and Kara Tepe deposits: Surface exposures of the Karamağara Tepe and Kara Tepe deposits are separated by only 10 meters (pl. 3) and are geologically a single deposit. The deposit has a strike length of 1300 meters and a maximum width of 200 meters. Apparently, the deposit is a bedded replacement of calcareous beds that dip southeast (pl. 3, sections). The upper part of the deposit consists of iron and manganese oxides to a maximum depth of 75 meters and the lower part consists of siderite to a maximum explored depth of 300 meters (Izdar, 1963, pl. 6). Some unreplaced limestone lenses are present within the deposit.

The oxides presently being mined consist of soft, rather friable geothite and limonite and sooty black manganese oxide mixed with a small amount of silica gangue.

Maden Tepe deposits: The main Maden Tepe deposit (pl. 3) is relatively small and has been partly mined out. It is about 250 meters long, 50 meters wide, and has a maximum thickness of 40 meters in drill hole S8 (Izdar, 1963, pl. 7). The deposit consists of iron and manganese oxides and very locally, of siderite at the base. No downward extension of siderite is likely because the deposit lies in the bottom of a synclinal trough.

Two hundred to 600 meters east of the main Maden Tepe deposit is an area of mineralized bouders which constitute a deposit possibly as large as the main Maden Tepe deposit.

Mineral exploration

Magnetic and gravity surveys were not deemed suitable exploration methods for the Maden Tepe deposits. Electromagnetic methods may be effective but were not tried. Drilling of the eastern half of Maden Tepe would be desirable.

Bahçedami-Hasançelebi area

Geology and iron minerals

Magnetite-bearing metasomatized mafic rocks are exposed in an area 6 km long and 1 to 2 km wide between the villages of Bahçedami and Hasançelebi (pl. 1). The metasomatized rocks are cut by trachyte dikes.

Magnetite is irregularly distributed in veins and disseminations throughout the area. Veins range in thickness from a few centimeters to 7 meters, and many are found along walls of the dikes. Disseminated magnetite commonly makes up a few percent to about 15 percent of the metasomatized rock. Variations in magnetite concentration in the area are indicated on the magnetic map (pl. 5).

Mineral exploration

Magnetic survey: The detailed magnetic survey of a large part of the area sought significant concentrations of magnetite. Maximum anomalies in the area exceed 10,000 gammas and are 200 to 350 meters long (pl. 5). They are caused by magnetite veins and disseminations in metasomatized mafic rocks. Significant concentrations of massive magnetite were not observed. The strong anomalies are due to unusually high magnetic susceptibility of the disseminated magnetite rather than to massive magnetite.

Drilling: One hole was drilled south of Davulgu several years ago and a second was drilled in 1969 near Hasançelebi to test the easternmost anomaly (pl. 5). There is no log available of the first hole; the second was drilled entirely in magnetite-bearing metasomatized rock (table 5).

Iron prospects

Kirmizi Tepe

The Kirmizi Tepe prospect is 4 km from Bahçedami on a ridge of serpentinized mafic and ultramafic rock (pl. 1), which apparently weathers extensively to red iron-oxide-bearing silicified breccia. Although small lenses of massive hematite are present locally, most of the silicified rock contains only an estimated 5 to 10 percent iron oxide. No significant concentration of iron minerals was found.

Sīvritepe and Maḡara Tepe

Sīvritepe is a conical hill 1 km west of Bahçedami (pl. 1, Fe 2a) and Maḡara Tepe (pl. 1, Fe 2b) is a ridge ½ km southwest of Sīvritepe. Sīvritepe is underlain by mafic volcanic rocks and is capped by gently dipping trachyte. Iron oxide (magnetite and hematite) is present in the trachyte as tabular lenses parallel to bedding. Such a lens at the top of the hill is 2 meters thick, strikes northeast, and dips 9°NW. A second lens near the summit on the west side of the hill is 1.5 meters thick. Magnetite is disseminated locally in trachyte and boulders of such material are found on the western slope of the hill.

The magnetometer survey of the Bahçedami-Hasançelebi area (pl. 5) was extended into the Sīvritepe-Maḡara Tepe area and shows two anomalies evidently caused by flat lying lenses of iron oxide as well as by boulders of iron oxide. No important iron deposit appears to be present.

At Maḡara Tepe a shallow-dipping hematite-magnetite lens about 2 meters thick is exposed within an area of iron boulders 100 meters in diameter. A magnetic anomaly about 600 meters long, that includes this area, has a maximum amplitude of more than 10,000 gammas (pl. 5), and indicates that the deposit is more extensive than the single exposure.

Table 6.--Hasançelebi drill hole data.
(Description by Zekikendroglu)

Coordinates: From 1:25,000 topographic map

x: 10.800

Y: 02.775

z: 1250 m

Vertical drill hole

Geologic log

Interval (meters) From	To	Percent core recovery	Description
0.00	2.00	10	Iron oxide fragments 30-40 cm long rich in hematite, magnetite, and partly limonitized.
2.00	8.00	Sediment	Metasomatized mafic rock; little magnetite. Light-colored scapolite(?) crystals in the rock.
8.00	17.00	27	Metasomatized mafic rock; much magnetite. In some parts it is possible to see small magnetite crystals.
17.00	30.00	25	Metasomatized mafic rock; less magnetite, the major color is light green. Percentage of magnetite variable.
30.00	37.00	35	Metasomatized mafic rock; magnetite and abundant scapolite(?) crystals. Length of crystals is 3-5 cm; magnetite crystals are more abundant than scapolite.
37.00	44.60	35	Metasomatized mafic rock; less magnetite than above.
44.60	47.65	17	Metasomatized mafic rock; coarse-grained magnetite and scapolite(?) crystals. Magnetite crystals are more common than the scapolite(?) crystals. Length of crystals is about 3-5 cm.
47.65	64.65	27	Metasomatized mafic rock; fewer coarse-grained magnetite crystals. Length of crystals changes between 3-5 cm; more coarse-grained scapolite(?) crystals. Major color of the rock is light green or green.
64.65	78.65	26	Metasomatized mafic rock; the magnetite rock is dark green black; no crystals.
78.65	80.65	90	Metasomatized mafic rock; coarse-grained magnetite and scapolite(?) crystals. Magnetite crystals are most common. Crystals as much as 5 cm in length.

80.65	90.45	43	Metasomatized mafic rock; magnetite is more abundant. Also pyrite crystals in fractures; pyrite crystals 5-8 mm length.
90.45	97.50	27	Metasomatized mafic rock; little magnetite. Pyrite crystals abundant. Pyrite crystals 5-10 mm length.
97.50	110.35	19	Light green metasomatized mafic rock; much magnetite. General color of rock is dark green to black; pyrite crystals in fracture zones. Crystals are 5-10 mm in length.

Kurucagöl Tepe

The Kurucagöl Tepe prospect is 1½ km east of the railroad and 1 km north of the southern margin of the mapped area (pl. 1, Fe 4). The iron deposit consists of a well exposed steeply dipping hematite-limonite lens along a northwest-trending fault that cuts a conglomerate bed in the Cretaceous sedimentary-mafic volcanic sequence. The deposit is about 100 meters long and has a maximum width of 7 meters. The vertical extent appears to be small.

Catalli Tepe

The Catalli Tepe (pl. 1, Fe 5) prospect is 600 meters southeast from the Kurucogöl Tepe prospect. It is an area of boulders of iron oxide and manganese oxide on a ridge 100 meters in diameter. The boulders are similar to those at the Deveci mine. No outcrops are present, but the limited area indicates that the boulders are derived from a small deposit.

Origin of the iron deposits

Iron deposits in the district are related to syenite and to mafic-ultramafic serpentinized intrusive rocks.

Deposits related to syenite

The Karakuz mine area and the Bahçedami-Hasançelebi area contain magnetite and hematite deposits probably related to the intrusion of a syenite(?) batholith which underlies much of these areas but crops out only locally (pl. 1). Syenite magma contains very little iron and probably was not the source of the iron deposits. Hydrothermal activity accompanying the syenite intrusion is believed to have remobilized iron and redeposited it in the intruded rocks. Iron-bearing silicate minerals and iron oxides in the intruded mafic rocks, especially in basalt, probably were the source of the iron. The mafic rocks were metasomatized by emanations from the syenite intrusion. Scapolite and other minerals formed and iron was released, transported by hydrothermal solutions, and deposited as magnetite and hematite.

Deposits related to serpentinized rocks

Apparently, the Deveci mine deposits and some of the iron prospects are related to the intrusion of mafic and ultramafic rocks, which were the probable source of iron released by serpentinization, transported by low-temperature hydrothermal solutions, and redeposited. At the Deveci mine the iron apparently was redeposited as siderite through metasomatism of carbonate rocks. Subsequent weathering of the siderite produced the surface iron oxide deposit and associated manganese oxides.

While this is the probable mode of origin, positive evidence is lacking. It is not known why iron was not deposited near other serpentine-carbonate rock contacts west of the Deveci mine.

REFERENCES

Aytug, G., 1969, Hekimhan-Hasançelebi demir Zuhurlari: MTA Rept. 491, unpub.

Barosh, P. J., Serim, Salim, Gençel, Ilker, Şengün, Metin, and Ekren, Faruk, 1972, Geology of the Konakpinar-Sarica area, Sivas Province, Turkey: U. S. Geol. Survey open-file rept. (IR) TU-19.

Baykal, F., and Erentöz, C., 1966, Explanatory text of the geological map of Turkey: Sivas sheet, MTA Bull.

Duransoy, A., 1960, Hekimhan Karakuz mevki demir sondajlarina ait on hesaplar: MTA Rept. No. 605, unpub.

Izdar, E., 1963, Geologisher baa, magmatismus, and lagerstatten der ostlichen Hekimhan-Hasançelebi zone (Ostonatolien), MTA Bull. 112.

Jacobson, H. S., and Boğaz, R., 1972, Geology of the Karakuz iron mine and vicinity, Hekimhan district, Turkey: U. S. Geol. Survey open-file rept. (IR) TU-6), 20 p., 3 figs., 3 pls.

Kovenko, V., 1936, Note sur la visite de quelque gites peu importants de la region de Karakuz Tep-Alvar Köy, MTA Rept. no. 815, unpub.

__________, 1938, Rapport supplementaire sur la region des gites de fer de Hasancelebi: MTA Rept. no. 811, unpub.

Leo, G. W., Önder, Ercan, Kiliç, Mehmet, and Avci, Murat, in press: MTA Bull., foreign ed.

Meer Mohr, A. varder, 1961, Report of the results of the exploration program for the Karakuz iron deposits: MTA Rept. no. 96, unpub.

Ozdogan, R., 1961, Hasançelebi-Karakuz demir madeni reservsi Hakkinda rapor: MTA Rept. no. 472, unpub.

Yilmaz, S., 1960, Karakuz ve Deveci köyü demir yaraklari hakkinda rapor: MTA Rept. no. 63, unpub.