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GEOLOGY OF THE KARALAR-YEŞILER AREA

NORTHWEST ANATOLIA, TURKEY

By

Richard D. Krushensky

and

Yavuz Akçay

and Erdoğan Karaege

Maden Tetkik ve Arama Enstitüsü

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CONTENTS

CONTENTS--continued

CONTENTS--continued

ILLUSTRATIONS

TABLES

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ABSTRACT

Rocks cropping out in the Balikesir I 18 c_1, c_4, c_2, and d_3 quadrangles of western Turkey consist, from the base up, of the following: 1) phyllite, marble, schists, and meta-claystone of probable Precambrian or Cambrian age; 2) limestone of Middle Permian age; 3) sandstone and shale of Late Triassic age; 4) limestone of Late Jurassic age; 5) andesitic, dacitic, and rhyodacitic volcanic rocks of Neogene age; 6) lacustrine sandstone and conglomerate of probable Neogene age; and 7) alluvium of Holocene age. The section is intruded by serpentinized dunite stocks of probable Late Permian age, and intruded and locally metamorphosed by a granodiorite-quartz monzonite batholith and stocks of rhyodacite and quartz latite of Neogene age.

Two periods of folding and an intermediate period of thrusting are apparent even though no major folds have been recognized in the mapped area, and only a few folds can be traced for more than a few hundred metres. The first period of folding, probably during the Middle Permian, gave rise to east-west oriented folds in the regionally metamorphosed sequence. A second period of folding gave rise to northeast-trending folds in the sandstone-shale sequence and possibly similarly oriented folds in the metamorphic sequence. Both paleontologic and structural evidence indicate the limestone units were later moved into the area as low-angle thrust sheets or as gravity slides, probably after the Jurassic. The northeast-trending folds are related in time to the intrusion of the granodiorite-quartz monzonite batholith and may have been produced by that intrusion in the early Neogene. The formation of extensive northeast-trending normal faults and the mineralization of these faults by hematite, galena, sphalerite, chalcopyrite, and stibnite-cervantite accompanied or shortly followed the intrusion of the batholith and related stocks.

INTRODUCTION

Location and accessibility of the area

The mapped area lies in the province of Balikesir in the Biga Peninsula of northwestern Turkey, approximately 220 km southwest of Istanbul. It is southeast of the provincial capital of Çanakkale. It comprises the Balikesir I 18 c_1, c_4, d_2, and d_3 quadrangles, and forms a block bounded by lat 39°30'00", and 39°45'00" N. and by long 27°07'30" and 27°22'30" E. The mapped area includes about 600 sq km. Major east-west highway 62 crosses the area and connects the provincial capital of Balikesir 45 km east of the mapped area with the city of Edremit 7 km west of the area. From this highway all-weather gravel-surfaced or dirt roads lead to the principal villages in the northern half of the d_3 quadrangle, the northern quarter of the c_4 quadrangle, and the western half of the d_2 quadrangle. Other areas are serviced by a few dirt-surfaced oxcart roads, generally passable in the dry season by 4-wheel-drive vehicles. Extensive areas, including some villages, are reached by foot trails only.

Major parts of the quadrangles lie within the Kalkim and Edremit National Forests. Deforested upland areas and the National Forests are commonly used for grazing. Perhaps 20 percent of the mapped area is used for growing olives, fruit, grain, and vegetables.

The mapped area (hereafter called the Edremit map area) consists chiefly of well dissected but essentially youthful upland, cut on the western side in the d_3 quadrangle by the alluvium-filled valley of the Havrançayi (çayi, river). Broad ridges with well-integrated drainage characterize the area. Flat, undissected uplands are restricted to small areas on the southern margin of the d_3 quadrangle, to Kocaçal Tepe in the north-central part of the d_3 quadrangle, and to the southeast corner of the d_2 quadrangle. Relief is only moderate, the most extreme being about 550 m between 1007 m at the top of Ayi gediği (gap) and 450 m at Baş Köprü (köprü, bridge) in the northwestern quarter of the d_2 quadrangle. Similar relief over a shorter lateral distance is present in the southeastern corner of the d_2 quadrangle where the Çinarli Dere (dere, creek) cuts a mass of limestone. The d_3, most of the d_2, and the southwestern corner of the c_4 quadrangles lie in the watershed of the Havrançayi and drain to the Aegean Sea. The northern part of the d_2 quadrangle drains to the Sea of Marmara via the Gönençayi, and most of the remainder of the map area is drained by the Kocaçayi to Kuş Gölu (gölu, lake) and the Sea of Marmara.

Previous work

Early geologic studies that included the Edremit map area were of a reconnaissance nature and produced only highly generalized maps of small scale (Techihatcheff, 1867, scale 1:2,000,000; and Philippson, 1918, scale 1:3,700,000). Studies by Kaaden in 1956, Topkaya in 1947, and Kovenko in 1945(?), utilized 1:100,000-scale base maps. The resulting geologic maps are held in the archives of MTA; they are highly generalized and explanatory notes for the maps are not available. Kaaden (1959) combined parts of these maps and published them as a simplified compilation at 1:250,000. Recently Gümüş (1964, scale 1:65,000) and Aslaner (1965, scale 1:50,000) studied parts of the present map area.

Geologic studies of nearby areas of particular interest include those of Erk (1942), in the Gemlik area; Aygen (1956), in the Balya area; Erguvanli (1957), and Kalafatçioğlu (1963), in the Ezine area; and Schuiling (1959), and Bingöl (1968), in the Kazdağ area.

Purpose and method of investigation

The Balikesir I 18 c_1, c_4, d_2, and d_3 quadrangles were mapped as part of a cooperative program between the Maden Tetkik ve Arama Enstitüsü (MTA) and the U.S. Geological Survey (USGS) during the period March 1968 to June 1970, under the auspices of the Government of Turkey and the Agency for International Development (USAID), U.S. Department of State. The general purpose of the project was to demonstrate the value of quadrangle geologic mapping in delineating mineralized areas, define stratigraphic and structural relationships of significance in regional mapping, and help determine factors controlling the base metal mineralization and emplacement of iron.

Field work began in April 1968, utilizing 1:25,000-scale paper base maps. Aerial photographs, scale 1:20,000, were made available in mid-July 1968 and used thereafter. Field mapping of the d_3 and the western two-thirds of the c_4 quadrangle was conducted by Krushensky and Karaege with the field assistance of H. Filibeli, T. Soyder, H. Erturkân, and Wolfgang Hilger from April through October 1968. Krushensky and Akçay mapped the d_2 quadrangle, part of the c_1 quadrangle, and with Karaege finished the c_4 quadrangle, and Karaege mapped most of the c_1 quadrangle from April through October 1969. Geology was transferred by inspection from aerial photographs to paper topographic base maps that were compiled by photogrammetric methods and printed for the Turkish General Map Directorate.

Petrographic studies included the examination of about 600 thin sections and comparison of numerous chemical and spectroscopic analyses.

Acknowledgments

The study profited greatly from field conferences with Recai Kutlu, Chief of MTA's western regional office; Necdet Polater, formerly Edremit Camp Chief for MTA; and John P. Albers, Chief of Party, USGS. We are also indebted to Osman Baydar, Geologist, MTA, for access to his unpublished studies of the Bağirkaç mine.

GEOLOGIC SETTING

The Edremit map area lies on the southeastern flank of the Kazdağ massif and, according to Brinkmann (1968, p. 112), is well within the zone of the North Anatolian rise. This megastructural feature of northern Turkey extends for more than 150 km in a north-south direction and for more than 1000 km along the Black Sea coast. Structurally it includes the Serbo-Macadonian massif of Greece, Bulgaria, Romania, and Yugoslavia, and the Transcaucasian massif of Russian Armenia (Brinkmann, 1968, p. 112-113). The Kazdağ and Uludağ massifs (fig. 1), domelike structures characteristic of the old core areas in at least the western part of the North Anatolian rise, consist of regionally metamorphosed sedimentary rocks--now amphibolite-facies schists and gneisses, serpentinized ultramafic rocks, and orthogneissic silicic igneous rocks, all of possible Early Paleozoic or Precambrian age. These cores are separated from overlying low-grade regionally metamorphosed schist, phyllite, and quartzite by a major thrust fault (Bingöl, 1968, p. 95, 117). The low-grade metamorphic rocks are, according to Bingöl, stratigraphic equivalents of the cores, thrust onto the cores from peripheral areas. These regionally metamorphosed rocks are flanked and partially overlain by Upper Paleozoic and Mesozoic sedimentary rocks (Erk, 1942, p. 227-234; Kaaden, 1959, p. 20; Brinkmann, 1968, p. 113-114; Aygen, 1956, p. 75-79) and by Cenozoic marine, lacustrine, and volcanic rocks and alluvium (Erguvanli, 1957, p. 49-52; Kaaden, 1959, p. 23-24; and Kalafatçioğlu, 1963, p. 65-66).

The area of the North Anatolian rise has been intruded by little-known, Lower Paleozoic or possibly Precambrian orthogneiss (possibly palingenetic gneiss) (Kaaden, 1959, p. 24) and by middle Carboniferous, Permian, and Paleogene ultramafic and silicic plutonic rocks (Kaaden, 1959, p. 27; Kalafatçioğlu, 1963, p. 66-68; and Coğulu and Krummenacher, 1967, p. 828-829). The area has been affected by probable Precambrian (Schuiling, 1959, p. 89; Brinkmann, 1968, p. 112), middle Carboniferous to Permian (Kaaden, 1959, p. 30; Schuiling, 1959, p. 89), and early Paleogene folding (Coğulu and Krummenacher, 1967, p. 827; Pinar and Lahn, 1955, p. 28).

STRATIGRAPHY

Rocks in the Edremit map area include low-grade schists, phyllite, and quartzite of pre-Late Triassic age; limestone of middle Permian age; sandstone and shale of Late Triassic age; limestone of Late Jurassic age; andesitic and dacitic and rhyodacitic volcanic rocks of Neogene age; lacustrine sandstone, conglomerate, and saline deposits of probable Neogene age; and alluvium of Holocene age. Serpentinized ultramafic rocks, probably of Late Permian age, granodiorite-quartz monzonite, rhyodacite, and dacite of Tertiary age intrude the sequence.

Approximately 80 percent of the mapped area is covered by volcanic rocks; prevolcanic rocks crop out chiefly in the d_2 quadrangle, the northern half of the d_3 quadrangle, and in the southeast corner of the c_4 quadrangle.

Pre-Tertiary system

Metamorphic sequence of Kalabak

Metamorphic rocks in the area of Kalabak village are the oldest rocks in the mapped area; they include actinolite-chlorite schist, quartz-rich phyllite, banded marble, conglomeratic quartz-rich phyllite, actinolitic quartz-rich phyllite, actinolitic and chloritic metaquartzite and metaclaystone. The sequence is well exposed in the northwestern corner of the d_3 quadrangle near the village of Kalabak. The unit crops out from 1.1 km south of the village to the northern border of the quadrangle, from the southwestern to the northeastern corner of the d_2 quadrangle, in the northwestern corner of the d_2 quadrangle, and from the area of Çulfa Çukuru on the central eastern border of the d_2 quadrangle to the north-central border of the c_1 quadrangle (pl. 1). The sequence is not formally named because contact relations with stratigraphically older rocks are unknown in the area of study.

The major part of the outcrop area of the metamorphic sequence of Kalabak is covered by pine forest and thick saprolite. As a result, outcrops are scattered. The best outcrops are in the ridge between Kalabak and the northern border of the d_3 quadrangle. There the rocks consist of actinolite-chlorite schist, tremolite schist, quartz-rich phyllite with biotite-rich shear surfaces, thin-layered marble in black metaclaystone, and actinolite-chlorite schist with isolated lenses of quartz-rich phyllite.

The section in the southwestern part of the d_2 quadrangle is similar, but the actinolitic and chloritic rock types are less common; metaclaystone and quartz-rich phyllite become progressively more abundant toward the northeast. Beyond Elmacıkücü Sr. (ridge) chloritic and actinolitic rocks are rare (d_2 quad.). The sequence at the Bağirkaç mine (d_2 quad.) is exceptional as it shows two 2-3 m-thick layers of actinolite-epidote schist interbedded with thin-layered marble, metaclaystone and quartz-biotite phyllite. Locally in the Çardak Burun (ridge) area (d_2 quad.) the rock consists chiefly of actinolite schist and isolated lenses of quartz-rich phyllite. The major rock type exposed in the d_2 quadrangle, however, consists of a dark-gray, very fine grained, quartz-rich phyllite that shows biotite concentrated on silky-appearing fracture surfaces. The rock appears to have been a very fine grained sandstone or siltstone in which the clayey layers are memtamorphosed to biotite, and the original quartz-rich layers are relatively unaffected. The biotite-rich layers typically show a crepelike or crisp appearance and a silken luster. The relative amounts of quartz and biotite are highly variable; rocks much richer in biotite range to biotite phyllite or biotite schist, and rocks richer in quartz range to metaquartzite. This quartz-rich phyllite-biotite schist-metaclaystone-metaquartzite sequence is also the dominant rock type in the northwest corner of the d_2 quadrangle. Farther to the east, in the area of Çulfa Çukuru, a herdsman's summer village on the mideastern border of the d_2 quadrangle, rock of the Kalabak sequence is less metamorphosed and consists chiefly of metaclaystone and marble. Metaclaystone is used here to describe a rock that shows crepelike fracture surfaces with a silken luster, but in which metamorphism has not significantly altered the original mineralogy or physical character of the very thin bedded clay-rich rock. Both the metaquartzite and metaclaystone locally, for example, on the northern side of Kiygin Tepe (hill), on the northern end of Yutburun, and along the course of Bicki Dere near the contact of the Kalabak with the Halilar Formation, show elongate and apparently stretched but not granulated pebbles of quartzite.

Laterally discontinuous, very finely banded, light-gray marble crops out sporadically from the area just north of the village of Kalabak as far as Firincik gedigi on the northern border of the d_2 quadrangle, in the northwestern corner of the d_2 quadrangle, and locally east of Tavşan Tepe in the Çulfa Çukuru area (pl. 1). It appears irregularly throughout the section, and, with the exception of the area of the Bagirkaç mine, forms isolated blocklike masses without lateral continuity. Outcrops generally show thicknesses of from 2 to 6 m and rarely, as near the confluence of the Bagirkaç and Bicki rivers, as much as 60 m. Characteristically the marble has sharp, crosscutting lateral contacts with enclosing metaclaystone and quartz-biotite phyllite. The strike of foliation in the phyllite and metaclaystone generally parallels banding in the marble, but foliation of the schistose rock at the lateral contact is highly contorted. Outcrops in the Firincik gedigi show irregular blocks of marble from a few centimetres to tens of centimetres apart. The shapes of adjacent blocks indicate that they were at one time a single mass. Examination of the enclosing phyllite indicates a progressive contortion toward the break in the marble and a filling of the fractures with highly contorted phyllite. Metamorphism of the phyllite to hydrogrossularite is shown only in the narrowest parts of breaks between two different pairs of limestone blocks. The garnet zone grades into contorted, but otherwise typical phyllite via narrow zones of pistacite. The nonrounded, abrupt, crosscutting contacts of the marble blocks and enclosing schistose rocks and the evident movement of phyllite into fractures between once unseparated blocks suggest that the marble blocks are in the first stages of boudin formation. The blocks were originally exotic to the environment, that is olistoliths, and probably emplaced by submarine gravity gliding.

Marble of the Kalabak sequence just northeast of Kalabak includes layers (to 20 cm) much thicker than the common thinly-layered rock. Some of these thicker layers show cavernous weathering along the entire length of outcrop, but parallel layers that are megascopically alike are not so weathered. Crude testing with dilute hydrochloric acid indicates that the cavernous-weathered layers are more calcareous and that those without such weathering are dolomitic. The layering, therefore, is compositional and probably reflects original bedding.

Marble in the Bağirkaç mine area is unique in the mapped area because there it is very thinly bedded, finely crystalline layers 2-10 cm thick interbedded with metaclaystone, actinolite-pistacite schist, and quartz-rich phyllite. There is no apparent tendency to form boudin. The lower grade of metamorphism indicated by the metaclaystone and the structural competence of even thin bands of marble may indicate a lessening of the effects of regional metamorphism and deformation toward the east and northeast.

Actinolitic and chloritic schists are green, pale-yellowish green, and unctous where chlorite is dominent, and pale-bluish green where actinolite is dominant. Both rock types are streaked and more or less stained with limonite in outcrop.

Low-grade pre-Triassic metamorphic rocks similar to those described above have been reported by Aygen (1956, p. 70) in the Balya area to the northeast, by Bingöl (1968) in the Kazdağ area to the west, and by Aslaner (1965, p. 6-7) and Gümüş (1964, p. 14-36) in the Edremit area. The same metamorphic rocks may also crop out in the Ezine-Ayvacik area at the western end of the Biga Peninsula (Erguvanli, 1956, p. 48; Kalafatçioğlu, 1963, p. 62).

Study of thin sections indicates that the metamorphic rocks of the Kalabak sequence were derived from three main rock types. These are, in order of predominance in the section, shaly, quartz-rich, and volcanic. These appear in outcrop sections as intimately interlayered mixtures of two or three components.

Quartz-rich and quartz-biotite phyllites consist of alternating layers of generally fine grained xenomorphic quartz and sparse to rare albite with layers rich in biotite. The quartz-rich phyllite differs from the quartz-biotite phyllite chiefly in the lesser number of biotite-rich layers. Individual layers are sharply demarked both because of compositional differences and because of grain size differences; grains within a single layer are remarkably uniform and unlike those of adjacent layers.

Biotite is present as microscopic, light-brown, pleochroic, very thin and generally elongate and rounded plates having smooth margins. Rarely it is poikiloblastic and has ragged margins. Lineation of the elongate plates is moderately developed and foliation well developed. Individual plates do not cut the plane of foliation at high angles. Very finely crystalline quartz and sparse albite enclose the biotite and generally show a pronounced orientation of crystallographic axes. This preferred orientation is much greater than that in the quartz-rich layers. The amount of biotite is difficult to estimate because of the geometry of the plates and their small size, but the quantity of biotite is probably less than 40 percent in even the most biotite-rich layers.

Quartz and sparse albite form xenomorphic grains which make up as much as 95 percent of the biotite-poor layers. Individual grains are small, 0.026-0.052 mm. Albite is generally untwinned, and quartz is non-strained. Inclusions within the quartz and feldspar are rare. Meta-quartzite in thin section looks essentially like the quartz-rich phyllite except that biotite is absent. Commonly the metaquartzite shows minor poikiloblastic muscovite, and relatively large (0.3-0.4 mm) grains of quartz, microcline, and plagioclase. The microcline shows characteristic crosshatch twinning; the quartz is strained; and the plagioclase twinned and argillized. These mineral grains show no granulation trails, and it is clear that mechanical degradation of these grains has not proceeded far. The metamorphic rocks were apparently derived from fine-grained sandstone and siltstone with highly variable amounts of clay.

Schistose rocks in the Kalabak sequence were derived from mixtures of volcanic and quartzose rocks, or from volcanic rocks alone, and consist chiefly of actinolite schist, actinolite-chlorite schist, and actinolite-quartz phyllite. Actinolitic schists show excellent foliation and lineation. Actinolite ranges from only feebly pleochroic, colorless to green, to the typical light-yellow green to blue green, and constitutes as much as 75 percent of the rock. It forms single, elongate, needlelike crystals or bundles of slender crystals radiating from a point and lying chiefly in the plane of foliation. Epidote, as much as 15 percent of the rock, occurs as pistacite, and as clinozoisite, the latter in the more schistose and actinolite-rich rocks. Elongation of the epidote is in the direction of schistosity, but the mineral is very poorly crystallized. Chlorite, as much as 25 percent of the rock, occurs as poorly foliated masses between the actinolite crystals. It is pale green and yellow green in plane-polarized light, and shows either pale-yellowish-gray birefringence or anomalous blue colors; presumably it is prochlorite and penninite. Xenomorphic quartz and minor albite comprise from 20 to 75 percent of these rocks. Both are very fine grained (-0.05 mm), but locally they form broad platy xenoblastic crystals that enclose actinolite, epidote, and biotite. Locally actinolite-chlorite-epidote and quartz-albite lie in distinct bands. This banding may be the result of metamorphic segregation or possibly of original sedimentary bedding. Tourmaline, distinctive because of its relatively high relief and marked colorless to deep-blue pleochroism under plane-polarized light, is rare in the actinolitic quartz-rich phyllite. Actinolitic quartz-rich phyllite with biotite is common, and rarely contains detrital spinel surrounded by poikiloblastic cordierite. In one thin section, reaction of spinel and silica has apparently gone to completion and only cordierite is present. The presence of cordierite appears completely dependent on the presence of detrital spinel, and together with the evident low metamorphic grade of the rocks, suggests both low temperature-pressure conditions during formation as well as a lack of shearing during and after formation.

Metaclaystone, that is, rock showing only minimal indications of regional metamorphism, but with the silky fracture surface of phyllite, closely resembles shale in thin section. The bulk of the rock consists of clay-size materials and disseminated carbon, and it is extremely finely bedded. Relic grains of quartz and feldspar to 0.02 mm constitute perhaps 20 percent of the rock. Low-grade metamorphism is, however, indicated by poorly crystallized poikiloblastic muscovite and pistacite lying at high angles to the plane of foliation. Very thin (0.013-0.015 mm) layers of fine-grained muscovite give the rock its characteristic silky cleavage. Locally also the metaclaystone shows minute granulated lenticles of calcite that enclose actinolite crystals at high angles to the foliation. None of the poikiloblastic minerals in the metaclaystone appear to have been rotated during or after growth, and the rock shows no microfolding or other deformation of the foliation. The very low grade of metamorphism and the parallelism of foliation in the metaclaystone with compositional layering in enclosed marble, suggest that foliation in the metaclaystone is in fact original sedimentary bedding.

The chemistry of the actinolite-chlorite schists and probably of the actinolite quartz-rich phyllite suggests that the rocks were derived from volcanic rocks. Metamorphism of these rocks has left no relic structures, but the interlayering of thin beds of actinolite-chlorite schist with marble and metaclaystone in the lower part of the section exposed at the southern end of the Bağirkaç mine suggests that there, at least, the original rock was a tuff.

The lower stratigraphic contact of the Kalabak sequence has not been seen in the mapped area, and study of what appears to be the same sequence in surrounding areas has not revealed that contact. Bingöl (1968) believes that the contact in the Kazdağ massif, previously reported by Schuiling (1959, p. 88) as an unconformity, is indeed a thrust fault in which low-grade metamorphic rocks, stratigraphically equivalent to the higher grade core area, have been thrust over the core. The metamorphic sequence of Kalabak is overlain unconformably by the Halilar Formation of Late Triassic age in the northwest corner of the d_3 quadrangle and in the d_2 and c_1 quadrangles.

Fossils have not been found in the Kalabak sequence or its apparent equivalents in surrounding areas; its age is thus known only as pre-Late Triassic. Kaaden (1959, p. 19) has suggested that these low-grade metamorphic rocks be correlated with the Silurian-Devonian section in the Istanbul area because of lithologic similarities in the two areas. However, the Silurian-Devonian section in the Istanbul area is unmetamorphosed according to H. Pamir (MTA, oral commun., 1970). The distance between the two areas, the lack of detailed work in the intervening area, the lack of fossils in the Edremit area, and the extreme variability of the section in the Edremit area seem good reasons for leaving the correlation of the Kalabak sequence an open question. Brinkmann (1968, p. 113) believes that the metamorphic rocks of the old core areas of the Kazdağ and Uludağ massifs may be of Cambrian or even of Precambrian age. If Bingöl's thesis as to the age equivalence of the core rocks and the overthrust low-grade metamorphic rocks is correct, then the Kalabak sequence may also be of Cambrian or Precambrian age.

Limestone of Ayakli

Limestone of Middle Permian age that underlies lava flows of the Hallaçlar Formation and is in fault contact with apparent Halilar Formation is informally called the limestone of Ayakli, from the village of that name in the southeast corner of the c_4 quadrangle.

Outcrops are discontinuous and most are restricted to the vicinity of Ayakli. One outcrop area, however, is also known from the village of Küçüdere about 2 km south of Havran just west of the mapped area. The rock unit is not formally named because of the unknown nature of its lower depositional contact.

Outcrops are generally massive, dark- to medium-gray weathering dark grayish brown on the fresh surfaces, fine- to medium-crystalline, fossiliferous limestone. Locally the upper part of the section, exposed just north of Ayakli, includes some dark-grayish-brown, coarse-grained, fossiliferous arenaceous limestone. Clastic grains consist of medium to coarse sand-size angular to subrounded quartz and minor hornblende with some sparse clastic limestone, all in a very finely crystalline grayish-brown limestone matrix. Both the limestone and arenaceous limestone near Ayakli, and the limestone near Esi Burun and Geymene Tepe, locally consist of little else but Foraminifera in a strikingly colored, bright-orange, limy mud matrix.

The limestone of Ayakli is unconformably overlain by the andesitic-dacitic lava flows of the Hallaçlar Formation. The best exposures of this upper contact are seen near the top of Büyükasar Tepe 1.3 km north-west of Ayakli. There the Hallaçlar lies on an erosion surface that cuts across both the limestone of Ayakli and the Halilar Formation. The upper contact is similarly exposed in the valley of the Malca Dere just east of Ayakli. The lower contact is also well exposed in Büyükasar Tepe where massive fusulinid-bearing limestone makes a very sharp contact with the underlying, nonfossiliferous, quartzose sandstone. This sandstone has been mapped as Halilar Formation. Identification of this sandstone as Halilar necessitates a thrust or gravity glide contact with the overlying limestone of Ayakli. Outcrops of the limestone of Ayakli west of the mapped area are similar to those near Ayakli; that is, massive, dark colored, and highly fossiliferous.

Foraminifera collected by the writers from outcrops of the limestone have been identified by R. C. Douglass (U.S. Geol. Survey, written commun., 1970) as Climacammina sp., Geinitzina sp., Tetrataxis sp., Schwagerina sp., Parafusulina sp., Yangchienia sp., Neoschwagerina sp., and Verbeekina sp. These forms, according to Douglass, indicate a Late Permian[1/] age for the rock. Aygen (1956, p. 71-74) in his study of the Balya area 32 km to the northeast, notes an extensive bibliography about the Permian limestone of that area, and reports the following fusulinids identified by R. Ciry of the University of Dijon: Neoschwagerina craticulifera (Schwager), Sumatrina aff. S. pesuliensis Ozawa and Tobler, Schubertalla sp., Verbeekina verbeeki (Geinitz), Sumatrina annae (Voltz), Parafusulina sp., Polydiexodina sp., P. capitanensis (Dunbar and Skinner), Schwagerina sp., Stafella sp., Yangchienia tobleri (Thompson), and Stafella cf. S. haymanaensis (Ciry). These together with the following brachiopods: Tscherysschewia yakowlewi Stoyanow, Derbyia grandis Waagen, Neophricodothyris caroli Gemmellaro, and Spiriferellina panderi var. buriensis Reed, suggest that the section in the Balya area spans the entire Permian. Erk (1942, p. 34-64) in an elaborate and intensive study noted similar lithologies that, on the basis of fusulinids and other fossils, also appear to span the Permian in the Bursa-Gemlik area. Studies of the Permian section in the Ezine area by Kalafatçioğlu (1963, p. 64-65) show a section, from the base up, of conglomerate, sandstone, massive white limestone, black limestone, and overlying interbedded marl, clay, limestone, and sandstone. Limestone high in the section contains Glomospira sp., Neoschwagerina cf. N. craticulifera Schwager, and Hemigordius, indicative of a Middle Permian age. Kaaden (1959, p. 20) has also identified limestone of Middle Permian age in the Orencik area on the basis of included fusulinids.

1/ North American usage; Middle Permian of European usage.

Halilar Formation

<u>Type locality and distribution</u>.--Sandstone and shale of Late Triassic age that overlie the Kalabak sequence and underlie the Bağburun Formation are here named the Halilar Formation. The type area is on the east side of the Köktoyen Dere about 400 m north of the village of Halilar near the north-central border of the d_3 quadrangle. The type section of this formation is described in Appendix A. The Halilar has been informally divided into lower, middle, and upper members. Both the middle and upper members are well exposed in the type area. The formation consists, from the base up, of basal conglomerate, conglomeratic and quartzose arkose, shale with interbedded fine-grained sandstone, feldspathic sandstone, shaly sandstone, and calcareous sandstone, all locally conglomeratic. The formation is about 630 m thick.

The best exposures of the middle and upper members are in the type area, but exposures are also good east of Orhan Dere about 2 km north of the south-central border of the d_2 quadrangle. Exposures of the formation in the southern part of a northeast-trending belt that crosses the d_2 quadrangle are good but discontinuous. Other areas of outcrop in the northwest and northeast parts of the d_2 quadrangle, the southeast quarter of the c_4 quadrangle, and the northwestern part of the c_1 quadrangle are poor because of heavy forest and deep soil. The lower contact with the Kalabak sequence is well exposed in the northwest corner of the d_3 quadrangle, and the upper contact with the Bağburun Formation is well exposed in the area of Kurtluca Dere 2 km east of Kocaçal Tepe in the north-central part of the d_3 quadrangle.

Lower member.--The lower member of the Halilar is best exposed in the area west of Çakal Tepe in the north-central part of the d_3 quadrangle and to the north in the d_2 quadrangle. It consists chiefly of pale-brown to light-gray-brown, coarse- to medium-grained arkose and feldspathic sandstone. Both are locally conglomeratic and contain cobbles and pebbles as much as 20 cm in diameter of quartzite, phyllite, and schistose rocks. The conglomerate stringers are lenslike and do not extend for more than a few metres or tens of metres along strike.

A conspicuous basal conglomerate crops out in the northwest corner of the d_3 quadrangle and locally along the Halilar-Kalabak contact west of Baş Köprü at the foot of Küserlik Mvk. ridge in the north-central part of the d_2 quadrangle. The conglomerate is best seen in the east wall of the valley of Alidede Dere about 200 m northwest of the point where the contact fault between the Kalabak and Halilar changes strike and trends toward the northwest. The conglomerate consists chiefly of angular to well-rounded boulders and cobbles of quartz-rich phyllite, actinolite-chlorite schist, thin-banded finely crystalline marble, and fine-grained metaquartzite. These are enclosed in a variable amount of finer clasts of the same rock types; rounded, coarse sand-size quartz, subrounded to angular feldspar, and abundant detrital biotite and chlorite. Careful examination of all these outcrops of conglomerate indicates that "granite" clasts identified by Kaaden (1959, p. 21) are contained in a lithologically similar basal conglomerate of Neogene age exposed south of Kalabak (d_3 quad.). The physically more resistant rock types are rounded and presumably derived from a more distant source, whereas the less resistant rock types are subangular to angular and presumably derived from the Kalabak exposed in the immediate area.

Study of thin sections of the lower member shows as much as 40 percent of angular to subangular intensely argillized plagioclase clasts, as much as 60 percent of rounded quartz clasts, and subordinate lithic clasts held in a matrix composed chiefly of biotite and chlorite. Some sparse to rare, generally unaltered microcline and orthoclase are also present. Quartz clasts generally show trails of minute unidentified inclusions and many show optical strain. Rounded lithic clasts composed of argillized plagioclase and quartz are sparse. Interestingly, however, the quartz in these clasts also shows trails of inclusions, suggesting that the lithic and quartz clasts have the same source. Small rounded lithic clasts of biotite schist, quartz-rich phyllite, and actinolite-chlorite schist are rare in most thin sections, but more common in sections taken from nearer the base of the member. The matrix--as much as 20 percent of the rock, but locally as little as 2 percent--consists of irregular, shredded-looking biotite, some penninite after biotite, and apparent prochlorite with minor, very small grains of quartz and feldspar. The biotite and chlorite are commonly wrapped around individual clastic grains, and separate the clasts one from the other. Rocks with a small amount of matrix (less than 5 percent) show individual grains closely packed but not intergrown.

Replacement of the matrix biotite and chlorite with generally fine-grained xenomorphic quartz is common over wide areas of outcrop of the lower member. The altered rock resembles metaquartzite texturally. Individual thin sections show that silicification proceeded outward from fractures that cut the rock and were later filled with quartz. The process of silicification can be observed in the area of a single thin section. Uncommonly, as in the east-central part of the d_2 quadrangle between Alanburun and Kiyğin Tepe, both the matrix and plagioclase in lithic and mineral clasts are replaced, and the rock is 95 percent or more quartz. Much of the lower member was mapped by Kaaden (1959, pl. 1), Aslaner (1965, pl. 4) and Gumuş (1964, pl. 4) as granodiorite.

Middle member.--The middle member of the Halilar Formation crops out in a highly faulted and apparently slightly folded belt extending from northwest of Kocaçal Tepe in the d_3 quadrangle to the south-central part of the d_2 quadrangle. The middle member consists chiefly of dark, bluish-gray-weathering, very fine grained, black shale interbedded with medium- to light-brown, fine-grained sandstone. The beds of sandstone thicken upward in the section (2-4 cm near the base, 15-20 cm and rarely 1 m nearer the top). Generally the beds show sharp bottom contacts and a gradational contact with the overlying shale. Medium-gray-brown or yellowish-brown siltstone or mudstone crop out nearer the top of the section. Most of the shale in the d_3 quadrangle, especially that near Kedikaya and Kocaçal Tepe, is pyritized and locally the interbedded sandstone layers are also pyritized.

The contact between the lower and middle members is exposed west of Çakal Tepe, west of the normal fault that cuts the section there. Sandstone and arkose of the lower member grade over 5 m or less into black shale of the middle member. The lowest black shale is taken as the base of the middle member. Contact with the upper member is best exposed about 250 m north of Halilar in the eastern wall of the Köktoyen Dere valley (d_3 quad.). There black shale of the middle member is overlain conformably with a very sharp contact by massive light-brown and light-reddish-brown sandstone and arkose of the upper member.

Thin sections of shale from the middle member show only rare very fine-grained quartz and feldspar clasts in a mass of very thin bedded carbonaceous clay. Interbedded sandstones consist chiefly of rounded to subrounded, medium- to very fine grained quartz and clayey cememt.

Upper member.--The upper member is best exposed in the Gölükölen Mvk. in the south-central part of the d_2 quadrangle, in Sakarkaya Tepe about 1 km north of the south-central border of the d_2 quadrangle, and in the Akpinar Sivrisi (peak) area of the d_2 and d_3 quadrangles. The upper member in the Akpinar area consists of massive, coarse-grained, pale-brown sandstone, feldspathic sandstone, and minor arkose, all of which show numerous conglomerate stringers; shaly arkose; coarse conglomerate beds separated by thin shale partings; arkose; and calcareous conglomeratic sandstone. Conglomerate generally forms thin, areally restricted lenses, but one section of conglomerate is more than 16 m thick. Locally, in the Gölükölen Mvk., fine- to coarse-grained, conglomeratic, feldspathic, biotite-chlorite-rich sandstone like that mapped as "granodiorite" in the lower member, is interbedded with shale and siltstone.

Study of thin sections of the upper member indicates a unit that ranges from coarse to fine grained and from a quartz-rich sandstone to a plagioclase-rich arkose, both locally conglomeratic. The sandstone layers are commonly finer grained, better sorted, and consist of as much as 85 percent of subrounded to rounded quartz, very minor plagioclase, ragged, dark-brown biotite plates, and lithic quartzite clasts. The cement is generally minor in amount (5 percent or less) and chiefly calcite. Plagioclase is invariably argillized and may be partly replaced by the calcite cement. Feldspathic sandstone and arkose are lumped together in the following discussion because they show the same characteristics; they differ chiefly in the amount of feldspar present. Both are fine to coarse grained, generally poorly sorted, and highly variable in the degree of rounding. Feldspar is chiefly plagioclase and intensely argillized. Microcline with typical crosshatch structure is sparse and generally unaltered. Feldspar comprises from 10 to 35 percent of such rocks. Most of the arkose and feldspathic sandstone in the upper member contain a few percent of dark-brown, ragged-appearing but commonly large 2-4 mm) plates of biotite. Lithic clasts commonly consist of quartzite with minor quartz-biotite phyllite, biotite schist, and marble. The matrix comprises generally less than 10 percent of these rocks and consists of calcite and clay.

Examination of a chert outcrop near the middle of the upper member shows an abundant finely crystalline silica mass with scattered round and spiculelike fossil forms.

Rock tentatively mapped as Halilar in the southeast and eastern part of the c_4 quadrangle lacks fossils that would prove the age of the unit. Lithologically the rock looks much like the upper member of the Halilar; component clasts are probably more angular, and the content of detrital chlorite and biotite is much less than that of the type Halilar. The questionable Halilar in the c_4 quadrangle does, however, contain small rounded pebbles of mica schist, phyllite, and larger pebbles of white quartzite like those in the upper member of the Halilar Formation in the d_3 quadrangle.

The Halilar Formation is unconformably overlain by the Bağburun Formation and the contact is well exposed in the area of Kiranba Tepe about 1 km east of Sarnıçköy, in Asar Tepe farther to the east along the valley of Değirmen Dere, all in the d_3 quadrangle, and near the village of Çulfa Çukuru in the d_2 quadrangle.

Fossils collected by the writers from the uppermost shaly sandstone of the lower member of the Halilar Formation have been identified as Placites sp., Septocardia sp., and Cassianella sp. by N. J. Silberling (U.S. Geol. Survey, written commun., 1969) and Oxycolpella Dagys, apparently O. oxycolpos (Emmrick) of the Rhaetian Stage Upper Triassic, by R. E. Grant (U.S. Geol. Survey, written commun., 1969). Placites is a diagnostic form for the middle or upper Norian (Upper Triassic); and the other forms also indicate a Late Triassic age for the unit. The writers have not found any identifiable fossils in the middle member, but Kaaden (1959, p. 21) reports Rhynchonella arpadica Bittner, R. concordiae Bittner, Halobia sp., Daonella sp., Posidonomya sp., and Neritopsis sp., all according to Kaaden, of Late Triassic age. Black pyritiferous shale apparently identical with that of the Edremit area has been reported by Aygen in the Balya area. There the shale contains Halobia neumayri also of Late Triassic age. The upper member of the Halilar Formation presents some problems in age assignment. The writers have collected numbers specimens of Septocardia sp. of Carnian and Norian age from what we believe to be the upper member of the Halilar just northwest of Kedikaya. We found no other fossils. Kaaden (1959, p. 22) reports collecting Pecten (variamussium) aff. P. pumilium from a sandstone section north-northeast of İnönü Köy (d_3 quad.). He correlated this section with others a few tens of kilometres to the north, just south of Terzialani (fig. 1) which contained forms identified as Atractites sp., and Rhacophyllites sp. (probably R. limatus Gemm), and consequently he assigned the sandstone-conglomerate section, here called the upper member of the Halilar, to the Lower Jurassic. Kaaden (1959, p. 21), however, also considered the shale sections in the Balya and Edremit areas to be equivalent, but the sandstone and conglomerate concordantly overlying the shale in the Balya area contain Macrodon juttensis Pichl., Rhynchonella levantina Bittner, R. baliana, Pergamidia eumenea Bittner, Posidonomya pergamena Bittner, Mysidioptera sp., Megalodus sp., Schafhautlia manzavinii Bittner, Spirigerella cf. S. emmrichii Suess, Terebratula (Phaetina?) turcica Bittner; according to Aygen (1956, p. 76-77) these fossils are of Norian (Late Triassic) age. To the north, between Iğdir and Gemlik at the eastern end of the Sea of Marmara, Erk (1942, p. 69-71) reports a Triassic section composed, from the base up, of sandstone, conglomerate containing distinctive blue limestone pebbles, yellow sandstone, and calcareous sandstone. The lower sandstone contains Halobia stryriaca Mojs., Terebratula sp., and Rhynchonella sp., all of Late Triassic age.

Limestone of Koçacal Tepe

Limestone, here informally called limestone of Koçacal Tepe from abundant outcrops in the hill of that name in the northern central part of the d_3 quadrangle, crops out as discontinuous, generally erosion-resistant masses in a belt extending from Koçacal Tepe to the northeast corner of the d_3 quadrangle, in a generally steep-sided tableland in the southeast corner of the d_2 quadrangle, as a second but smaller belt of discontinuous masses in the Çulfa Çukuru area, and as small bosses on the northern border of the c_1 quadrangle.

Outcrops are generally massive, white-weathering, white to pale-gray-brown or light-gray on fresh surface, very finely crystalline or dense limestone. All outcrop areas are cut by closely spaced irregular fractures filled with white, pale-brown, or hematite-red calcite. Fracturing is more closely spaced and fracture fillings are more deeply colored nearer the base of the exposed section in any one area. Movement on the fractures was apparently minimal as there is no rounding of the uneven fracture surfaces.

The section exposed along the Havrançayi where that river cuts Kocaçal Tepe is typical of much of the middle and upper parts of the section. The limestone in Kocaçal Tepe consists of three poorly differentiated zones: the lowest consists of well-bedded (15-25 cm) limestone with abundant to sparse, generally angular, fossil fragments set in a medium-gray, limy mud; the middle part of the section becomes progressively lighter colored and more massive upward, until bedding is no longer seen. Beds in the lower part of this middle section range from 15 cm to 3 m in thickness, and the rock consists of pale-gray-brown or very pale gray, very finely crystalline to dense limestone. The upper part of the section exposed in Kocaçal Tepe is a pale-gray-brown to white calcarenite in which generally rounded clasts (1-3 mm across) of dense limestone are set in a very abundant, finely crystalline to dense limy mud. Locally, in Kocaçal Tepe outcrops and in the limestone mass in the southeast corner of the d_2 quadrangle, the limestone contains common to sparse accretionary oolites, that is, oolites consisting of a massive dense nucleus surrounded by one or more layers of coarsely crystalline calcite. The oolites are set in a very abundant finely crystalline to dense limestone matrix. The quantity of oolites, nowhere more than 40 percent, and their very small size, are probably insufficient to call the rock an oolitic limestone.

Bedding is not present in most of the outcrops of the upper part of the limestone of Kocaçal Tepe. However, outcrops near the base of the section south of Sakarkaya Tepe (southern border of d_2), and between Akpinar Sivrisi and Ustunluk Mvk. (northern part of d_3) show well-bedded limestone. Individual beds are demarked by parting surfaces that extend for tens of metres, and locally for a few hundred metres; locally bedding is indicated by color, grain size, and weathering. The lowest beds in the Sakarkaya Tepe section show smooth rounded bowl-shaped depressions ± 15 cm across, a few centimetres deep, and spaced about 5 cm apart. These depressions appear to be primary bedding features. A few centimetres above these beds the limestone appears to consist of a coarse conglomerate, but examination of the rock indicates very abundant ammonites in a subordinate amount of calcarenite matrix. Similarly bedded limestone is present in the Akpinar Sivrisi area and other outcrop areas to the south toward Sarniçköy. Ammonites, although present in these latter areas, are much less abundant.

The limestone of Kocaçal Tepe is overlain by other rocks only in the Ballicak Tepe area about 2 km south of Sarniçköy where a small mass of the limestone, perhaps 200 m across, is in part overlain by andesitic lava of the Hallaçlar Formation. The lower contact is here interpreted as a low-angle thrust fault and is discussed in the section on structural geology.

Ammonites collected by the writers from outcrops on the west side of Üstünlük Mvk., northeast of Sarnıçköy, and from the cliffed exposures south of Kocaçaldüzü Mvk. (southeast corner, d_2) have been identified by R. W. Imlay (U.S. Geol. Survey, written commun., 1969) as _Perisphinctes_ (_Arisphinctes_) cf. _P._ (_A._) _plicatilis_ (Sowerby), _Sowerbycereas_ cf. _S. tortisulcatum_ (d'Orbigny), and _Lytoceras_ sp. These fossils indicate a Late Jurassic, probably Oxfordian age for the rock. Belemnites collected are, according to Imlay, of Late Jurassic age. Aslaner (1965, p. 46) reports _Phylloceras_ sp., _Holcophylloceras_ sp., _Hecticoceras_ sp., and _H._ aff. _H. puncatum_, and representatives of Pseudoperisphinctinae, Lytoceratidae, and Trachyceratidae from outcrops apparently identical to the limestone of Kocaçal Tepe in the area north of Edremit.

Bağburun Formation

Name and distribution.--Greenish-gray and yellowish-green lava, tuff, and volcanic breccia that unconformably overlie the Halilar Formation and are disconformably overlain by the Hallaçlar Formation or structurally overlain by the limestone of Kocaçal Tepe, are here named the Bağburun Formation. The type locality is the ridge of the same name near the east-central border of the d_2 quadrangle. Outcrops of the formation within the mapped area are discontinuous; the unit is poorly exposed, and confined to the northern half of the d_3 quadrangle, the southeastern quarter of the d_2 quadrangle, and the western border of the c_1 quadrangle. Fairly good exposures are present in the type area, south of the village of Sarnıçköy, and in the upper reaches of the Değirmen Dere in the northeast corner of the d_3 quadrangle. Rock of the Bağburun Formation in the mapped area is invariably prophyllitized; that is, more or less replaced by chlorite, calcite, pistacite, and pyrite. Prophyllitization of the rock prevents meaningful chemical analysis and hinders the assignment of the rock to a particular rock type or to a particular formation.

The formation was measured in the thickest section known, that exposed in the Bağburun Ridge. The Bağburun Formation is about 189 m thick in the type area (Appendix A.).

Petrography.--The entire section is prophyllitized. Hornblende is recognized chiefly on the basis of its elongate needlelike crystal form and cross sections; pyroxene is identified by its short thick crystal form and the characteristic shape of the crystals in cross section. Both hornblende and pyroxene are commonly replaced by chlorite, limonite, and possibly calcite. The rocks appear highly argillized, and the matrices of the breccias disintegrate into a granular mass rather than fracture when the rock is broken.

In areas of even more intensely altered rock the absence of key minerals and, locally, of overlying rock makes the identification of the rock and its assignment to a particular formation difficult. Outcrops in the Kizilkiran Mvk. in the northwest corner of the d_3 quadrangle, a good example, are 95 percent or more replaced by silica. Sparse embayed quartz phenocrysts, pseudomorphs of limonite after hornblende, and thin plates of white mica, apparently biotite leached of iron, are the only remaining identifiable traces of the former rock. Nearer the southern border of the Kizilkiran outcrop area the rock is less altered, and consists of gray-green and yellowish-green lava with abundant pseudomorphs of chlorite and limonite after hornblende, sparse chalky plagioclase, biotite, and embayed quartz phenocrysts, all characteristic of the Bağburun Formation. The characteristic gray-green lava also crops out just east of the village of Sarnıçköy, but outcrops in and south of the village consist entirely of volcanic breccia. The clasts range in color from black to light-greenish yellow, and in texture from sparsely to abundantly phenocrystic. The variation in color and texture in the clasts suggests that the rock is not an autobrecciated lava flow, but rather a mudflow deposit composed of volcanic debris. Other variations in the section are seen just north of Germe Tepe in the southeast corner of the d_2 quadrangle. The section just under the limestone of Kocaçal Tepe there shows eutaxitic structure typical of welded ash-flow tuff. All phenocrystic minerals other than quartz have been altered beyond positive identification in the hand specimen; plagioclase shows a chalky white nonshiny fracture surface, and the mafic minerals are indicated by granular masses of chlorite and limonite. Much of the rock shows the yellow-green color of pistacite.

Thin section study of the rock of the Bağburun Formation commonly shows plagioclase, hornblende, biotite, and quartz, and rarely pyroxene or sanidine, all in a highly argillized fine-grained matrix. Lava and tuff are easily distinguished on the basis of broken angular crystals in the tuffaceous rocks and whole crystals in the lava flows. Sanidine and quartz invariably have rounded and embayed shapes, but in the tuffaceous rocks fresh uncorroded fracture faces are also seen on these minerals.

Plagioclase is commonly completely replaced by calcite, by a combination of calcite and penninite, or less commonly by pistacite. All plagioclase not replaced is thoroughly argillized; locally within individual phenocrysts, evidence of albite twinning remains, and the plagioclase is both optically positive and shows a lower index than balsam. It apparently ranges from albite to oligoclase. Sanidine forms small, clear, and unaltered, generally rounded and corroded crystals in both lava flows and tuffaceous rocks. It does not exceed 10 percent in those rocks, but its presence as phenocrysts probably indicates additional potassium feldspars in the matrix. The rocks are therefore probably best called dacite or rhyodacite. Hornblende, in all the 45 thin sections studied, is completely replaced. Most commonly it is indicated by pseudomorphs of chlorite or calcite rimmed with iron oxide granules. Rarely it is replaced by chlorite and pistacite. Hornblende is indicated by typical amphibole cross sections. Pyroxene, apparently augite, is only rarely present in the nonquartz-sanidine-bearing rocks. It is largely replaced by calcite. Biotite, recognizable only because of its distinctive six-sided outline, is replaced by irregular granules of iron oxide. Locally it is replaced by penninite, pistacite, and calcite. Lithic clasts, although not easily recognized in the field, are present as small (less than 4 mm), generally well-rounded grains near the base of the section and as angular clasts in the tuffaceous rocks. They consist of quartz-biotite phyllite like that in the Kalabak sequence, and quartzite like that in the underlying Halilar Formation. Matrices of the least altered rocks in the Bağburun are invariably argillized and commonly partly replaced by calcite in even the most dense and fresh-appearing rocks. Commonly the matrices are also replaced by finely crystalline chlorite or chlorite and calcite, less commonly by pistacite and calcite. Pyrite is sparse and only locally present.

Contacts and age.--The contact of the Bağburun Formation and the overlying Hallaçlar Formation is generally poorly exposed because of the ease of weathering of the Bağburun. However, the contact is well exposed in Kiranba Tepe east of Sarniçköy where an erosion surface cuts across both the Bağburun and the underlying Halilar Formation. Exposures of the contact in the northeast corner of the d_3 quadrangle show the Hallaçlar lying on an erosion surface cut on the Bağburun. Within the mapped area it is not possible to prove or disprove that the Bağburun had been folded prior to the eruption of the lava flows of the Hallaçlar. Thus the nature of the Bağburun-Hallaçlar contact must await further study.

Where the Bağburun Formation is overlain by the limestone of Kocaçal Tepe the contact is a thrust or gravity glide fault, and it is discussed later in the section on structural geology. It is of interest to note, however, that breccia at the top of the Bagburun and immediately underlying the limestone in the Kara tarla area northeast of Sarniçköy and in Bakcak Mvk. south of Sârniçköy shows a bright-red color that gradually dies out at about 10 m depth from the contact. Breccia in the reddened zone is generally finer than that immediately underlying, and contains angular fragments of the overlying limestone. The reddened breccias may represent soil horizons developed prior to the emplacement of the limestone.

The lower contact with the Halilar Formation is well seen in the Kizilkiran Mvk. where the Bağburun fills valleys and lies on the sides of hills eroded in the Halilar. Nonfaulted contacts of the Bağburun and the Halilar Formations in the d_2 and the Bağburun-Kalabak contact in the c_1 quadrangle indicate deposition of the Bağburun on a southeast-sloping surface cut on both the Halilar and Kalabak.

Fossils have not been found in the Bağburun Formation, and its highly prophyllitized condition precludes radiometric age dating. As it overlies the Halilar Formation, the Bağburun is at least post-Late Triassic, and as it underlies the limestone of Kocaçal Tepe, it predates the emplacement of that allochthonous limestone plate. In addition, it almost certainly postdates the Late Jurassic age of the limestone as the limy sediments composing that rock probably were lithified prior to thrusting. The Bağburun is, therefore, probably Cretaceous or younger. Previous workers (Gümüş, 1964, pl. 4; Aslaner, 1965, pl. 4; Kaaden, 1959, pl. 1, p. 30) did not recognize the stratigraphic and structural relationships of the Bağburun and Halilar Formations with the limestone of Kocaçal Tepe; and the Bağburun, Hallaçlar and Dede Tepe Formations were lumped by them into one unit.

Tertiary system

Hallaçlar Formation

Name and distribution.--Rhyodacite and minor labradorite rhyodacite, trachyandesite, and olivine trachyandesite lava flows and minor flow-breccia and tuff that disconformably overlie the Bağburun Formation and the limestones of Kocaçal Tepe and Ayakli and are disconformably overlain by the Dede Tepe Formation are here named the Hallaçlar Formation. The type area is that of the village of Hallaçlar near the east-central border of the d_3 quadrangle. A section (Appendix A) was measured from about the junction of the Gelin Dere and the Kabaklik Dere to the contact with the overlying Dede Tepe Formation on Kuşakkiran Tepe about 800 m east of Hallaçlar. Where relatively unaltered, the Hallaçlar can be seen to consist of 90 percent or more of rhyodacite lava flows. Alteration of the formation is pervasive and locally intense. The Hallaçlar is about 300 m thick in the type area and more than 350 m thick to the west in the Büyüksari Tepe area (d_3 quad.). Areas of essentially 1) unaltered rock, 2) completely silicified rock, and 3) argillized, silicified, and pyritized rock have been separated on the map (pl. 1).

The Hallaçlar Formation crops out as two irregular bands in the southern half and along the northeastern border of the d_2 quadrangle, over all but the northwest corner and western border of the c_1 quadrangle, and in the southeastern corner of the d_2 quadrangle. Areas of relatively unaltered Hallaçlar lie chiefly in the northeast quarter of the c_4 quadrangle and extend up into the central part of the c_1 quadrangle; a major area lies south of the Eğmir mine, and irregular discontinuous patches lie in the southern half of the d_3 quadrangle and southeastern quarter of the c_4 quadrangle. Areas of complete silicification are commonly, although not invariably, associated with faults or high ridges or peaks. The largest such area lies along the ridge on which the Eğmir mine is located. Other patches lie southeast of the Eğmir mine and across the southern half of the d_3 quadrangle. All other areas of outcrop are highly altered.

Description.--Relatively unaltered Hallaçlar is characteristically medium to dark gray or reddish brown, and contains common to abundant vitreous, pale-yellow plagioclase phenocrysts, shiny, black to dark-brown biotite, and dark-green, partly altered pyroxene phenocrysts. The matrix is commonly partly altered and granular appearing in even the least altered rock; rarely, as in the Köylüce area (d_3 quad.), it is black and very dense. The black color of the unaltered matrix is derived from finely crystalline magnetite, and that of the altered rock from fine-grained hematite. Flowbanding is common. Andesite flows in the Küc Sapçi area of the northeast corner of the c_4 quadrangle and extending up into the c_1 quadrangle are atypical in that they show alternating bands of pale-pink and light-gray rock. Otherwise they are much like the typical Hallaçlar. Flow-breccia, that is, volcanic breccia formed by the fracturing of the cooled crust of a moving lava flow and the mixing of the crustal clasts with the still fluid lava, is common at the tops of flows in the central part of the c_1 quadrangle. The breccia is flow-breccia rather than a mudflow deposit, as the clasts show a common texture, color, and mineral composition, and they are mineralogically like the matrix, which locally shows flow banding.

Unaltered dacitic lava flows, although rare in the Hallaçlar Formation, are locally dominant in the Karaçam Tepe area in the east-central part of the c_4 quadrangle. These flows are typically medium to dark gray brown and reddish brown. They contain common to sparse, generally altered chalky-white plagioclase; sparse, dark-brown biotite; sparse, partly altered, prismatic hornblende; rare, dark-green pyroxene; and sparse, rounded and embayed quartz; all in a very fine grained hematite-bearing matrix. See table 1 for analyses.

Table 1.--Analyses of the Hallaçlar Formation.

[Method used was a single-solution procedure (see Shapiro, 1967)

Analysts: P. Elmore, G. Chloe, J. Glenn, S. Botts, L. Artis, J. Kelsey, and H. Smith; U. S. Geological Survey]

	Typical andesitic facies					Dacitic facies			Feeder dike
Lab. No.	W172 311	W172 312	W172 313	W172 320	W172 328	W172 318	W172 330	W172 327	W172 325
Field No.	10/6/ 68-3	11/6/ 68-1	11/6/ 68-4	19/6/ 68-3	2/8/ 68-2	18/6/ 68-2	9/8/ 68-1	1/8/ 68-1	15/7/ 68-2
SiO_2	60.4	52.9	55.6	59.4	57.5	58.5	59.7	59.8	51.5
Al_2O_3	18.0	16.3	18.5	16.2	17.0	16.6	15.9	17.2	17.2
Fe_2O_3	3.1	5.2	4.5	4.3	5.3	4.9	3.5	4.5	4.5
FeO	2.1	3.1	2.4	1.2	1.4	1.2	1.7	.80	4.6
MgO	2.2	3.4	1.4	3.2	2.6	2.4	3.0	1.5	3.3
CaO	5.5	8.4	6.5	6.3	5.9	6.2	5.9	4.5	8.0
Na_2O	3.3	2.9	4.1	3.4	3.6	2.7	3.0	3.5	3.0
K_2O	2.2	2.6	3.6	2.6	2.5	2.6	2.5	2.5	3.0
H_2O+	.35	.85	.67	1.2	1.6	1.2	1.1	2.6	.86
H_2O-	1.7	1.3	.33	1.2	1.5	1.7	2.6	1.9	.84
TiO_2	.79	.90	.72	.59	.72	.64	.56	.58	1.1
P_2O_5	.30	.47	.53	.28	.31	.34	.22	.28	.49
MnO	.09	.17	.18	.11	.12	.12	.12	.14	.04
CO_2	.05	1.4	.86	.06	.05	.08	.05	.05	1.4
Total	100	100	100	100	100	99	100	100	100

Large amounts of the outcropping rocks of the Hallaçlar Formation are partly replaced by calcite and are argillized, silicified, and commonly pyritized. The content of lead and copper in the Hallaçlar (table 2) appears directly related to the degree of alteration of the unit. Lead in the least altered rock is 50-70 ppm, in moderately altered rock 200-300 ppm, and in highly altered rock 500-700 ppm; exceptionally it is 3000 ppm. Copper increases irregularly from 20-30 ppm in the least altered rock to 100-150 ppm in the most highly altered rock. The increase in lead and copper with degree of alteration, the well-crystallized character of kaolinite that constitutes as much as 60 percent of the altered rock (P. Blackmon, U.S. Geol. Survey, written commun., 1970), and the pervasive pyritization of the altered rock, together indicate that hydrothermal activity rather than surficial weathering was responsible for the alteration. Outcrops of all but the completely silicified rock are very easily weathered, pale-yellow or light-yellow-gray, earthy masses that show chalky-white powdery pseudomorphs of calcite and quartz after plagioclase. The altered rock generally shows no mafic minerals, but rarely outlines of hornblende and pyroxene are indicated by soft, pale-green, limonite-stained, chlorite pseudomorphs. Specimens of altered Hallaçlar taken from outcrops not superficially weathered, chiefly those exposed by recent landslides or in cliff faces, show abundant, very fine crystalline, disseminated pyrite. Pyritization of the otherwise argillized and silicified rock is common. Areas surrounding small intrusives, areas of completely silicified rock, and the rock immediately underlying the silicified rock are commonly devoid of pyrite. Fractures cutting these areas, especially the completely silicified and underlying rock, are lined with quartz crystals, and all show hematite-limonite that ranges from thin films to thick crusts. The absence of pyrite in these areas may be ascribed to superficial weathering, but more probably the pyrite was removed and hematite deposited by solutions derived from local intrusives and from the granodiorite pluton.

Areas of the Hallaçlar Formation mapped as completely silicified are 98 percent or more quartz. Pseudomorphs of opaque, white granular quartz after plagioclase are the only indications of the former texture and nature of the rock. All traces of mafic minerals are lacking. Quartz phenocrysts in the originally dacitic rocks are preserved as rounded, clear, vitreous quartz in a mass of finely crystalline quartz. Such silicified dacite is best seen in the ridge north of the Eğmir mine. There, only textures of dacitic tuff beds intercalated with dacitic lava flows, the alignment of the original plagioclase phenocrysts, and the original quartz phenocrysts in the lava flows are preserved. Angular clasts of completely silicified rock in the hematite ore at the Eğmir mine show the same textures and were clearly derived from the same silicified dacitic rock.

Petrography.--Thin section study of the rock of the Hallaçlar Formation confirms the existence of the two main rock types identified in the field; that is, rhyodacite and dacite. The rhyodacite rocks show common to sparse plagioclase and sparse augite and biotite in a generally abundant fine-grained groundmass.

Table 2.—Partial semiquantitative spectroscopic analyses of unaltered and altered andesitic and dacitic lava flows from the Hallaçlar Formation.

[Results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are to be reported as mid-points of these brackets, 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of a reported value is approximately plus or minus one bracket at 68 percent confidence or two brackets at 95 percent confidence. Analyst: J. L. Harris, U.S. Geological Survey. N = not detected, at limit of detection, or at value shown. L = detected, but below limit of determination or below the value shown. All values are reported in parts per million.]

Lab. no.	Field no.	Elements reported in parts per million Ag	Ba	Cu	Mo	Pb
W172 307	19/4/ 68-4	N	700	30	3	50
W172 309	6/6/ 68-4	N	1000	70	3	70
W172 311	10/6/ 68-3	L	2000	20	5	50
W172 312	11/6/ 68-1	L	2000	20	5	50
W172 313	11/6/ 68-4	L	3000	10	5	50
W172 316	17/6/ 68-1	L	1500	70	N	70
W172 317	17/6/ 68-2	L	1500	20	3	70
W172 319	19/6/ 68-1	L	1000	30	3	50
W172 326	16/7/ 68-1	N	1000	20	3	70
W172 327	1/8/ 68-1	N	1000	20	3	70
W172 329	6/8/ 68-3	L	1000	30	5	70
W172 330	9/8/ 68-1	L	1000	20	5	50
W172 341	18/10/ 68-1	L	1500	30	3	70
W172 310	10/6/ 68-2	1	700	150	10	500
W172 318	18/6/ 68-2	1	2000	50	3	700
W172 320	19/6/ 68-3	L	1000	50	3	200
W172 325	15/7/ 68-2	L	1500	20	5	150
W172 328	22/8/ 68-2	L	1500	100	5	150
W172 337	17/9/ 68-2	L	3000	20	5	150
W172 340	15/10/ 68-4	1	1500	30	3	300
W172 342	18/10 68-3	7	1500	50	3	3000

Specimens W172-307, 309, 311, 312, 313, 316, 317, 319, 326, 327, 329, 330, and 341 are essentially unaltered andesitic and dacitic lava flows from the Hallaçlar Formation; specimens W172-310, 318, 320, 325, 328, 337, 340, and 342 are altered to various degrees; 325 is from a feeder dike; 340 and 342 were collected from within 500 m of the contacts of the trondjemite stocks at Ağağidamlar (d_3 quad.) and Dereoren (d_3 quad.), respectively.

Plagioclase is labradorite (An_{58-42}), shows both continuous and reverse zoning, and is euhedral and commonly unaltered. Rarely it shows marginal sieve texture, chiefly the inclusion of irregular masses of glass like that in the groundmass. Plagioclase phenocrysts are commonly partly resorbed in rock in which pyroxene microlites are common in the groundmass. Pyroxene phenocrysts are sparse to common. Sections of even the least altered rock show pigeonite partly replaced by chlorite and calcite. Rarely augite phenocrysts are agglutinated into relatively large, granular-appearing masses. Biotite is sparse to rare, and invariably shows abundant iron-oxide granules--magnetite(?)--on crystal margins, rarely throughout the crystals. The groundmass commonly shows trachytic texture and consists of abundant feldspar and pyroxene microlites and small magnetite crystals in a pale-green glass. The glass is partly replaced by clay in even the least altered rock.

Dacitic lava flows in the Hallaçlar Formation have common to sparse plagioclase, sparse hornblende, and rare augite, biotite, and quartz phenocrysts in a generally glassy groundmass. Plagioclase is andesine-labradorite (An_{56-30}), has continuous and reverse zoning, is generally unaltered, and euhedral. Both plagioclase and augite show sieve texture in which irregular masses of the groundmass are included in marginal areas of the phenocrysts. Hornblende shows parallel extinction, dark-yellow-brown to very dark reddish pleochroism, and is apparently basaltic hornblende. Biotite is crowded with iron oxide granules and is dark brown. Uncommonly the biotite contains skeletal ilmenite crystals. Quartz phenocrysts are generally clear and free of inclusions, but they are invariably rounded and deeply embayed by the formerly fluid groundmass. The groundmass of the dacitic lava flows consists predominantly of pale-green glass with sparse feldspar and magnetite microlites.

Thin sections of altered rocks from the Hallaçlar show initial replacement of groundmass glass by clay, and the progressive replacement of augite, hornblende, and biotite, in that order, by chlorite and calcite. Plagioclase phenocrysts are replaced by calcite and minor chlorite, but replacement is generally not complete until after the complete removal of the mafic minerals. Large-scale replacement of the groundmass by clay, calcite, and chlorite appears only after the augite has been completely replaced. Pistacite rarely appears as an alteration product; it is present chiefly in the altered lava flows in the valley of the Köy Dere just east of Eğmir. Sections from this rock also show rare topaz. Careful examination of the area, however, revealed no indication of pegmatites or veins, pneumatolitic or otherwise. Pyrite appears in the altered rocks only after the mafic minerals and all secondary chlorite have been replaced. It is generally present only in altered rock having appreciable quantities of clay, calcite, and quartz; and it is progressively removed as the quantity of quartz increases. Rocks in which the pyrite is completely or partly removed show films and locally crusts of limonite-hematite on fracture faces. In the early stages of replacement of pyrite, limonite is disseminated throughout the rock. This, too, is removed as the quartz content increases. Quartz replaces all the secondary minerals involved in the alteration of the original rocks, and apparently directly replaces otherwise unaltered rock, ultimately resulting in a chertlike, very fine grained, opaque white rock with pseudomorphs of coarser-grained quartz after plagioclase and sparse quartz phenocrysts. The calcite-chlorite pseudomorphs after plagioclase may be replaced directly by silica, or they may be removed and the resulting cavities later filled by quartz, as in the ridge north of Eğmir.

Contacts and age.--The Hallaçlar Formation is overlain disconformably by the Dede Tepe Formation; the contact is best seen in the valley of the Karalar Dere in the southwest corner of the d_3 quadrangle. There a valley at least 600 m deep was eroded into the already altered and partly silicified Hallaçlar, and subsequently filled with lahar deposits of the Dede Tepe Formation.

Fossil material has not been found in the Hallaçlar, but a K/Ar date of 23.6$\pm$.6 m.y. (J.D. Obradovich, U.S. Geol. Survey, written commun., 1971) on biotite from the Hallaçlar indicates an early Neogene (middle Miocene) age for the formation.

Dede Tepe Formation

Name and distribution.--Mineralogically similar lahar deposits, ash-fall tuff, and minor ash-flow tuff and lava flows of early Neogene age that disconformably overlie the Hallaçlar Formation are here named the Dede Tepe Formation. The type locality is in the area of Dede Tepe in the southeastern quarter of the d_3 quadrangle southeast of the village of Karaoğlanlar. The tuffaceous and laharic upper part of the formation is excellently exposed in the type area, and the laharic lower part is well exposed in the ridges between the village of Dereöbasi and the top of Karakeçe Tepe in the central southern part of the d_3 quadrangle. The Dede Tepe Formation crops out over much of the southern half and the northeast quarter of the c_4 quadrangle, and as two irregular east-northeast-trending bands in the southern third of the d_2 quadrangle. The unit is predominantly a quartz latite but also includes subordinate rhyodacite and minor latite and rhyolite. See table 3 for analyses.

Table 3.--Analyses of the Dede Tepe Formation.

[Method used was a single-solution procedure (see Shapiro, 1967)

Analysts: P. Elmore, G. Chloe, J. Glenn, S. Botts, L. Artis, J. Kelsey, and H. Smith; U. S. Geological Survey.]

Lab. No.	W172 314	W172 323	W172 335	W172 315	W173 792	W172 333	W172 336	W172 331	W172 332
Field No.	13/6/68-2	11/7/68-1	22/8/68-1	13/6/68-3	21/8/69-5	14/8/68-1	10/9/68-1	12/8/68-1	12/8/68-2
SiO_2	66.2	66.3	61.8	64.7	63.9	63.6	61.8	64.7	64.3
Al_2O_3	15.1	14.4	15.4	16.4	15.6	17.0	16.4	15.6	17.1
Fe_2O_3	3.7	1.8	3.9	3.7	3.0	3.1	4.1	4.5	3.5
FeO	.52	1.4	1.3	.64	1.4	.64	1.3	.44	.84
MgO	1.3	1.7	2.4	1.0	2.2	.90	1.4	1.6	1.2
CaO	3.2	3.2	3.6	3.7	4.1	3.7	3.7	4.6	3.6
Na_2O	2.2	2.3	2.5	3.0	3.0	3.2	3.0	3.2	3.3
K_2O	2.9	3.6	2.9	2.7	4.0	3.4	4.3	2.9	3.2
H_2O+	1.1	1.5	2.7	.96	1.0	2.1	1.4	.65	.75
H_2O-	2.4	2.9	2.0	1.6	.73	1.2	1.6	.75	1.2
TiO_2	.51	.38	.26	.51	.48	.56	.55	.54	.50
P_2O_5	.26	.29	.37	.30	.28	.37	.17	.30	.30
MnO	.09	.08	.06	.09	.08	.05	.09	.10	.06
CO_2	.05	.08	.05	.05	.02	.05	.05	.05	.05
Total	100	100	99	99	100	100	100	100	100

Specimen 13/6/68-2 consists of a red lava, 13/6/68-3 of a welded ash-flow tuff, 11/7/68-1 of a crystal tuff, 22/8/68-1 of a crystal-vitric tuff, 21/8/69-5 of a bedded lithic tuff, 14/8/68-1 and 10/9/68-1 of lahar, and 12/8/68-1 and 12/8/68-2 of the coarse porphyritic lava that crops out locally near Yürekli at the base of the Dede Tepe Formation.

Lower part.--The lower 250 m of the Dede Tepe Formation, as measured between Dereöbasi and Karakeçe Tepe, consists predominantly of volcanic breccia of quartz latite composition. The breccia is a mudflow composed of volcanic detritus. These mudflows contain lithic clasts of various colors, textures, compositions, and degrees of weathering and rounding, all enclosed in a similarly mixed matrix. They lack sorting; bedding, other than that resulting from deposition of one mudflow upon another, is absent.

The base of the section at Dereöbasi consists of 15 to 30 percent of rounded to angular lithic clasts, from 2 cm to 1 m on a side, in a pale-gray tuffaceous matrix. Dark-brown to white altered andesite constitutes as much as 10 percent, and characteristically dense to glassy, angular, pale-gray and white scoriaceous clasts constitute as much as 25 percent of the rock. Both the pale-gray lithic clasts and the tuffaceous matrix show abundant to sparse, shiny, black hornblende, vitreous plagioclase, and common to sparse quartz, biotite, and potassium feldspar. The white scoriaceous lithic clasts are composed chiefly of glass and are fragile and very angular. Both the pale-gray and white lithic clasts are probably essential components, whereas the andesite is accidental and was derived from the underlying Hallaçlar Formation. The andesite clasts show varying degrees of alteration from slightly altered to completely silicified. The extreme angularity of crystal clasts, and white and pale-gray lithic clasts, the mineralogic similarity of the white and pale-gray lithic clasts and the matrix, and the massive character of the deposits suggest that the detritus in the lower part of the Dede Tepe Formation was explosively erupted and later moved into nearby topographic lows as mudflow deposits. Similar characteristics are seen in ash-flow tuffs, but thick deposits of such tuff commonly show at least incipient welding of the finer glass shards in the matrix. The matrix of these breccias shows no such welding, and significantly, shards are absent.

Breccia higher in the section in the Dereöbasi area shows angular, dense to glassy, pale-reddish-brown lithic clasts in addition to the white and pale-gray lithic clasts. These reddish-brown clasts have flow-banding, and make little or no contribution to the matrix. Lithic clasts higher in the section range from 2 cm to 2 m on a side, but the quantity of large blocks is probably less than 1 percent of the breccia. Clasts from 2 to 20 cm in diameter are typical and constitute as much as 20 percent of the rock. Locally they weather out as a lag gravel on the outcrop.

Upper part.--The upper 246.4 m of the Dede Tepe Formation measured from the Hallaçlar-Dede Tepe contact on the Çakilli Dere to the top of Dede Tepe is typical of the upper part of the formation in the c_4 and d_3 quadrangles, and consists chiefly of interbedded mudflow deposits and air-fall tuff. The mudflow deposits are much like those in the lower part of the section near Dereöbasi. Lithic clasts in this part of the section are, in order of abundance, pale-greenish gray, white, and pale-reddish brown. All show shiny, black hornblende, vitreous plagioclase, quartz, potassium feldspar, and black biotite phenocrysts. The enclosing tuffaceous matrix consists of crystals of the same minerals, angular fragments of sphene as much as 6 mm across, plus very dense, pale-green grains of devitrified glass. The tuff ranges from very dense, porcelainlike clinkstone to the more typical lapilli tuff. Crystal, lithic, and vitric or glassy components are combined in various proportions in the tuff layers, but the dominant types are crystal-vitric tuff, lithic-crystal-vitric tuff, and lithic-vitric tuff. Crystalline clasts are characteristically unaltered and very angular. They consist of the typical unaltered hornblende, vitreous plagioclase, quartz, potassium feldspar, and biotite. Lithic components are the same types as seen in the interbedded mudflow deposits. The similarity of the glassy matrix in a particular bed to either the white, pale-gray, or pale-greenish-gray lithic clasts suggests that those clasts are essential. Pale-reddish-brown lithic clasts are like the lava seen in the measured section and may be either accessory or accidental ejecta.

Atypical ash-flow tuff.--The section just south of the Gökgedik Sr. is atypical in that it consists of about 200 m of massive, partly welded ash-flow tuff. The section there shows a lower pale-gray, very fine grained, mostly vitric ash-flow tuff overlain disconformably by pale-pink, partly welded, very fine grained, mostly vitric ash-flow tuff. Each unit has a concentration of accidental lithic clasts near its base. The basal accidental lithic clasts in the pale-pink tuff are particularly interesting. They are altered andesite, apparently from the Hallaçlar Formation, and at least one of the clasts contained visible native gold.

Lava unit.--Pale- to light-brown, very coarsely crystalline lava that weathers to a coarse grus, crops out just north of the village of Yürekli near the south-central border of the c_4 quadrangle. Similar-appearing rock is also present as large boulders (to 1 m on a side) in a lahar that forms the ridge between Kobaklar and Hüseyinpaşalar in the center of the c_4 quadrangle. The rock exhibits strikingly large phenocrysts as much as 2.5 cm long of common to abundant vitreous plagioclase; common to sparse dark-green hornblende (as much as 2 cm long); sparse to common potassium-feldspar and quartz; and sparse reddish-brown biotite in a very finely crystalline matrix that makes up from 2 to 40 percent of the rock. Both the potassium-feldspar and the quartz are rounded and embayed.

The lava unit was separated from the Dede Tepe as a member, and it has been mapped separately; however it was not given a formal member name, pending further study in areas of more extensive outcrop. See table 3 for analyses.

Petrography.--Thin-section study of the lahar and tuff deposits in the Dede Tepe Formation confirms the mineralogic identifications made in the field. Although quantities of individual minerals vary greatly, plagioclase, hornblende, quartz, anorthoclase, and biotite are generally present, in that order of abundance. Plagioclase (An_{42-26}) is generally unaltered, angular in the tuff deposits, and has continuous and reverse zoning. Hornblende is of two types; one having abundant iron-oxide granules on crystal borders or throughout the crystal, parallel extinction, and very dark reddish-brown to black pleochroism, is clearly basaltic hornblende; the other has inclined extinction, distinct color rings from the center outward in cross section, and no iron-oxide granules. Potassium feldspar has a very small 2V and the crosshatching characteristic of anorthoclase. Both anorthoclase and quartz show extreme resorbtion and embayment. Biotite, where associated with basaltic hornblende, also shows iron-oxide granules on crystal margins or throughout the crystal. The pale-gray, white, and pale-reddish-brown lithic clasts in both mudflow and tuff deposits characteristically contain plagioclase, hornblende, quartz, anorthoclase, and biotite phenocrysts. The pale-greenish-gray lithic clasts, quantitatively dominant in many of the tuff beds, are very fine grained and show only feldspar microlites. Crystal clasts in the ash-flow tuff are like those in the air-fall tuff deposits.

Matrices of the crystal-vitric and lithic-vitric tuffs are predominantly glass with very fine grained, angular crystal or lithic clasts. Glassy matrices of air-fall tuffs are generally unaltered, whereas those of ash-flow tuffs are both unaltered and altered. Commonly the ash-flow tuffs show densely to moderately welded glass shards with conspicuous spiculites of an unidentified mineral, or the shards may be completely devitrified and show a radiating pattern of very fine quartz and feldspar crystals. Both the glassy and devitrified matrices of the ash-flow tuffs show the pseudoflow structure characteristic of welded ash-flow tuff. Matrices of the lithic-vitric tuffs are generally obscured by the very abundant, angular, minute lithic clasts. Most are argillized.

Contacts and age.--The Dede Tepe Formation is overlain disconformably by lacustrine tuff, conglomerate, marl, siltstone, limestone, and evaporite deposits in two separate areas on the eastern and southern borders of the c_4 quadrangle. These deposits lie on an erosional surface that cuts across the Dede Tepe and Halilar Formations just north of Geçmiş Köy (c_4 quad.), and on an erosional surface that cuts the Dede Tepe, Hallaçlar, and the limestone of Ayakli southwest of Ayakli.

Fossils have not been found in the Dede Tepe Formation. A specimen collected by the writers from the Sulutaş Tepe intrusive, a volcanic neck that was a feeder for the formation, gave an argon age of 20.3±0.6 m.y. and 20.8±0.7 m.y. for biotite and hornblende respectively (J. D. Obradovich, U.S. Geol. Survey, written commun., 1971) and indicate an early Neogene (middle Miocene) age for the formation.

Lake beds

Water-laid sedimentary and minor volcanic rocks of probable Neogene age form broad gently sloping terraces and low rounded hills in a belt across the western central two-thirds of the d_3 quadrangle, and generally gently sloping surfaces in smaller irregular-shaped and discontinuous areas in the southeastern part of the c_4 quadrangle. These lacustrine deposits are not known to be exposed in the d_2 and c_1 quadrangles. Outcrops are commonly poor because of a general lack of consolidation, and because of the effects of long-continued farming. Although a section has not been worked out in detail, or measured, the unit has been shown on the geologic map. The sequence is similar in different areas, although it may vary in detail; it is easily distinguished from the underlying rocks.

Best exposures of the base of the section are seen from the area south of Kalabak Köyü to the east on the flank of Kocaçal Tepe. South of Kalabak, a basal conglomerate consists of material ranging from coarse boulders to fine pebbles of phyllite, schists, and banded marble, all from the Kalabak sequence; feldspathic quartzite from the Halilar Formation; finely crystalline limestone from the Kocaçal Tepe sequence; andesite and dacite from the Hallaçlar and quartz latite from the Dede Tepe Formations; and coarse-grained granodiorite-quartz monzonite from an eroded batholith to the north. Farther to the east, clasts of the Bağburun Formation are present in the basal conglomerate, but in subordinate amounts, as the Bağburun is highly altered, soft, and easily broken down. On the flank of Çakir Tepe (d_3 quad.), the basal conglomerate consists chiefly of rounded pebbles of the hard feldspathic quartzite of the

Halilar Formation; on the flank of Kocaçal Tepe, numerous pebbles and boulders of the limestone of Kocaçal Tepe are conspicuous in the conglomerate. Rock higher in the section south of Kalabak consists of fine-grained, well-sorted, poorly consolidated, quartzose sandstone overlain by pale-brown, fine-grained tuff, clayey tuff, and pale-gray to pale-brown marl. Locally the marl contains abundant but poorly preserved gastropods and ostracodes. The ostracodes, according to J. E. Hazel (U.S. Geol. Survey, written commun., 1969), are probably fresh-water forms. Outcrops south of the Havrançayi near Aşağidamlar (a few tens of metres west of the d_3 quad.) are similar and contain scattered coarse aragonite crystals. To the east, near the turnoff to Köylüce from the main highway, the section consists of very fine grained, thin-bedded, silty tuff and interbedded lenses of aragonite. The section grades upward into massive limestone, and higher in the section, into finely bedded limestone. The silty tuff shows mud cracks and contains scattered fragments of plant fossils and disarticulated fish vertebrae, spines, and gill plates. None have been identified. Exposures of poorly indurated marl and silt on the northern end of Dede Tepe, just southeast of Kocaçal Tepe near the main highway, contain fragments of long bones, apparently leg bones, and horselike teeth; unfortunately they crumbled on removal from the marl.

Outcrops of the water-laid sequence are also present north of Geçmiş Köy (c_4 quad.) where a basal boulder conglomerate containing fragments of finely crystalline limestone like that in the Kocaçal Tepe sequence, and of tuff like that in Dede Tepe, onlaps the Halilar Formation. The conglomerate is overlain by a fine-grained, pale-gray-brown marl like that near Aşağidamlar. Farther south, near Ayakli, the lacustrine sequence consists of pale-greenish-gray and light-gray-brown silty tuff, pale-gray marl, and, near Eşi Burun (c_4 quad.), conglomeratic sandstone with pebbles from the limestone of Ayakli. Disarticulated fish vertebrae and gill plates are also present in a fine siltstone on the north side of the valley of the Karapinar Dere south of Ayakli. The upper part of the section also shows massive beds of silicified plant fossils just south of the c_4 quadrangle border, near Kocaçal Tepe.

These lacustrine rocks overlie the Halilar, Bağburun, Hallaçlar, and Dede Tepe Formations as well as the limestones of Kocaçal Tepe and Ayakli. The contact ranges from an angular unconformity where it crosses the Halilar Formation and the limestones to a disconformity where it crosses the Hallaçlar and Dede Tepe Formations.

Gastropods, ostracodes, fish remains, and plant fossils found in the lacustrine sequence have not been identified because of their poor preservation. However, Erguvanli (1957, p. 50) reports _Mactra caspia_ Eich., _M. podolica_ Eich., _M._ aff. _M. bulgarica_ Toula, and _M._ aff. _M. dobrigiaca_ Simion from a sequence near Ezine, which is lithologically identical to that in the Edremit area. Kaaden (1959, p. 24) found _Mactra_ sp., _Hydrobia_ sp., and _Planorbis_ sp. from similar sections near Demirci. The fossils, and probably the lacustrine section in the Edremit map area, are of Miocene age.

Quaternary system

Alluvium

Alluvium of Quaternary age is present along major streams in the d_3, c_1, and c_4 quadrangles and locally elsewhere. The deposits consist of poorly sorted and bedded gravel, sand, and minor silt. Rock types represented vary according to the area drained. Locally along the Kişla Dere, remnants of Quaternary alluvial terraces are preserved as boulder-block breccia tightly cemented by hematite.

Landslide debris

Landslides of Holocene age have developed along the western and southern margins of the limestone tableland in the southeast corner of the d_2 quadrangle and near the central-western border of the c_1 quadrangle. Six of the seven slides mapped lie in the d_2 quadrangle, are composed of angular blocks of the limestone of Kocaçal Tepe, and are inactive. These slides appear to have moved in response to the undermining of the limestone. The seventh slide, in the c_1 quadrangle, is composed of saprolite derived from the prophyllitized lava flows of the Hallaçlar Formation, and it is active. This slide formed as a direct result of unusually heavy run-off following heavy rain and snow of March 1968. The slide surface consists of a number of terracettes, each of which shows backward rotation. It is an excellent example of a slump. Although the slide is active it poses no danger for any inhabited area.

INTRUSIVE ROCKS

Intrusive rocks within and near the mapped area include partly serpentinized dunite bodies, part of a granodiorite-quartz monzonite batholith, a granitic pegmatite stock and related dikes, and rhyodacite-quartz latite stocks. These intrusives range in age from Late Paleozoic to Neogene.

Serpentinized dunite-peridotite

The oldest intrusive rocks in the mapped area are ten small largely serpentinized stocks that cut the Kalabak sequence in the d_2 quadrangle. The largest, on Dede Kirani Sr., is about 550 m by 300 m; four others on Demirölen Sr., range downward in size from 750 m long by 150 m wide. The five remaining stocks are less than 100 m across, and are generally widely separated. All of the serpentinite stocks show steep outward-dipping contacts that cut local foliation and rock types in the Kalabak sequence. The two largest stocks show local screens of hornfels roughly parallel to and along the original intrusive serpentinite-Kalabak contact. However, elsewhere the remaining contacts of the same stocks and contacts of all of the other serpentinite stocks show no evidence of metamorphism. As the local screens of hornfelsed rock are present only near or at places where the serpentinite is intruded by the granodiorite-quartz monzonite batholith, they appear to be a product of that intrusion.

The serpentinite is typically dark green to black, and locally light-bluish green or light-yellow green. Commonly it is irregularly cut by narrow (.5 cm or less) veins of bluish-gray chrysotile asbestos and veins and knots of light-yellowish-green talc. Characteristically the serpentinite stocks show a prominent banded structure in which long ribbonlike bands of spotted dark-green serpentinite alternate with generally narrower bands of lighter colored serpentinite.

Study of thin sections indicates that the spotted bands are composed of relatively coarse-grained partly serpentinized (antigorite) olivine and the lighter bands are composed entirely of finer grained antigorite. Olivine is colorless and anhedral, and adjacent grains show differing positions of extinction, and extinction within grains is nonundulatory. Translation lamellae are absent. The olivine and pseudomorphic antigorite show a mesh structure in which adjacent grains within a band fit together like a mosaic. Shearing of the olivine-antigorite is not apparent in any of the thin sections studied.

The distribution of olivine through many bands, the mesh structure of the olivine-antigorite, and the lack of other mafic minerals or plagioclase or their alteration products, suggests that the original rock in the majority of stocks was a dunite (table 4). Serpentinite from the northernmost two small stocks, northwest of Küruçam Sr., contain scattered pseudomorphs of talc after enstatite and rare blue-green chlorite (pumpellite?) after plagioclase. In those stocks the original rock was apparently a periodotite.

Table 4.--Analyses of serpentinized dunite stocks in the d_2 quadrangle.

[Method used was a single-solution procedure (see Shapiro, 1967)

Analysts: P. Elmore, G. Chloe, J. Glenn, S. Botts, L. Artis, J. Kelsey and H. Smith; U. S. Geological Survey]

Lab. No.	W173 747	W173 775	W173 778	W173 800	W173 801	W173 803
Field No.	13/6/69-4 1/	14/7/69-2 2/	22/7/69-1 2/	1/9/69-4 3/	1/9/69-15 4/	2/9/69-1 4/
SiO_2	43.0	43.8	40.0	39.3	44.5	37.0
Al_2O_3	1.3	.43	1.2	.90	1.3	10.0
Fe_2O_3	5.8	5.6	5.4	5.8	4.1	2.6
FeO	3.3	2.4	1.7	2.5	3.2	5.5
MgO	35.6	35.7	37.2	36.9	36.2	31.1
CaO	1.4	.48	.68	.68	1.8	4.1
Na_2O	.10	.03	.10	.16	.08	.26
K_2O	.03	.00	.03	.00	.00	.06
H_2O+	7.1	9.5	12.1	12.2	7.6	7.5
H_2O-	.66	1.1	.67	.82	.58	.41
TiO_2	.03	.06	.01	.04	.02	.56
P_2O_5	.00	.00	.00	.00	.01	.04
MnO	.20	.20	.08	.17	.14	.17
CO_2	.29	.06	.25	.11	.08	.18
Total	99	99	99	100	100	99

1/ Includes minor wollastonite, a contact-metamorphic effect of the granodiorite batholith.
2/ Chiefly antigorite.
3/ Antigorite and olivine.
4/ Collected near the hydrothermally altered northern end of the longest stock on Demirölen Sr.

The general lack of metamorphism at the serpentinite-Kalabak contact and the lack of shearing of the antigorite suggest that the dunite was intruded as a "cold" crystal mush. In addition, formation of the banded structure, probably originally alternating bands of finely crushed and less finely crushed olivine, must also have taken place prior to serpentinization. Lack of optical strain and translation lamellae may be ascribed to intercrystal fluids that lubricated the dunite-peridotite during intrusion. However, such lubrication might also be expected to have prevented the formation of crush bands. Alternatively, and perhaps more likely, optical strain and translation lamellae were removed by annealing during and following the intrusion of the granodiorite-quartz monzonite batholith. Lack of accord between attitudes in the banded serpentinite and the enclosing phyllite of the Kalabak sequence, and the general lack of shearing of the antigorite also indicate that intrusion and serpentinization postdate regional folding and metamorphism of the Kalabak. Serpentinization may have accompanied intrusion of the batholith or may have occurred at some previous time. Alteration of the serpentinite to talc on the northern end of the large stock on Demirölen Sr. was probably caused by silica-rich fluids given off by the batholith. Contact metamorphism of the serpentinite-Kalabak is discussed in a later section.

Although concentrations of chromite and magnetite were not seen in the field, specimens of serpentinite were collected for Ni-Cr analyses. The analyses of seven specimens show a range of .10 to .26 percent and a median of .12 percent chromium; a range of .14 to .37 percent and a median of .26 percent for nickel (analysts: C. Burton and F. Simon, U.S. Geol. Survey analytical laboratories, written commun., 1970). These percentages are close to the worldwide averages for ultramafic rocks, and they do not suggest any unusual concentrations in the stocks.

The age of intrusion of the dunite-periodotite stocks is not known from direct evidence, however, the stocks do cut the Kalabak sequence, and two of the stocks are cut by the granodiorite-quartz monzonite batholith. A radiometric age date of 24.2 ± 0.9 m.y. B.P. (John Obradovich, U.S. Geol. Survey, written commun., 1971) for the batholith places a minimum age of middle Miocene on the dunite-peridotite intrusions. The fact that these stocks intrude only the Kalabak sequence and never the nearby Halilar Formation also suggests that the stocks were intruded prior to deposition of the Halilar and thus prior to the Late Triassic. The massive character of the antigorite also suggests that the stocks were intruded after the last period of folding and regional metamorphism, the Hercynian (Middle Permian) according to Kaaden (1959, p. 30) and Kalafatçioḡlu (1963, p. 69).

Granodiorite-quartz monzonite

Much of the central western and southeastern parts of the d_2 quadrangle is underlain by a batholith composed of light-colored, coarsely crystalline, and porphyritic rock that ranges in composition from granodiorite to quartz monzonite and very locally to hornblende granite. One small stock of a similar-appearing rock crops out near the Manaster Dere in the east-central part of the d_2 quadrangle; it is correlated with the batholith on the basis of lithologic similarity. The batholith extends to the west, approximately 20 km or more beyond the quadrangle boundary, and it has been mapped (Kaaden, 1959, pl. 1; Gümüş, 1964, pl. 4; Aslaner, 1965, pl. 4) both to the northeast and southwest of the present study area. Its actual extent in those areas is unknown, however, as Kaaden (1959), Gümüş (1964), and Aslaner (1965) included extensive areas of the Halilar Formation within the bounds of the batholith.

Within the mapped area, the batholith discordantly cuts the foliation of the Kalabak sequence and metamorphoses that unit. Excellent exposures are seen 500 m west of Kozcağiz Tepe in the southwest quarter of the d_2 quadrangle. There coarsely crystalline biotite-quartz gneiss dips into the batholith at about 90°, is cut by coarsely crystalline granodiorite-quartz monzonite and stoped into the batholith. Contacts with the Kalabak sequence on the eastern margin of the batholith are sharp, and field relations, as seen on Kadincik Çayi just north of Dede Kirani and on the Kestanelik Dere northeast of Kozcağiz Tepe, indicate an eastward dip on the contact. Chilled contacts or finely crystalline border facies are nowhere seen in the batholith, and the crystal size in the small granodiorite-quartz monzonite stock is essentially the same as that of the batholith. Presumably the country rocks were sufficiently heated that the border areas of the intrusive rock were not chilled. The contact with the Halilar on the northern side of the batholith is less clear because of the lithologic similarity between the batholith and the narrow contact aureole developed in the Halilar. Field relations suggest that the contact dips steeply to the north. Locally, in the headwaters of the Doşeme Dere (d_2 quad.) the batholith-Halilar contact is extensively sheared, and part of the rock is replaced. Biotite and feldspar in the Halilar are replaced by quartz as much as 200 m to the north, away from the contact, and the Halilar is sheared to a progressively greater degree toward the contact. The plutonic rock near the contact is also sheared, although not replaced, and constituent phenocrysts of orthoclase and hornblende are broken, rounded, and somewhat aligned. The discordant contacts and the few stoped blocks suggest that the batholith was injected forcefully, in part by piecemeal stoping, but chiefly by pushing the country rock aside. Granitization does not appear to have been an important process in the emplacement of the batholith at least along this contact.

The granodiorite-quartz monzonite is light or medium gray to light-pinkish gray and weathers to a light-yellowish-gray grus. Megascopically the rock is generally homogeneous, and has conspicuous large (to 5 cm) phenocrysts of pink orthoclase in a coarsely crystalline groundmass of plagioclase, anorthoclase, quartz, hornblende, biotite, and conspicuous sphene. Hornblende is the only mineral seen in the field that varies strikingly in relative quantity.

Plagioclase (An_{45-15}) is subhedral-rectangular, highly corroded and embayed, has oscillatory zoning, and is locally coated with rims of oligoclase-quartz myrmekite. It constitutes from 25 to 40 percent of the rock. Potassium feldspar occurs both as conspicuous large phenocrysts of orthoclase (to 5 cm long) and as completely anhedral masses of anorthoclase enclosing plagioclase, the mafic minerals, and quartz. The orthoclase and anorthoclase constitute from 20 to 40 percent of the rock. Both plagioclase and potassium feldspar are locally sericitized, and orthoclase is locally argillized. Hornblende is unaltered, in euhedral but locally corroded prismatic crystals as much as 1.5 cm long, and is commonly crystallized over small cores of augite. Hornblende constitutes about 15 percent of the rock. Locally, on Kale Teppe near the western border of the d_2 quadrangle, hornblende constitutes as much as 35 percent of a distinctive-appearing hornblende granite over areas as large as a few hundred square metres. Quartz is completely anhedral and commonly shows abundant trails of minute fluid inclusions. It constitutes from 5 to 20 percent of the rock. Well-formed rhombic crystals and irregular masses of sphene as much as 0.5 cm across are a characteristic accessory in most outcrops of the batholith. Rare small euhedral apatite and very rare zircon are typical minor accessories. See table 5 for analyses.

Table 5.--Analyses of the granodiorite-quartz monzonite batholith and the granitic pegmatitic stock. [Method used was a single-solution procedure (see Shapiro, 1967), analysts: P. Elmore, G. Chloe, J. Glenn, S. Botts, L. Artis, J. Kelsey, and H. Smith, U. S. Geological Survey.]

Lab. No.	W173 757	W173 758	W173 784	W173 720	W173 770	W173 771	W173 772
Field No.	19/6/69-5[1]	19/6/69-6[1]	5/8/69-1[1]	14/10/69-3[2]	10/7/69-3[3]	10/7/69-5[4]	11/7/69-1[4]
SiO_2	58.0	60.3	57.7	62.7	74.5	72.9	75.7
Al_2O_3	16.1	15.8	16.3	15.4	12.8	12.7	13.0
Fe_2O_3	3.5	2.6	3.8	2.6	.42	.42	.37
FeO	3.3	3.0	2.6	2.3	.12	.24	.36
MgO	3.2	3.7	3.1	1.6	.24	.35	.12
CaO	6.3	5.5	6.8	4.5	1.0	2.1	.50
Na_2O	3.1	3.2	3.3	3.3	2.5	2.5	3.2
K_2O	2.9	3.2	3.1	3.3	5.9	5.9	5.1
H_2O+	1.0	1.0	.68	1.4	.81	.78	.68
H_2O-	.18	.14	.12	.12	.29	.29	.11
TiO_2	.87	.65	.78	.52	.10	.13	.17
P_2O_5	.49	.41	.50	.25	.02	.01	.03
MnO	.14	.12	.17	.16	.04	.04	.04
CO_2	.11	.06	.66	1.8	.04	.76	.08
Total	99	100	100	100	99	99	99

1/ Collected from the granodiorite-quartz monzonite batholith in the d_2 quadrangle.
2/ Collected from a batholith of similar composition and age in the Şamli area.
3/ Identified in the field as a hornblende granodiorite, collected in the d_2 quadrangle.
4/ Collected from the granitic pegmatite stock in the d_2 quadrangle.

The relative age of the granodiorite-quartz monzonite batholith can be estimated from field evidence as postdating the Late Jurassic and possibly even the Mesozoic, because it intrudes the thrust plate of the limestone of Kocaçal Tepe of Late Jurassic age. The contact is seen about 4.5 km west of Edremit (fig. 1) and north of the village of Yolören west of the mapped area. It also intrudes the Kalabak sequence, the dunite bodies, and the Halilar Formation. Argon ages of 23.5 ± 0.6 m.y. and 24.2 ± 0.9 m.y. on biotite and hornblende respectively (J. D. Obradovich, U.S. Geol. Survey, written commun., 1971) indicate an early Neogene (middle Miocene) age for the rock. Lithologically similar plutonic rock in the Şamli area gives an argon date of 22.1 ± 0.6 m.y. and 21.7 ± 0.7 m.y. on biotite and hornblende respectively (J. D. Obradovich, U.S. Geol. Survey, written commun., 1971) and indicates a younger but still early Neogene (Miocene) age.

Granitic pegmatite

Granitic pegmatite crops out as a small stock near the center of the d_2 quadrangle along the contact of the Kalabak sequence and the granodiorite-quartz monzonite batholith, and as unmapped dikes of variable but generally narrow width that cut the batholith, the Kalabak sequence, and the Halilar Formation.

The stock and the majority of pegmatite dikes consist of graphitic intergrowths of quartz and microcline perthite with sparse to rare highly corroded albite, and rare biotite, hornblende, sphene, and columbite. Niether stock nor dikes show zoning nor minerals other than columbite that are suggestive of complex pegmatites. The dikes range from simple quartz-microcline perthite pegmatite to quartz-rich microcline-poor pegmatite to simple quartz dikes. Both mircocline perthite and albite are commonly unaltered, but locally the albite is highly sericitized and the microcline slightly argillized. Biotite and hornblende are very rare and unaltered. Quartz is common and typically shows the abundant trails of inclusions seen in the quartz of the granodiorite-quartz monzonite batholith. Columbite is present as poorly crystallized tabular crystals throughout the stock; well-crystallized sphene, although less common than in the batholith, is present as an accessory. One pegmatite dike in the southwest corner of the d_2 quadrangle shows rare molybdenite and chalcopyrite throughout.

Pegmatite dikes in the northern part of the d_2 quadrangle in the Dereüstü Tepe area consist of abundant quartz, platy albite (cleavelandite), and fine- to coarse-crystalline muscovite. Thin-section study indicates that the finely crystalline mica is sericite, derived from the alteration of the albite. As all coarse muscovite seen is also enclosed in sericite, it too may be an alteration product. Neither sphene nor columbite is present in these dikes.

Both stock and pegmatite dikes cut the Kalabak sequence and the granodiorite-quartz monzonite batholith and thus postdate these units. An argon age of 22.9 ± 0.6 m.y. (J.D. Obradovich, U.S. Geol. Survey, written commun., 1971) on slightly chloritized biotite also suggests a Neogene (Miocene) age for the granitic stock.

Rhyodacite stocks

Two stocks distinctly different from the rhyodacite-quartz latite stocks noted below crop out in or near the mapped area. The smaller is triangular in outline, about 100 m across, and is 1.7 km north of Çulfa Çukuru near the eastern border of the d_2 quadrangle. The larger stock, probably a volcanic neck, is elliptical, 900 m in width and 1100 m long in a northerly direction, and crops out 4.5 km south of the southwest corner of the d_3 quadrangle at Sulutaş Tepe.

Both stocks are coarsely porphyritic, light to pale gray brown, and contain phenocrysts of plagioclase, hornblende, augite, biotite, and quartz in an abundant light-brown finely crystalline groundmass.

Plagioclase (An_{42-31}) constitutes as much as 25 percent of the rock, and forms large (to 1 cm in length) euhedral-rectangular but corroded phenocrysts that show oscillatory zoning. Hornblende and augite together constitute as much as 15 percent of the rock. Hornblende commonly occurs as elongate well-crystallized prismatic crystals, but it also is present as reaction rims on augite. Augite also forms euhedral crystals without reaction rims of hornblende, or any other indication of reaction with the matrix. Quartz is present as rare rounded and embayed phenocrysts. Apatite, euhedral magnetite, and zircon are typically present but in trace amounts only. The groundmass, as much as 40 percent of the rock, consists of light-brown intergrown quartz and feldspar. See table 6 for analyses.

Table 6.--Analyses of specimens from the Dereören and Sulutaş Tepe stocks

[Method used was a single-solution procedure (see Shapiro, 1967)
Analysts: P. Elmore, G. Chloe, J. Glenn, S. Botts, L. Artis, J. Kelsey, and H. Smith, U. S. Geological Survey]

Laboratory No.	W173743	W172321	W172322
Field No.	1/7/69-1 1/	20/6/68-1 2/	20/6/68-2 2/
SiO_2	60.4	61.7	61.0
Al_2O_3	15.0	15.9	16.2
Fe_2O_3	2.7	2.7	2.3
FeO	2.4	1.5	2.0
MgO	1.9	3.4	2.6
CaO	3.8	5.6	4.7
Na_2O	2.8	3.6	3.6
K_2O	5.0	2.6	2.9
H_2O+	2.1	.91	1.0
H_2O-	.56	1.0	1.6
TiO_2	.56	.40	.46
P_2O_5	.25	.34	.38
MnO	.12	.09	.08
CO_2	2.4	.20	1.2
Total	100	100	100

1/ From a relatively nonprophyllitized part of the Dereören stock.
2/ From the Sulutaş Tepe stock approximately 4 km south of the southwest corner of the d_3 quadrangle.

The relative age of the stocks is well established by field evidence as the small stock north of Çulfa Çukuru clearly cuts the Halilar Formation and metamorphoses the limestone of Kocaçal Tepe. It is thus at least post-Late Jurassic in age. The larger stock south of the village of Karalar (southwest corner d_3 quad.) and outside the mapped area cuts and distorts air-fall tuff of the upper part of the Dede Tepe Formation, and appears to have contributed to the younger tuff in that formation. An argon age of 20.3 ± 0.6 m.y. on biotite and 20.8 ± 0.7 m.y. on hornblende (J. D. Obradovich, U.S. Geol. Survey, written commun., 1971) indicates that the stock is early Neogene (Miocene) in age. The common age, the sequence in time, mineralogic and chemical similarity of the rhyodacite-trachyandesite of the Hallaçlar Formation, the granodiorite-quartz monzonite batholith, the granitic pegmatite stock and associated dikes, the quartz latite of the Dede Tepe Formation, and the rhyodacite to quartz latite stocks suggest that these intrusive and volcanic rocks are comagmatic.

Quartz latite stocks

Two stocks composed of porphyritic hornblende-rich rhyodacite-quartz latite crop out within the d_3 quadrangle and a third crops out just west of the quadrangle near Aşağidamlar. The largest, between Eğmir and Dereören, is rectangular and about 1100 m on a side; the second, at Kedikaya (d_3 quad.), is elliptical and 350 m wide and 550 m long in an easterly direction; the third, 950 m west of Aşağidamlar, is triangular in outline and 600 m wide and 1000 m long, also in an easterly direction.

All three stocks are texturally and mineralogically similar and consist of abundant small phenocrysts of plagioclase, hornblende, and quartz, all in a very finely crystalline matrix. Thin-section study indicates that the rock is largely replaced by calcite, chlorite, and pistacite. Pyrite, common in propylitized rocks, is absent. Plagioclase (An_{20-7}), about 30 percent of the rock, shows abundant irregular inclusions of the groundmass, and it is commonly replaced, first by sericite, and secondarily by calcite. Hornblende, from 20 to 15 percent of the rock, is invariably replaced by a combination of penninite, calcite, and pistacite. It is indicated only by the characteristic rhomb-shaped cross sections. Biotite is sparse to rare, and largely replaced by penninite and calcite. Quartz, from 5 to 10 percent of the rock, is alone unaffected by hydrothermal alteration, but it is typically corroded and embayed. The groundmass consists of very fine grained feldspar microlites and devitrified glass. It is largely replaced by chlorite, calcite, and pistacite. One relatively unaltered specimen from the Dereören stock has been analyzed (see table 6).

The age of these rocks cannot conclusively be proven from field relationships within the mapped area, but evidence seen in the stock west of Aşağidamlar is conclusive. The Kedikaya stock in the central part of the d_3 quadrangle intrudes the Halilar Formation, forms a breccia at the stock-country rock contact, and is thus post-Late Triassic in age. Contacts of the Dereoren stock with the Hallaçlar Formation are generally poorly exposed, and the Hallaçlar could be interpreted as either unconformably overlying the stock or as intruded by the stock. The stock clearly cuts the Halilar, brecciates the sandstone, and secondarily silicifies it as much as 10 m away from the contact. The stock west of Aşağidamlar intrudes the andesitic lava of the Hallaçlar at a nearly vertical angle, brecciates the lava, and forms a silicified aureole that extends for some metres away from the contact. Small dikes from the Aşağidamlar stock can also be seen to intrude the Hallaçlar lava. The stock, therefore, postdates the Hallaçlar Formation, and the other two similar stocks in the d_3 quadrangle are probably of the same age.

CONTACT METAMORPHISM

A contact aureole borders the granodiorite-quartz monzonite batholith in the d_2 quadrangle. The aureole is generally narrow, extending only a few metres from the pluton into the serpentinite, and generally no more than 20 m into the phyllite-marble of the Kalabak sequence. Locally, narrow screens of hornfelsed rock lie roughly parallel to the serpentinite-Kalabak contact. These are present only near the contact of the serpentinite and batholith, and are believed to be part of the aureole of the batholith. Dacite and rhyodacite stocks in or near the mapped area do not show contact aureoles, rather, they are surrounded by zones of hydrothermally altered, chiefly silicified and propylitized rock. Intrusion of the small dacite stock north of Çulfa Çukuru did lead to the recrystallization of the adjacent limestone of Kocaçal Tepe, but without more profound mineralogic changes. Apparently the original small size of these intrusives, combined with a presumed moderate initial temperature, was insufficient to modify the intruded rocks to any great extent.

The sedimentary and regionally metamorphosed rocks of the d_2 quadrangle vary greatly in their reaction to intrusion. Feldspathic sandstone of the Halilar Formation is little affected as the major minerals of the sandstone were stable under conditions of intrusion. The only noticeable change in the sandstone is the replacement of the normal groundmass chlorite by biotite, and the local replacement of both by quartz. Reaction to intrusion by the Kalabak sequence is, on the contrary, more varied, and a number of metamorphic assemblages were formed.

The aureole bordering the granodiorite-quartz monzonite batholith is continuous from the southwest corner of the d_2 quadrangle to Dede Kirani in about the middle of the quadrangle. North of Dede Kirani, the contact and the aureole are largely concealed and little known because of heavy soil and forest cover. Typically the batholith-Kalabak contact aureole, between the southwest corner of the quadrangle and the midslope of Palamutluk Mvk. is about 450 m wide. This relatively wide aureole suggests that the batholith-Kalabak contact dips at a shallow angle to the east.

Typically the batholith metamorphoses the phyllite of the Kalabak to a hornblende-quartz-orthoclase hornfels of the hornblende hornfels facies. Olistoliths of magnesian marble are common within the aureole between Atizi Mvk. and Çal Sr., in the southwest corner of the d_2 quadrangle; they are locally present as far north as the Dede Kirani Sr. All are largely metamorphosed to skarn with the introduction of large quantities of iron, silica, and aluminum. Magnetite is an abundant and ubiquitous mineral throughout the skarn, and occurs along strike of the aureole in combination with pistacite, actinolite, and hydrogrossularite. Locally, on the west side of Çal Sr., and in the isolated patch of Kalabak just west of Çal Sr., specularite-hydrogrossularite hornfels is predominant. Skarn with lesser quantities of iron, generally associated with the magnetite-bearing skarn but farther away from the intrusive contact, consists of hydrogrossularite-vesuvanite-diopside hornfels, and hydrogrossularite-vesuvanite-actinolite hornfels. These rocks are commonly very coarse; garnet and vesuvanite can be determined by crystal form, and the rock might better be called a granofels. The garnet is typically well zoned and shows slight birefringence. Metamorphism in the larger olistoliths decreases abruptly away from the contact to a very coarse-crystalline marble.

Local and impersistent screens of hornfelsed rock between the serpentinite and Kalabak are very narrow, never exceeding 5 m and commonly less. Metamorphic grade generally decreases away from the serpentinite and toward the phyllite, but rock types are telescoped, and patches of hornfels of one grade are commonly isolated in masses of another grade.

Mineral assemblages apparently derived chiefly from the metamorphism of the phyllite include the following: cordierite-hypersthene-anorthite hornfels and wollastonite-vesuvanite-diopside-plagioclase hornfels of the pyroxene hornfels facies; grossularite-diopside-wollastonite-microcline hornfels, grossularite-tremolite-diopside-calcite hornfels, and anthophyllite-cordierite-quartz-biotite-calcite hornfels of the hornblende hornfels facies; and actinolite-biotite-albite hornfels, and zoisite-quartz hornfels of the albite-epidote hornfels facies. Contact metamorphic assemblages derived from the magnesian limestone of the olistoliths consist of brucite-spinel-forsterite-calcite hornfels of the pyroxene hornfels facies; and tremolite hornfels--probably of the albite-epidote hornfels facies.

Contact hornfels of the serpentinite on the west side of the stock on Dede Kirani and on the west side and southern end of the largest stock on Demirölen show fibrous elongate platy anthophyllite and sheves of needlelike cummingtonite isolated in serpentinite. These minerals indicate contact metamorphism to about the amphibolite facies.

STRUCTURAL GEOLOGY

Rocks of the area have been deformed by folding and the formation of thrust or gravity glide faults and normal faults; the older rocks are typically more deformed and younger rocks less so. The oldest unit, the Kalabak sequence, has been folded into both east and northwest-trending, sharply defined, antiforms and synforms; folds in the Halilar are northeast-trending, gentler, and less numerous than those in the Kalabak. The limestone of Kocaçal Tepe and Ayakli, allochthonous plates emplaced by low-angle thrust or gravity glide faults, were apparently not folded after emplacement in the mapped area, but they are cut by numerous northeast-trending high-angle normal faults, and now form elongate horst and graben structures.

Two features that may have influenced the formation of these structural features are the metamorphosed sedimentary-igneous complex known as the Kaz dağ massif, about 15 km to the west, and the granodiorite-quartz monzonite batholith that locally intrudes the west side of the d_2 quadrangle.

The Kaz dağ massif has long been recognized as consisting of a central core of moderate-grade regionally metamorphosed sedimentary and igneous rocks that show a pronounced north-south structural alignment, overlain discordantly by a sequence of low-grade, regionally metamorphosed sedimentary and volcanic rocks having pronounced east-west structural alignment (Schuiling, 1959, p. 89; Kaaden, 1959, p. 17-18). Only recently has Bingöl (1968, p. 117-118) suggested that rocks of the Kaz dağ represent low- and intermediate-grade metamorphic facies of the same depositional sequence in which low-grade rocks from the periphery have been thrust over intermediate-grade rocks of the core. Although we have not studied the low-grade sequence in detail in the Kaz dağ area, and the area between the Kaz dağ and the present map area has not been closely examined, Bingöl (oral commun., 1970) and the authors agree that the Kalabak sequence described here is essentially identical with the low-grade thrust sequence described by Bingöl (1968, p. 57-64) in the Kaz dağ massif. The massif presently shows a northeast topographic trend; that this trend is at least as old as the Late Triassic is indicated by the northeast-trending contact of the Kalabak and the onlapping Halilar. This aspect of the outcrop pattern is, however, not an example of active tectonism, but rather, a passive inheritance from a previously active period.

Folds

Two periods of folding are apparent in the area even though no major folds are seen and only a few folds can be traced more than a few hundred metres. The first period of folding affected the Kalabak sequence. Four minor antiforms and two synforms have been mapped. Axial trends range from northwest to east-west, and the structures plunge both to the east and west. Field evidence for the northeast-trending major "syncline" mapped by Gümüş (1964, pl. 4) was not seen. The generally east-trending axial traces parallel those of the low-grade thrust sequence in the Kaz dağ, and like them may have formed in response to north-south compressional stress. The apposed plunge of a number of the fold axes could be explained as folds lying on the flanks of a northeast-trending antiform, developed after the formation of the east-west folds. Such an antiform could have developed in response to the probably east-west compressional pressures that were responsible for the thrusting of the Kalabak low-grade metamorphic sequence. The formation of the east-trending folds predates the Late Triassic as the folds are truncated and overlain by the Halilar Formation of Late Triassic age.

Where the Kalabak sequence is well exposed, it can be seen to have reacted to folding stresses as an incompetent member. The best examples are seen on Domuzanli Dere (d_2 quad.) just east of the largest group of serpentinized dunite bodies. There, for example, axes of two minor folds crop out less than 3 m apart; one fold, a synform, plunges north and is overturned to the west; the other, an antiform plunges east and is overturned to the north. This apparently chaotic distortion may have been produced during the Middle Permian Hercynian period of folding and regional metamorphism or during the post-Hercynian but still pre-Late Triassic period of dunite intrusion.

Folds are not seen in the massive lower member of the Halilar Formation, and are only locally seen in the middle and upper members. Reasons for the latter are that the middle member is generally highly distorted by closely spaced faults, and that the upper member is silicified over much of its outcrop area, and primary bedding features are destroyed.

A northeast-trending syncline was traced for over 700 m in the shaly middle member of the Halilar just west of Kedikaya in the d_3 quadrangle before the axial trace was lost in a jumbled mass of fault blocks. A north-trending syncline to the south in the limestone of Kocaçal Tepe in the hill of the same name may be a continuation of the syncline near Kedikaya, or it may be an unrelated fold produced during or before the thrusting of the limestone. The difference in strike of the synclinal axes and the fact that the thrust fault under the Kocaçal Tepe plate cuts moderately dipping beds in the upper member of the Halilar in the Akpinar Sivrisi area suggests that the folds are unrelated and that the limestone of Kocaçal Tepe was folded before or during emplacement. Both folds, however, plunge to the south. A second northeast-trending fold axis, also a syncline, is mapped in the upper member of the Halilar just west of the Dereören stock in the d_3 quadrangle. Timing of the folding of the Halilar must be post-Late Triassic, the age of deposition of the Halilar, and pre-Late Jurassic, the earliest date at which the limestone thrust could have cut the already folded Halilar.

Faults

Faults in the mapped area are of two types: low-angle thrust or gravity glide faults that underlie the limestones of Kocaçal Tepe and Ayakli, and high-angle normal faults that cut most of the layered units in the area and form a series of elongate horst and graben structures in the northwest-central part of the area.

Kocaçal Tepe thrust

Evidence in the mapped area indicates that the limestone of Kocaçal Tepe of Late Jurassic age is an allochthonous low-angle thrust or gravity glide plate overlying the Bağburun and Halilar Formations. The thrust relationship is best seen in the Akpinar Sivrisi area of the d_2 and d_3 quadrangles. There, beds in the limestone dip about 47° NNW., and beds in the Halilar less than 3 m beneath the nearly horizontal contact dip 35° SE. Other examples in which steeply dipping beds in the limestone can be seen to abut against the nearly horizontal contact of the limestone and underlying rock are seen on the western side of Ustunluk Mvk 1.7 km southeast of Akpinar Sivrisi (d_2 quad.), Sülfarlik Tepe just north of Sarniçköy (d_3 quad.), and just north of Imam Pinar (d_2 quad.) 1.3 km northwest of Akpinar Sivrisi. Interestingly, sandstone at the sandstone-limestone contact in the Akpinar area has been broken into a coarse, very angular breccia cemented with clear calcite. Brecciation decreases downward away from the contact and ceases about 2 m from the contact. The blocks, about 6 cm on a side, retained their angularity. Presumably the fracturing of the sandstone resulted from the drag of the overriding limestone plate. No indication of rotation of the sandstone blocks is apparent.

A breccia composed of limestone clasts in a light-orange-brown matrix crops out locally from Ballicak Tepe, south of Sarnicköy, northward to Kayali Tepe in the Çulfa Çukuru area of the d_2 quadrangle. The breccia is invariably restricted to the contact of the limestone of Kocaçal Tepe and the underlying rock. Typically the breccia is lens shaped or podlike, and, locally in the southeast quarter of the d_2 quadrangle near the head of Davulkuluçukur Dere and on Sakarkaya Tepe, is as much as 25 m thick. The breccia is completely massive and composed of angular, somewhat tabular clasts, 1-2.5 cm across, of pale-gray-brown, dense calcarenite exactly like that of the overlying limestone of Kocaçal Tepe. Finely ground, pale-orange-brown limestone constitutes 90 percent of the matrix; angular clasts of quartz, sericitized plagioclase, and very rare, angular, highly altered, quartz-bearing-lithic volcanic clasts comprise the remaining ten percent. Quartz, feldspar, and volcanic lithic clasts like those in the breccia matrix are unknown in the limestone of Kocaçal Tepe or in the limestone clasts in the breccia. Clearly they are derived from the underlying Halilar and locally the Bağburun Formations. Although the breccia is normally tightly cemented, outcrops in the Morkemic (d_3 quad.) area show clasts with only a thin coating of matrix, enough to cement the clasts together at points of contact, but not enough to fill the interstices.

The formation of the limestone breccia is difficult to explain by any other than structural means. We believe that it is a friction breccia sloughed off the limestone and to a slight extent the underlying sandstone or volcanic breccia during movement of the limestone over the underlying rock. Breccia along the Bağburun-limestone contact in the Bakcak area west of Sarnıçköy and elsewhere consists of a compound volcanic breccia; that is, a volcanic breccia that has been rebrecciated. This breccia commonly shows a pronounced hematite stain, stronger near the Bağburun-limestone contact and ceasing about 10 m below the contact. There is no evidence of hydrothermal activity to explain the presence of the hematite stain. The restriction of the stain to the Bağburun-limestone contact and the fact that the limestone lies directly on both the Halilar and Bağburun Formations suggests that the allochthonous limestone plate may be resting on an erosion surface, and that the hematite-stained breccia may be an old soil horizon.

Although the aerial extent of the allochthonous limestone plate is not known from previous studies, the plate clearly comprises the large block of limestone north and just west of Edremit. It also extends as far east as Balya (fig. 1) where the structural relationship of the limestone and underlying rocks was correctly described by Aygen (1956, p. 84-85), and to Şamli where it was noted by G. W. Leo (U.S. Geol. Survey, oral commun., 1969).

The thrust relationship of the limestone of Ayakli and the underlying sandstone of the Halilar Formation is indicated only by paleontologic evidence, that is, Permain overlies Triassic; as both the limestone and sandstone are without bedding, structural evidence of thrusting is not available. It is possible that the Kocaçal Tepe and Ayakli thrust plates are one; that is, a single thrust fault affected both rock units, or it is possible that the limestones were emplaced as two separate thrusts. Clearly, emplacement of the blocks predates the Miocene Hallaçlar Formation, as blocks of both allochthonous limestones and the surrounding autochthonous rocks are covered by the andesitic lava flows of the Hallaçlar Formation. Late Mesozoic-Middle Tertiary movement of allochthonous low-angle thrust plates is now seen to extend in an arc from central Turkey (Bailey and McCallien, 1953, p. 437-438) through the present study area, and to the Greek Peloponnesos (Temple, 1968, p. 692-693). The mechanism of emplacement, however, is moot. Temple (1968, p. 694) has suggested large-scale gravity sliding off sequentially formed fold crests to explain the features seen in the Peloponnesos, and he dismisses the possibility of a rooted thrust "because of the extreme incompetency of the strata, which could not conceivably have transmitted lateral stress for any appreciable distance." The limestones of Kocaçal Tepe and Ayakli, although fractured throughout, maintained their structural identity and were apparently more competent than the units studied by Temple, and the possibility of a rooted thrust moving south from the North Anatolian rise cannot in this area be dismissed.

High-angle normal faults

High-angle normal faults are concentrated chiefly in the pre-Tertiary rocks of the northwest-central part of the mapped area, whereas faults in the pre-Tertiary rocks of the southeast part of the area and in the widespread volcanic rocks of Tertiary age are relatively rare. This rarity of faults, however, may be more apparent than real, as the extreme alteration of the Hallaçlar and the internal lithologic uniformity of the Hallaçlar and the Dede Tepe tend to obscure the evidences of faulting.

The high-angle faults can be divided into two sets, one striking N. 20°-45° E., and the other N. 40°-60° W. Although dips vary locally along strike, both sets are essentially vertical. The faults appear normal, and the throw, based on the displacement of the base of the limestone of Kocaçal Tepe, is generally less than 50 m. The northeast-trending set persists for long distances along strike, commonly offsets the northwest-trending set, and forms a series of horsts and grabens elongated to the northeast. The offset relationship is not constant over wide areas, however, and it is clear that the northwest-trending set predates and postdates the formation of the northeast-trending fault set. Strike slip movement on the northeast-trending fault set is seen in only one right-lateral fault that bounds the major part of the Egmir hematite deposit on the north. The right-lateral cuts and displaces to the right a high-angle normal fault that trends north-northeast. Most of the long, northeast-trending faults cut the limestone of Kocaçal Tepe and two cut the Bağburun and Hallaçlar Formations, indicating that one and possibly all the faults postdate the Miocene. The normal faults are related in time to the intrusion of the granodiorite-quartz monzonite batholith, and they may have formed as a result of that intrusion. A number of the high-angle faults, including the definitely post-early Neogene (Miocene) fault, are of particular interest as they are mineralized with galena, sphalerite, chalcopyrite, pyrite, and hematite after pyrite.

Although the volcanic rocks of the area appear unaffected by folding and largely unaffected by faulting, positive proof is lacking as the major part of the Hallaçlar has been altered and the flow foliation destroyed, and the major part of the Dede Tepe consists of nonbedded mudflow deposits. Atttitudes of flow foliation, where preserved in the Hallaçlar, and bedding in the air-fall tuff of the Dede Tepe show no coherent structural picture; the attitudes appear to have been dependent on the configuration of the surface of deposition rather than on postdepositional folding.

GEOLOGIC HISTORY

The following sequence of events, although undoubtedly incomplete and with some questions unresolved, presents our ideas on the geologic history of the mapped area: 1) deposition of mudstone, siltstone, shale, limestone, and tuff, probably in a marine eugeoclinal environment, prior to the Late Triassic. 2) Uplift, regional metamorphism of the section to phyllite, schists, and marble of the Kalabak sequence, folding of the sequence into east-west oriented folds, and possible thrusting of the folded sequence over higher grade regionally metamorphosed rocks of the same sequence now exposed in the Kaz dağ massif, probably during the Middle Permian or Hercynian orogenic period. 3) Intrusion of dunite and peridotite bodies, probably during the Late Permian. 4) Erosion. 5) Marine onlap and the deposition of feldspathic sandstone, arkose, shale, and conglomerate of the Halilar Formation, during the Late Triassic. 6) Subaerial deposition of the dacitic volcanic rocks of the Bağburun Formation, during the Paleogene or less probably the Cretaceous. 7) Erosion. 8) Movement from the North Anatolian rise into the area of one or more low-angle allochthonous thrust or gravity glide plates of the limestones of Kocaçal Tepe and Ayakli, during the early Paleogene or the Cretaceous. 9) Erosion. 10) Subaerial deposition of the volcanic lavas of the Hallaçlar Formation, during the Miocene. 11) Intrusion of a granodiorite-quartz monzonite batholith followed shortly by the intrusion of a granitic pegmatite stock and dikes, and accompanied by folding of the overlying rocks into northeast-oriented folds, during the Miocene. 12) Argillization of the Hallaçlar Formation, conversion of the iron from mafic minerals to pyrite, and the concurrent silicification of the upper part of the Hallaçlar by hydrothermal solutions, serpentinization of the dunite-peridotite bodies (if this had not occurred previously), and contact metamorphism of the serpentinized dunite, during the Miocene. 13) Erosion. 14) Deposition of the volcanic rocks of the Dede Tepe Formation and stocks of similar composition. 15) Erosion. 16) Deposition of lacustrine conglomerate, sand, and silt, during the Neogene. 17) Intrusion of stocks near Dereören, Aşağidamlar, and Kedikaya, accompanied, preceded, or shortly followed by high-angle normal faulting. 18) Local mineralization of the normal faults with galena-sphalerite-chalcopyrite, stibnite, and mineralization of some faults and adjacent fault block surfaces with hematite (iron derived from the oxidation of pyrite near stocks, probably in the late Neogene. 19) Deposition of alluvium and the formation of landslide deposits during the Quaternary.

ECONOMIC GEOLOGY

Mineral deposits within the study area include hematite, magnetite, galena-sphalerite-chalcopyrite, molybdenite, stibnite, and gold. Currently the only deposits being worked in the area are the hematite deposits of the Eğmir and Aşağidamlar areas. Base-metal mining has had a long history in the area, and was carried on intermittently until the winter of 1968 when the Halilar mine was at least temporarily abandoned. Prospect pits and short adits in deposits containing magnetite, molybdenite, stibnite, and some base metals all have been abandoned. Some of these deposits, however, may be of economic interest, and the extent and tenor of the deposits should be determined. Magnetite deposits within the area are clearly related to the intrusion of the granodiorite-quartz monzonite batholith; and hematite and base metal deposits are probably also genetically related to the intrusion of the batholith and its differentiates, but proof in the form of direct field evidence is lacking.

Hematite and magnetite deposits

Eğmir deposits

The Eğmir hematite deposits lie along the northern part of the boundary between the d_3 and c_4 quadrangles, along a northeast-trending ridge, south of, under, and north of the village of Eğmir. The deposits consist chiefly of a sequence of east-dipping, hematitized, volcanic breccia beds in which the clasts are silicified rhyodacitic lava and tuff, and the abundant matrix consists of hard to soft, earthy hematite. The deposit is exposed to the deepest level in the pit south of the village, and there the beds can be seen to be thicker and the clasts larger toward the west, and thinner and smaller toward the east, in the direction of dip. Bedding is only rudely developed between breccia layers, and bedding within the matrix of a single bed is absent. The northern pit complex appears to have penetrated chiefly the upper part of a thick, massive, nonsorted, hematitized breccia like that that caps the deposit to the south.

The major part of the Eğmir deposit is limited on the north by a northeast-trending high-angle right-lateral fault. The right-lateral fault cuts an older north-northeast-trending high-angle normal fault which is downthrown on the east. The northern part of the normal fault cuts across the nose of Taş Burun, and forms the western border of a small and low-grade segment of the ore body. The southern part of the normal fault is largely covered by mine dumps, but it is indicated by a north-northeast-trending zone of specular hematite that shows slickensides. This southern part of the normal fault appears to limit the major part of the ore body to the west. A second high-angle normal fault downthrown on the west limits the ore body to the east and south of the right-lateral fault. This normal fault has not been traced as far as the right-lateral fault, and it appears that the erosion of the valley of the Kalahisar Dere has removed the former northeastern extension of the ore body. Structurally the ore body lies in a northeast-trending graben, well exposed in the southern pit, and apparently only superficially exposed in the northern pit.

Rock surrounding the Egmir deposit consists of intensely and extensively altered rhyodacite of the Hallaçlar Formation. The rock, like that over much of the d_3, c_4, and c_1 quadrangles is largely argillized and partly silicified. The altered rock shows no evidence of the original feldspar, biotite, amphibole, pyroxene, magnetite, or secondary pyrite. Rhyodacitic lava and tuff in the area are completely silicified, and only the original embayed quartz phenocrysts and finely granular quartz pseudomorphs after feldspar indicate the original texture of the rock. Pyrite, an abundant constituent of the argillized Hallaçlar in most areas, is strikingly absent. A roughly rectangular, 1.45 km long by 1.1 km wide, prophylitized quartz latite stock and a smaller irregular quartz latite stock intrude the altered rhyodacite only a few hundred metres from the ore body. High-angle normal faults that cut the country rock abut against, but do not cut, the stocks. The stocks either postdate the faults, or the intrusion of the stocks may have been responsible for the faulting.

Aşağidarlar deposit.--Hematite deposits in the Aşağidamlar area on the western border of the d_3 quadrangle are strikingly similar to those in the Eğmir area. The mineralized rock near Aşağidamlar consists of a sequence of rudely layered hematitized volcanic breccia, thicker and with coarser clasts toward the southwest, and thinner and with smaller clasts toward the northeast, the direction of dip. The breccia consists of angular silicified andesite clasts in a matrix of earthy hematite. Fossil leaves, sparse in the Eğmir deposits and abundant in the Aşağidamlar deposits, appear identical to the leaves of the Çinar tree (plane tree) Platanus sp. that grows in the area today. The deposit is limited to the southwest by a northwest-trending high-angle normal fault, downthrown on the northeast. Silicified andesite forms the upthrown block and presently contributes a talus of silicified andesite clasts to the surface of the downthrown block. A prophylitized quartz latite stock like that near the Eğmir area intrudes argillized andesite 1.7 km west of Aşağidamlar, and the high-angle normal fault noted above abuts against but does not cut the stock. Again pyrite is absent from the argillized andesite in the immediately surrounding area. We do not believe that these similarities can be considered coincidental, but rather, that they strongly suggest a similar origin for the deposits.

98a follows

The following is our current thinking on the history of hematite mineralization of the Eǧmir and Aşaǧidamlar areas: 1) deposition of the lavas and tuff of the Hallaçlar Formation; 2) erosion; 3) intrusion of the granodiorite-quartz monzonite batholith at shallow depth beneath the area; 4) argillization of the Hallaçlar by fluids given off by the batholith; 5) conversion of the iron-bearing minerals to pyrite, and concurrently the silicification of the upper part of the Hallaçlar section; 6) normal faulting; 7) erosion and the formation of talus deposits on the dowthrown fault blocks; 8) intrusion of the quartz latite stocks; 9) oxidation of the pyrite, and transfer of the iron via nearby faults to a surface or near-surface environment where the iron was deposited as hematite in talus deposits that lay on the down-thrown sides of the faults. Lake beds south and a few tens of metres west of the Dereoren quartz latite stock are also mineralized with hematite. This mineralization may be genetically related to that at the Eǧmir mine.

Jacobson and Türet (U.S. Geol. Survey, written commun., 1970) have studied the Eğmir deposit and have made a series of recommendations regarding future studies of the deposit. Their recommendations include the following: 1) a sampling program to determine the amounts and distribution of deleterious elements such as copper and arsenic; 2) concentration tests; 3) cost-factor studies; and, if the deposit is of sufficient economic interest, a second stage of 4) drilling and sampling to determine tonnage and grade; 5) detailed geologic mapping; 6) diamond drilling to prove additional reserves beyond the present mine area; 7) pilot plant testing of the previously worked out concentrating and sintering procedures; and 8) a detailed economic feasibility study. As their suggestions are detailed, no additional recommendations as to the exploitation of the Eğmir deposit will be made here. Exploration for iron ore in western Turkey might profitably include examination of areas of altered, pyritized andesite near plutons of intermediate composition, particularly near associated quartz latite stocks.

Atizi Mvk. deposits

Magnetite-bearing skarn occurs in the contact aureole between Atizi Mvk. and Kozağdiz Mzl. (cemetery) and in the small mass of Kalabak isolated within the granodiorite batholith just west of Çal Sr. in the southwestern quarter of the d_2 quadrangle. The lithology of both areas has been noted in the section on contact metamorphism. The magnetite deposits are small, scattered along the intrusive contact, and are contaminated with contact metamorphic silicate minerals and base-metal sulfides (table 7). All magnetite bodies that crop out have been prospected, and all prospects have been abandoned. None of the magnetite bodies appears to be of economic interest.

Table 7.--Partial semiquantitative spectroscopic analyses of samples from mineralized areas in and near the Balikesir I 18 c_1, c_4, d_2, and d_3 quadrangles

[Results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are to be reported as mid-points of these brackets, 1, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of a reported value is approximately plus or minus one bracket at 68 percent confidence or two brackets at 95 percent confidence. Analysts: J. L. Harris and N. Rait, USGS] N = not detected, at limit of detection or at value shown; L = detected, but below limit of determination or below value shown. All values are reported in parts per million.

	Contact metamorphic aureole, Atizi Mvk., SW-d_2	Bağirkaç Mine [1/]	Çulfa Çukuru Mine		Halilar Mine		Boxworks of irregular, mineralized areas in d_2 quad			Sinlikurşun Mine just north of N. border, d_2 quad			Breccia from normal faults in limestone of Kocaçal Tepe		Molybdenite-bearing pegmatite		
Lab. No.	W173 767	W173 753	W173 798	W173 805	W173 308	W173 740	W173 749	W173 750	W173 751	W173 754	W173 755	W173 756	W173 739	W173 765	W173 768	W173 769	W173 806
Field No.	9/7/ 69-1	18/6/ 69-4	24/7/ 69-1	22/9/ 69-7	22/5/ 68-2	22/5/ 68-3	17/6/ 69-1	17/6/ 69-2	17/6/ 69-3	19/6/ 69-2	19/6/ 69-3	19/6/ 69-4	4/9/ 69-17	7/7/ 69-1	9/7/ 69-8	9/7/ 69-9	9/10/ 69-5
Mn	30000	15000	100000+	100000+	700	700	3000	500	200	10000	3000	1500	150	500	200	3000	500
Ag	N	1500	700	500	300	300	10	100	20	700	2000	700	N	N	N	N	N
Bi	N	3000	30	N	N	N	N	70	N	100	200	70	N	N	N	N	N
Cd	N	N	500	300	1500	2000	N	N	N	5000	3000	500	N	N	N	N	N
Co	70	1500	20	N	20	20	N	N	N	15	50	N	N	N	N	N	N
Cu	3000	100000	700	700	3000	1000	500	1000	300	15000	15000	15000	7	7	50	700	700
Mo	20	7	7	20	5	20	N	30	7	70	20	50	N	N	700	1000	10
Pb	50	3000	100000+	100000+	100000+	100000+	1500	2000	2000	100000+	3000	5000	30	50	70	500	700
Zn	7000	700	20000	20000	100000+	100000+	N	N	N	100000+	100000+	90000	N	N	N	N	N

1/ Samples from the Bağirkaç, Çulfa Çukuru, and Halilar Mines and the irregular mineralized areas in the northern part of the d_2 quadrangle are composite; others are single grab samples.

Table 7.—Partial semiquantitative spectroscopic analyses of samples from mineralized areas in and near the Balikesir I 18 c_1, c_4, d_2, and d_3 quadrangles. [Results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are to be reported as mid-points of these brackets, 1, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of a reported value is approximately plus or minus one bracket at 68 percent confidence or two brackets at 95 percent confidence. Analysts: J. L. Harris and N. Rait, U.S. Geological Survey. N = not detected, at limit of detection or at value shown; all values are reported in parts per million.]

Lab. no.	Field no.	Mn	Ag	Bi	Cd	Co	Cu	Mo	Pb	Zn	Location
		Elements reported in parts per million									
W173 767	9/7/ 69-1	30000	N	N	N	70	3000	20	50	7000	Contact metamorphic aureole, Atizi Mvk., SW-d_2
W173 753	18/6/ 69-4	15000	1500	3000	N	1500	100000	7	3000	700	Bağirkaç mine[1]
W173 798	24/7/ 69-1	100000+	700	30	500	20	700	7	100000+	20000	Çulfa Çukuru mine
W173 805	22/9/ 69-7	100000+	500	N	300	N	700	20	100000+	20000	Çulfa Çukuru mine
W173 308	22/5/ 68-2	700	300	N	1500	20	3000	5	100000+	100000+	Halilar mine
W173 740	22/5/ 68-3	700	300	N	2000	20	1000	20	100000+	100000+	Halilar mine
W173 749	17/6/ 69-1	3000	10	N	N	N	500	N	1500	N	Boxworks of irregular, mineralized areas in d_2 quad.
W173 750	17/6/ 69-2	500	100	70	N	N	1000	30	2000	N	Do.
W173 751	17/6/ 69-3	200	20	N	N	N	300	7	2000	N	Do.
W173 754	13/6/ 69-2	10000	700	100	5000	15	15000	70	100000+	100000+	Sinlikurşun mine just north of N. border, d_2 quad.
W173 755	19/6/ 69-3	3000	2000	200	3000	50	15000	20	3000	100000+	Do.
W173 756	19/6/ 69-4	1500	700	70	500	N	15000	50	5000	90000	Do.
W173 739	4/9/ 69-17	150	N	N	N	N	7	N	30	N	Breccia from normal faults in limestone of Kocaçal Tepe
W173 765	7/7/ 69-1	500	N	N	N	N	7	N	50	N	Do.
W173 768	9/7/ 69-8	200	N	N	N	N	50	700	70	N	Molybdenite-bearing pegmatite
W173 769	9/7/ 69-9	3000	N	N	N	N	700	1000	500	N	Do.
W173 806	9/10/ 69-5	500	N	N	N	N	700	10	700	N	Do.

1/ Samples from the Bağirkaç, Çulfa Çukuru, and Halilar mines and the irregular mineralized areas in the northern part of the d_2 quadrangle are composite; others are single grab samples.

Base-metal deposits

Base-metal deposits in the mapped area are known in veins cutting the contact-metamorphic magnetite deposits described above, and in association with faults cutting the Kalabak sequence, the Halilar Formation, and the limestone of Kocaçal Tepe. Base-metal deposits have been prospected in the contact magnetite deposits noted above, but probably only incidentally to the search for iron-ore deposits, and base metals have been mined from faulted areas of the Kalabak sequence (Bağirkaç mine in the northeastern quarter of the d_2 quadrangle), from faulted areas in the limestone of Kocaçal Tepe (Çulfa Çukuru area near the d_2-c_1 quadrangle boundary), and from faulted areas in the Halilar Formation (Halilar mine near the village of the same name, near the northern border of the d_3 quadrangle). All these mines have been abandoned, but in each mine, study indicates the possibility of additional ore. Numerous abandoned base-metal prospects and a number of heretofore unknown deposits are now known in the mapped area. All are indicated on the geologic map (pl. 1). Faults known to be mineralized with base metals, pyrite, or hematite after pyrite are indicated on the geologic map as an aid to exploration.

Atizi Mvk. deposit

Base-metal deposits in contact-metamorphic rocks are found only in the area of magnetite-bearing skarn developed between Atizi Mvk. and Kozcağiz Mzl. in the d_2 quadrangle. The mineralization consists of galena, sphalerite, and sparse chalcopyrite with relatively abundant quartz and pyrite gangue (table 7) in thin, impersistent, and irregularly spaced veins. Minor malachite and aurichalcite are also present in a poorly defined zone away from the sulfide zone and closer to the nonmetamorphosed country rock. No veins were seen to penetrate the nonmetamorphosed country rock. Veins appear both wider and closer spaced near the contact, but no veins were seen to cross the batholith-country rock contact. The apparent lack of base-metal mineralization on either side of the contact zone, and the irregularity and general paucity of veins suggest that the deposits are of no economic value.

Base-metal mineralization is also known in the fault that cuts the Kalabak and Halilar near Elmacikücü Sr. just south of the center of the d_2 quadrangle, at two closely spaced localities along the Kalabak-Halilar contact in the northwest corner of the d_2 quadrangle, along a fault between the Kalabak and Halilar a few tens of metres northwest of Düztarla Mvk. near the south-central border of the d_2 quadrangle, and along a fault that cuts the Kalabak in the southwestern corner of the d_2 quadrangle.

Kelkiran deposit

Gouge lying in a short high-angle fault 600 m southeast of Kelkiran Mvk. in the southwest corner of the d_2 quadrangle was mined and the mine opening concealed at some past time. The base metals are deposited in the banded marble of the Kalabak sequence. Interestingly, rock within the western end of the fault zone consists of an abundant hematite-red, fine-grained matrix with common, irregular masses of crystalline, clear, yellow garnet, apparently hydrogrossularite.

Bağirkaç deposit

Base-metal mineralization in the rocks of the Kalabak sequence is best seen in the Bağirkaç mine in the northeastern quarter of the d_2 quadrangle. A tape-and-compass map and cross sections of the southern part of the mine area (figs. 2, 3, 4, 5) were made as an aid in assessing the economic potential of the deposit. Upper and lower margins of the pit faces and one mine terrace are mapped, and rock types and mineralized areas within the pits are indicated. Floors of the pits are covered with rubble, and rock types at the surface or in the subsurface are not indicated unless strongly suggested by nearby structures.

Rocks outside the mine pits crop out poorly and most surfaces are covered by float. Float and minor outcrop seen by the writers in the area immediately surrounding the mine consist of black to dark-greenish-gray phyllite. Characteristically the phyllite includes variable amounts of very thin bedded, gray metasiltstone, and locally some minor chlorite. Although the phyllite and metasiltstone have not been differentiated and are shown only as phyllite on the geologic map of the mine area (fig. 2), they have been separated in plots of the drill cores.

Outcrops of mineralized beds are limited to the south and west walls of the northern pit, the eastern wall of the smaller southern pit, to a small prospect pit 45 m west of the southern pit, and to the lower walls and floor of an adit cutting the east wall of the entrance to the northern pit. Mineralization is most commonly fine to medium crystalline disseminated (uncommonly massive) replacements of epidote-chlorite schist, metasiltstone, and marble. Faults cutting the mine area and the mineralized beds commonly show little or no mineralization.

The major outcrop of mineralized beds in the northern pit consists chiefly of interbedded phyllite, metasiltstone, and some epidote-chlorite schist. The metasiltstone and some of the phyllite are mineralized with disseminated sphalerite, galena, limonite-hematite, and very rare chalcopyrite (table 7). These beds strike west-northwest, dip north-northeast, and are cut by three faults: a) on the north by a normal fault (N. 63° W., 51° NE.), fault 4 on the map (fig. 2); b) on the east by a reverse fault (S. 30° W., 59° SE.), fault 6 on the map; and c) by a normal fault cutting the center of the outcrop (N. 61° E., 75° SE.), fault 1 on the map. Fault 1 clearly cuts fault 4, and fault 4 is also cut by fault 6. Throw and heave on all faults are unknown as key marker beds are lacking in the exposed section. Projected to the northeast (fig. 4) fault 5, and the sparsely mineralized beds seen in the adit show an apparent correlation with the section revealed in drill core of test hole SJ2. Sparsely mineralized phyllite (fig. 4) exposed in the floor of the adit and on the northern wall of the northern pit of figure 2 apparently correlates with mineralized phyllite and metasiltstone at about 570 m in SJ2. A greater incidence of phyllite in the drill core section can be attributed to minor facies changes over the intervening space. Mineralized beds in the foot wall southwest of fault 4 may lie between the 560 m and 552 m level in SJ2. This, however, forces the correlation of mineralized metasiltstone and phyllite in the mine pit with mineralized interbedded marble and epidote-chlorite schist, and phyllite in the test-hole section. Mineralized beds in the hanging wall of fault 7 are not seen in SJ2, probably because they have been displaced by faults 5 and 6.

Projection to the east of the major mineralized beds and faults (fig. 3) suggests that mineralized beds cropping out in the mine pit extend about 6 m to the east before they are cut by a normal fault, fault 5, and downthrown on the east. The throw is unknown. Mineralized beds in the downthrown hanging wall of the normal fault may continue to the east below the section shown in the core of SJ3, or these mineralized beds may be partially or completely cut by reverse fault 6. In this case the mineralized beds could be structurally thickened because of a westward displacement of the hanging wall.

The major outcrop of mineralized beds in the southern pit consists, from the base, of sparsely mineralized interbedded marble and phyllite, nonmineralized epidote-chlorite schist, mineralized epidote-chlorite schist 1 to 2 m thick, a second nonmineralized epidote-chlorite schist, and an upper 3-m-thick mineralized epidote-chlorite schist. Mineralization consists of fine- to medium-crystalline disseminated (rarely massive) sphalerite and galena with minor limonite. Projection of this sequence and faults (fig. 5) to hole SJ3 suggests a complete lack of correlation between the two sequences. Facies change between the two sequences might account for differences, but a fault between the pit and SJ3 is more likely.

Çulfa Çukuru deposit

Base-metal mineralization in the Çulfa Çukuru area affects the limestone of Koçaçal Tepe and possibly the underlying Bağburun and Halilar Formations. Mineralization seen at the surface is concentrated in the limestone along two north-northeast-trending high-angle faults that form a small graben just west of Çulfa Çukuru and along a cross fault that limits the limestone to the northeast. The limestone east of the Akpinar Dere, both in the graben and southeast of the graben, shows massive replacement bodies in addition to the fault-controlled deposits. Mineralization consists of sphalerite, galena, and some chalcopyrite in an abundant gangue of quartz and silicified limestone. The mineralized zone in the southeastern graben fault ranges from 40 to 70 cm wide at stream level; the fault is covered with colluvium about 6 m above stream level. Outcrops along the fault toward the northeast are poor but the ore appears to be concentrated in pods rather than strung out evenly along the fault. The area of the intersection of the southeast graben fault and the pregraben fault shows abundant clasts of gossan, but an outcrop is lacking. Massive replacement bodies in the limestone, apparently not controlled by faults or bedding, have been mined wherever they cropped out; but considerable ore appears to remain in walls and roofs of the old mine chambers, and previously undetected replacement bodies may still be present.

Halilar deposit

Base-metal mineralization in the Halilar mine is restricted to a single eastward-dipping high-angle normal fault that juxtaposes the shaly middle member downthrown on the east, and the lower sandstone member on the west. Mineralization appears restricted to a 1-1.5-m-thick zone of fault gouge, and consists of galena, sphalerite, and some chalcopyrite in an abundant gangue of quartz and pyrite (table 7). The mine consists of two small, similarly mineralized pits located on the same fault trace. Base-metal minerals in both pits occur in laterally and vertically impersistent pods and veins of crystalline quartz. Short joints that cross the mineralized parts of the fault are barren, and apparently postdate the time of mineralization. Outcrops along the fault to the north and south show no indications of base-metal sulfides or their oxidized equivalents, but they do show a persistent and locally strongly developed hematite stain. Trenching of the fault in these areas indicates that the hematite is produced by the oxidation of pyrite. Intense hematite stains along faults, therefore, may be a good surficial guide in base-metal exploration of faults in the area.

Known deposits of base-metal sulfides in the Edremit area generally are localized in high-angle faults in the country rock 2 to 3 km from the batholith. Significantly one noneconomic deposit cuts the contact aureole in the Atizi Mvk. area in the southwest corner of the d_2 quadrangle, and suggests the source of the base metals.

Veins of base-metal sulfides cut the magnetite and calc-silicate hornfels of the contact aureole in the Atizi Mvk. area, and suggest the following sequence: 1) concentration of the base metals within the proto-batholith magma; 2) cooling and subsequent fracturing of the border zone and aureole; 3) escape of magmatic fluids and contained base metals; 4) deposition of the base-metal sulfides in the contact aureole and beyond in high-angle faults. Alternatively, if the base metals had been held in the country rocks prior to the intrusion of the batholith, they would have been concentrated by available pore and magmatic fluids, moved out of the area in response to the intrusion of the batholith, and deposited in a cooler environment at some distance from the batholith.

The economic potential of the mineralized faults in the northern part of the d_3 quadrangle and in the d_2 quadrangle has not been demonstrated, and further exploratory work is clearly warranted. We strongly suggest that an intensive geochemical sampling program be undertaken along all faults showing base metals, pyrite, or hematite after pyrite in this area.

Molybdenite

Molybdenite is a minor constituent along with chalcopyrite in an otherwise simple quartz-orthoclase pegmatite that crops out in the south-western corner of the d_2 quadrangle (table 7). The dike strikes northeast, is essentially vertical, about 4 m wide, and no more than 20 m long in outcrop. An abandoned adit, about 6 m long and 3 m wide, follows the dike to the northeast. Possible extension of the dike to the northeast is unknown as the area is covered by colluvium from the Kalabak sequence. The dike does not crop out to the southwest.

The proving of the extent of the dike by trenching and possibly by drilling, and an extensive and detailed drilling and sampling program would probably be necessary to prove the potential of this sparsely mineralized deposit.

Stibnite and cervantite

Antimony in the form of stibnite and cervantite is present on the Yali Dere just northwest of the Dereören stock in the d_3 quadrangle, and on a high-angle fault that cuts the southeastern part of the c_4 quadrangle. In mineralized rock cropping out over about 4 sq m in the Yali Dere deposit, bladed stibnite and cervantite fill fractures in a secondarily silicified sandstone of the upper member of the Halilar Formation. There is no surficial indication of a fault control on either the mineralization or silicification. No work has been done to indicate the lateral or vertical extent of the deposit. Stibnite and cervantite also crop out in a short adit that cuts a high-angle normal fault in the Kabaağaç Mvk. area of the c_4 quadrangle. Surface indications of the deposit are limited to coarsely crystallized stibnite and an earthy yellow andesite of abnormally high specific gravity along the fault. The adit apparently has been abandoned and no geochemical work or trenching along or across the mineralized fault has been done. Neither lead nor arsenic minerals were seen in either deposit.

Gold

Native gold has been seen in only one specimen of hydrothermally altered andesite included in the base of a pink welded ash-flow tuff in the Dede Tepe Formation. The specimen was collected from the second unnamed ridge east of Karakuz Sr. in the southeast corner of the d_3 quadrangle. An MTA fire assay of the specimen indicated 5 grams of gold and 4 grams of silver to the metric ton. The results of the assay are low as most of the native gold, visible without the use of a hand lens, was known to have been removed prior to the analysis. About 30 samples, chiefly of the andesite-bearing tuff, and tuff from the welded middle and upper parts of the welded tuff unit, were collected and submitted to the U.S. Geological Survey for gold and silver analysis. Analyses of some of those samples appear in table 8. None show gold in economic quantities.

Table 8.--Fire assay-atomic absorption analyses of specimens from the Edremit area, Turkey. [Gold was determined by a combined fire assay-atomic absorption technique. Silver was determined by atomic absorption spectroscopy. Analyst: Carroll Burton, U. S. Geological Survey]

Lab.No.	Field No.	ppm-Au	ppm-Ag	Lab.No.	Field No.	ppm-Au	ppm-Ag
W172314	13/6/68-2	.05	2.0	W173788	21/8/69-1	.05	1.0
315	13/6/68-3	.05	2.0	789	21/8/69-2	.05	1.0
321	20/6/68-1	.05	2.0	790	21/8/69-3	.05	1.0
322	20/6/68-2	.05	2.0	791	21/8/69-4	.05	1.0
331	12/8/68-1	.08	2.0	792	21/8/69-5	.05	1.0
332	12/8/68-2	.05	2.0	793	21/8/69-6	.05	1.0
333	14/8/68-1	.05	2.0	794	21/8/69-7	.05	1.0
334	15/8/68-1	.08	2.0	795	21/8/69-8	.05	1.0
335	22/8/68-1	.05	2.0	796	21/8/69-9	.05	1.0
336	1-/9/68-1	.08	2.0	797	21/8/69-10	.05	2.8

Specimens 788 through 797 are from the basal part of the pink welded ash-flow tuff unit in the Dede Tepe Formation in the second ridge east of Karakuz Br. in the southeast corner of the d_3 quadrangle, 314 and 315 are from the pale gray welded ash flow tuff in the same area, specimens 333 through 335 are from dacitic breccia in the same area, and specimens 331 and 332 are from the lava of Yurekli near the village of Yurekli.

APPENDIX A

Description of type sections

Type section of the Dede Tepe Formation; upper 246.4 m measured from the Hallaçlar-Dede Tepe contact on the Çakilli Dere to the top of Dede Tepe, lower 250 m measured from Dereöbasi to the top of Karakaç Tepe in the southern quarter of the Balikesir I 18 d_3 quadrangle.

Neogene:

Lacustrine deposits

Disconformity

Neogene:

Dede Tepe Formation:	Metres
Volcanic breccia, massive, beds to 3 m thick, nonsorted, light-gray; with common to abundant, white, and light-gray, angular, dense to glassy, lithic clasts to 2 cm on a side; clasts exhibit abundant shiny black biotite and hornblende, and vitreous plagioclase, potassium-feldspar, and quartz phenocrysts; matrix composed of smaller lithic and crystal clasts like those above with white to pale-gray vitric ash, now chiefly devitrified---	47.5
Volcanic breccia, as above, in addition as much as 20 percent of light-reddish-brown, generally angular, glassy to dense lithic clasts to 1 m on a side, with abundant phenocrysts of plagioclase, biotite, hornblende, potassium-feldspar, and quartz in that order---	16

	Metres
Volcanic breccia, massive beds to 6 m thick, nonsorted, light-gray; common to abundant, white and light-gray lithic clasts in an abundant lithic-vitric matrix----------------------------	27
Volcanic breccia, massive, nonsorted, light-gray; abundant white and light-gray lithic clasts and sparse light-reddish-brown lithic clasts in an abundant pale-gray lithic-vitric matrix--	48.5
Lava, irregularly banded, light-reddish-brown, dense to glassy, characteristically with abundant phenocrysts of plagioclase, biotite, hornblende, potassium-feldspar, and quartz----------	2.3
Volcanic breccia, massive, nonsorted, light- to pale-greenish-gray, abundant, white and light-gray porphyritic clasts described above to 35 cm on a side; sparse lithic-crystal-vitric tuff matrix---	4.8
Volcanic breccia and interbedded tuff; breccia nonsorted, light-gray; abundant white, pale-green, and light-gray porphyritic lithic clasts in an abundant, but finer grained matrix of the same lithic components, and pale-green devitrified ash; tuff, thin-bedded, well-sorted, pale-greenish-gray, vitric tuff, and minor vitric-lithic tuff----------------------------------	68
Tuff, interbedded vitric and lithic-vitric, crystal-vitric tuff; vitric and crystal-vitric tuffs thinbedded; lithic-vitric tuff thin- to thick-bedded; vitric tuff is clinkstone---------	29.3
Volcanic breccia, massive nonsorted, light-greenish-gray, with abundant white, light-gray, and pale-greenish-gray lithic clasts, and sparse light-reddish-brown lithic clasts; all porphyritic; some dark-reddish-brown, coarsely porphyritic, andesitic lithic clasts from the underlying Hallaçlar Formation--	3

Metres

Volcanic breccia, massive, beds to 8 m thick, nonsorted; light-gray; abundant, angular to subrounded, light-gray, white, and sparse light-reddish-brown, dense to glassy, lithic clasts, white clasts show prominent phenocrysts of biotite, brown and gray clasts show phenocrysts of plagioclase, biotite, hornblende, potassium-feldspar, and sparse quartz; in an abundant pale-gray to medium-gray vitric-lithic matrix-- 220

Volcanic breccia, massive, nonsorted, medium-grayish-brown; common light-gray and white, dense to glassy lithic clasts with biotite and hornblende phenocrysts; abundant, dark-reddish-brown, rounded to subrounded, commonly deeply altered, coarsely porphyritic andesitic clasts from the Hallaçlar Formation; in a lithic-vitric matrix of smaller fragments of the clasts described and devitrified glass------------------------ 30

496.4

Neogene:

Hallaçlar Formation

Type section of the Hallaçlar Formation, measured along the Kabaklik Dere between the Havran River and the village of Hallaçlar in the east-central part of the Balikesir I 18 d_3 quadrangle. Note that the type section of the Hallaçlar includes no quartz latite rocks, nor mudflow deposits. Although both are locally present elsewhere, sections could not be measured in those areas because of alteration, soil cover, and low relief.

Neogene:

Dede Tepe Formation

Disconformity

Hallaclar Formation:	Metres
Lava, massive, very fine grained to dense groundmass, light-yellowish-gray; abundant phenocrysts of vitreous to opaque plagioclase to 6 mm; sparse, shiny black biotite; and sparse pyroxene altered to a soft bright-emerald-green chlorite; groundmass shows irregular, pale-yellow-gray areas, slightly scoriaceous	60
Lava, massive; fine-grained groundmass; light-yellowish-gray to light-greenish-gray; sparse phenocrysts of vitreous plagioclase up to 6 mm; rare black biotite; and rare to sparse pyroxene up to 4 mm, partly altered to an unidentified pulvurent yellow material; slightly scoriaceous	32
Lava, massive, fine-grained groundmass, medium- to dark-gray; common to sparse vitreous to opaque, plagioclase phenocrysts up to 5 mm long; sparse shiny black biotite; sparse pyroxene altered to green chlorite	11

	Metres
Lava, massive, dense to very fine grained groundmass, light-gray; abundant phenocrysts of vitreous to opaque plagioclase to 3 mm; sparse black biotite; and dark-green pyroxene; groundmass shows irregular pale-gray to white areas and rims around plagioclase phenocrysts------------------------------	7
Lava, massive, dense to fine-grained groundmass; medium- to light-gray, locally dark-reddish-brown; common phenocrysts of vitreous plagioclase to 3 mm; sparse black biotite and rare dark-green pyroxene; groundmass shows irregular light-gray or light-reddish-brown altered or devitrified areas-----	31
Breccia, massive, nonsorted, medium- to light-reddish-brown; clasts and matrix with common phenocrysts of vitreous to opaque plagioclase to 4 mm; sparse black biotite; and rare dark-green pyroxene; matrix very dense, light-brownish-gray; apparently autobreccia------------------------------	31.8
Lava, massive, fine-grained groundmass; medium gray-brown and medium-brown; abundant phenocrysts of vitreous plagioclase to 8 mm; sparse to rare, shiny black biotite to 2 mm; and sparse to rare greenish-yellow, altered pyroxene to 4 mm; plagioclase phenocrysts all show white opaque border zones; groundmass shows splotchy, reddish-brown and pale-brown devitrification centers or areas of alteration; weathers to a coarse grus---	51

	Metres
Lava, massive, fine-grained, greenish-gray and some light-gray; common phenocrysts of opaque plagioclase to 3 mm; sparse to rare black biotite; rare, altered, dark-green to yellow pyroxene; finely vesicular to scoriaceous---------	35
Lava, massive, dense, dark-gray to black; common phenocrysts of shiny black biotite to 2 mm; sparse to common, vitreous plagioclase to 4 mm; rare dark-green pyroxene--------------	13.5
Lava, massive, dense, dark- to medium-grayish-brown; abundant phenocrysts of vitreous plagioclase to 6 mm; majority show opaque white border zones; sparse shiny black biotite to 6 mm; no pyroxene---	8.4
Lava, massive, fine-grained, reddish-brown to light-yellowish-gray; intensely altered; common phenocrysts of plagioclase altered to pulvurent, white material; heavily pyritized-----	22.5
	303.2

Upper Jurassic:

Limestone of Kocaçal Tepe

Type section of the Bağburun Formation, measured along Bağburun Sr. from a normal fault near the Akpinar Dere to the top of Peynir Tepe on the east-central border of the Balikesir I 18 d_2 quadrangle.

Paleogene:

Hallaçlar Formation.

Disconformity

Cretaceous or Neogene:

Bagburun Formation	Metres
Lava, massive; very fine grained groundmass, reddish-brown, some pale-brown; abundant small phenocrysts of opaque, white to pale-greenish-gray plagioclase; sparse to rare, leached biotite; rare pseudomorphs of chlorite after hornblende-------	26.7
Lava, massive; fine-grained groundmass, medium- to light-greenish-gray; abundant to common phenocrysts of opaque white plagioclase to 1.5 mm; rare to sparse rounded quartz; and sparse pseudomorphs of chlorite after hornblende----------	44
Breccia, massive; nonsorted; greenish-brown clasts in light-brown matrix; clasts, abundant phenocrysts of altered opaque plagioclase to 2 mm; sparse dark-green pseudomorphs of chlorite after hornblende; rare, rounded quartz---------------	12
Lava, massive; fine-grained to dense; light-gray-green; abundant small phenocrysts of altered, opaque plagioclase; sparse pseudomorphs of chlorite after hornblende; rare rounded quartz in lower part of unit---	10.3
Lava, massive, dense, black; sparse small altered phenocrysts of plagioclase; rare, very small biotite---------------------	14

	Metres
Breccia, massive; poorly sorted to nonsorted; pale-yellow-green to gray-green; angular clasts in a dense to fine-grained, pale-brown, crystal-rich matrix--apparently a lithic-crystal tuff matrix; clasts with abundant to sparse phenocrysts of altered, opaque plagioclase; sparse altered biotite; rounded quartz; silicified near base---------------	40.7
Lava, massive; fine-grained; medium- to dark-grayish-green; common to abundant phenocrysts of altered, opaque plagioclase to 2 mm; sparse pseudomorphs of chlorite after hornblende; rare to sparse rounded quartz------------------------	41.5
	189.2

Upper Triassic:

Halilar Formation

Type section of the Halilar Formation, measured on the east side of Köktoyen Dere about 400 m north of the village of Halilar near the north-central border of the Balikesir I 18 d_3 quadrangle.

Cretaceous(?) or Neogene:

Bağburun Formation

Unconformity

Upper Triassic:

Halilar Formation

Upper member:	Metres
Sandstone, yellow-brown, massive, thick-bedded; poorly sorted, coarse- to fine-grained, feldspathic; sparse biotite flakes, poorly cemented with calcite and minor limonite; conglomeratic, pebbles of white quartzite, subrounded to rounded, to 2 cm on a side------------------	46.6
Sandstone and siltstone, grayish-brown and yellow-brown, thin-bedded (2-4 cm), medium- to fine-grained, well-sorted, feldspathic; biotite flakes common; poorly cemented with calcite and sparse limonite-----------------	21
Sandstone and conglomerate, yellow-brown, massive, thick-bedded (to 10 m), poorly sorted, feldspathic; conglomerate with rounded white quartzite pebbles and sparse schist and phyllite pebbles to 1.5 cm on a side---------------------	38.8
Sandstone, grayish-brown and yellow-brown, well-bedded, generally well-sorted; shale partings and thin mudstone beds common---	21

	Metres
Sandstone, light-yellow-brown, massive, thick-bedded, poorly sorted; angular, feldspathic grains; ranges to arkose, micaceous; conglomerate stringers abundant, pebbles throughout sandstone, phyllite, white quartzite, and sparse thin-banded marble------------------------------	5
Middle member:	
Shale and sandstone; shale grayish-brown, very thin-bedded, silty, about 60 percent of the section; sandstone-mudstone, light-grayish-brown, well-bedded, fine- to medium-grained, feldspathic--	43
Shale and sandstone; shale, dark-bluish-gray to black, very thin bedded, locally pyrite bearing. Sandstone, light-brown to light-grayish-brown, thick- to thin-bedded (5 m-3 cm), no internal bedding; micaceous; shale about 80 percent of the section-------------------------------------	39.4
Shale, black to dark-bluish-gray, very thin bedded; minor grayish-brown and reddish-brown shale associated with sandstone beds; thin-bedded (2-4 mm); three light-brown sandstone layers, fine- to medium-grained, feldspathic, ranges to arkose, poorly cemented with calcite-------------	14.4
Silstone, shale, and sandstone; siltstone, medium-gray-brown, thin-bedded; sparse shale, black, thin-bedded; three thin sandstone layers, light-gray-brown------------------------	25
Shale, black to dark-bluish-gray, massive to very thin bedded (1-2 mm), commonly breaks into small blocks with curved faces, locally pyrite bearing; sandstone, light-	

Metres

yellow-brown to pale-brown, thin- to medium-bedded (2-4 cm); no internal bedding, beds well demarked at base, merge into shale at top------------------------------------- 142.4

Lower member:

Arkose and feldspathic sandstone, light-gray-brown and pale-brown, massive, poorly sorted; predominantly coarse-grained, angular to subrounded, feldspar abundant (commonly over 20 percent); lithic, sand-size grains of feldspar-quartz also common; matrix of biotite-chlorite, locally replaced by quartz; locally conglomeratic; basal conglomerate (to 6 m thick) of schist, phyllite, metaclaystone, quartzite, and thin-banded marble boulders and blocks, poorly sorted, very coarse matrix of quartz, feldspar, biotite, and chlorite--------------------------------------- 230

626.6

Precambrian(?) or Cambrian(?)

Metamorphic sequence of Kalabak

Section of middle and upper members of the Halilar Formation measured in the area of Gölükölen Mvk. near the south-central border of the Balikesir I 18 d_2 quadrangle.

Upper Jurassic:

Limestone of Kocaçal Tepe

Unconformity

Upper Triassic:

Halilar Formation

Upper member:	Metres
Sandstone and siltstone; sandstone, light-gray-brown, thin-bedded, fine- to medium-grained, feldspathic, ranges to arkose, ripple marked. Siltstone, medium- to dark-gray-brown and dark-reddish-brown, thin-bedded, interbedded with minor dark-gray-brown shale--------------------------	123
Conglomerate and conglomeratic sandstone; massive, medium- to dark-gray and gray-brown, poorly sorted; rounded to subangular pebbles of white quartzite, phyllite, and lithic pebbles of feldspar-quartz, in abundant biotite-quartz-chlorite matrix-------------------------------------	61
Sandstone and siltstone; light-brown, well-bedded (5-10 cm thick), poorly sorted; feldspathic, ranges to arkose, micaceous; sparse small pebbles of white, rounded quartzite and lithic pebbles of feldspar-quartz----------------------	14

	Metres
Middle member:	
Shale, black, massive, some color banding, rare shreds of white mica--	39.4
Shale, black, massive, commonly breaks into small angular blocks; rare sandstone beds, light-gray-brown, to 3 cm thick, fine-grained, feldspathic and micaceous--------------	3.5
	240.9

Fault

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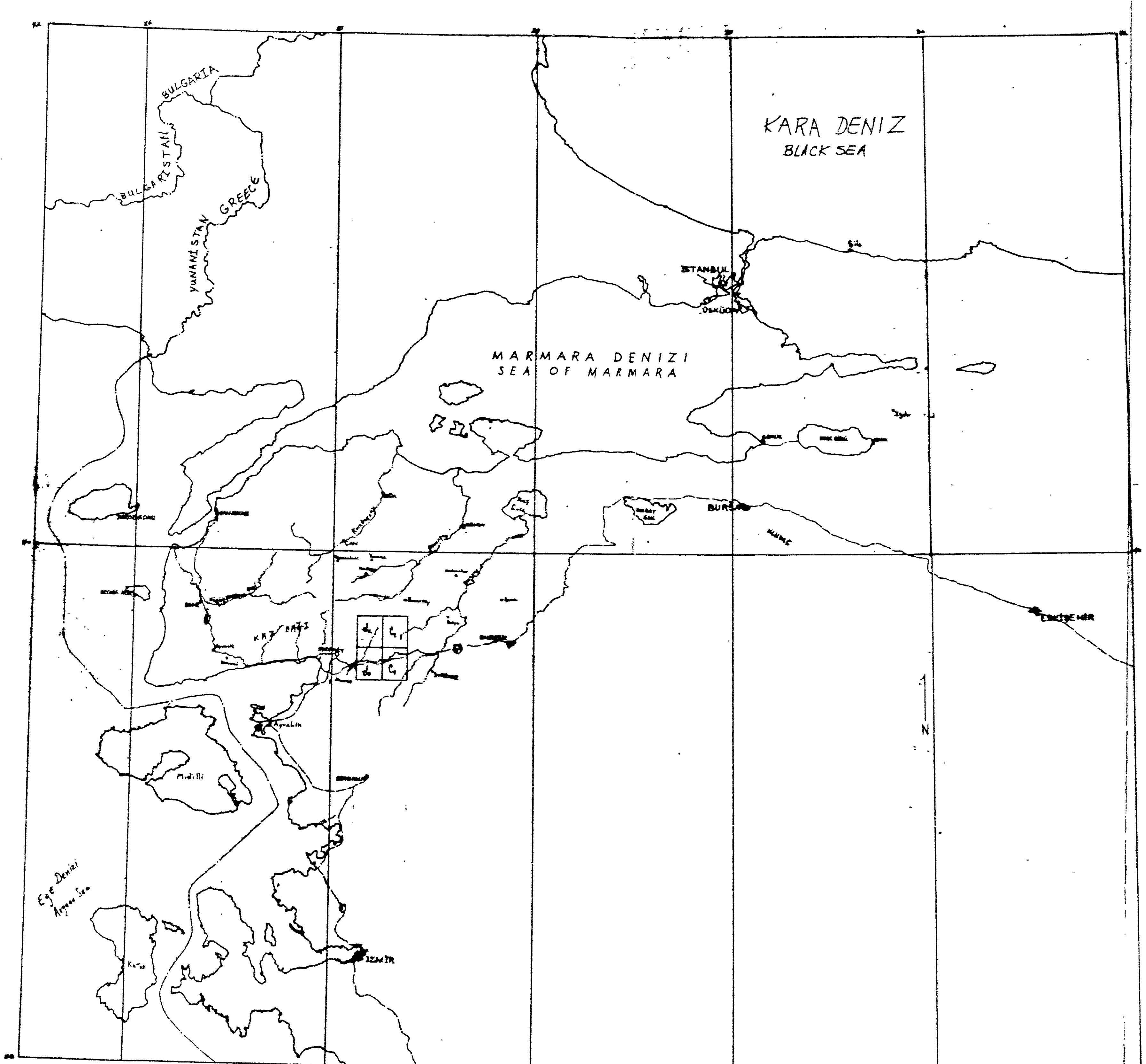
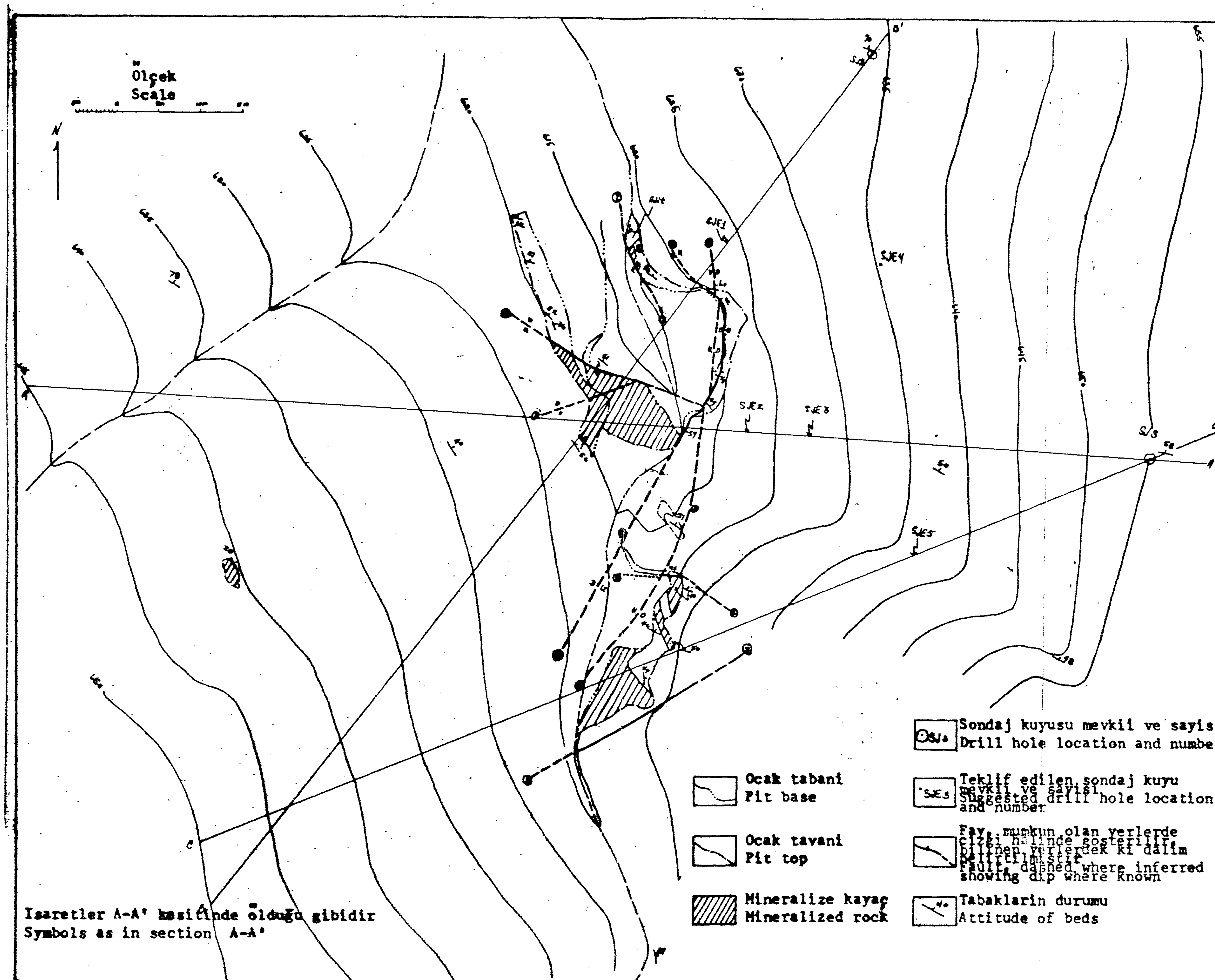


Şekil 1.— Başlica coğrafik özelliklerin mevkilerini gösteren Mevki Haritası, NW, Türkiye ve Balikesir I 18 c_1, c_4, d_2, ve d_3 paftaları.
Figure 1.-- INDEX MAP OF NORTHWESTERN TURKEY SHOWING THE LOCATION OF MAJOR GEOGRAPHIC FEATURES AND THE BALIKESIR I 18 c_1, c_4, d_2, AND d_3 QUADRANGLES

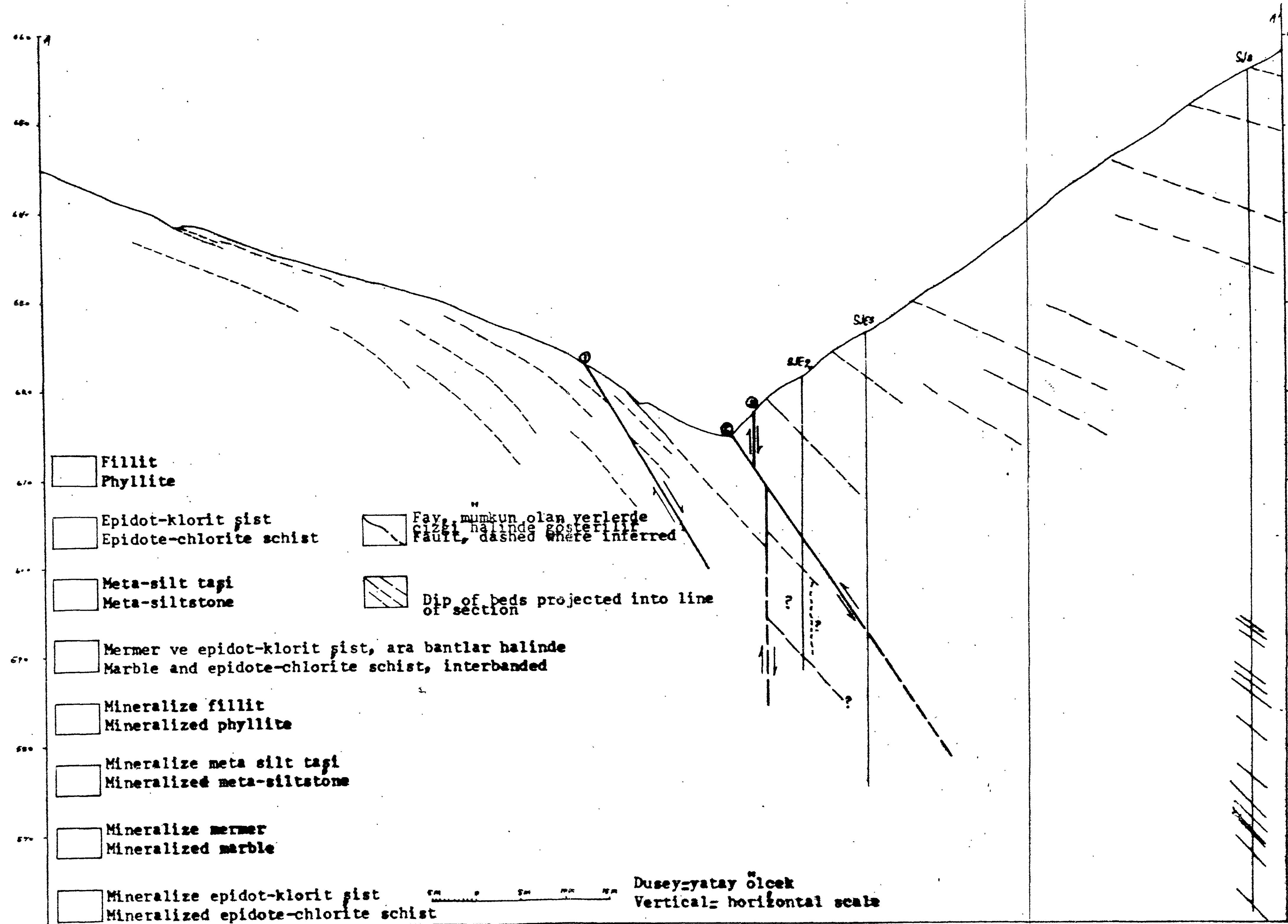
Ölçek
Scale 1/1,000,000



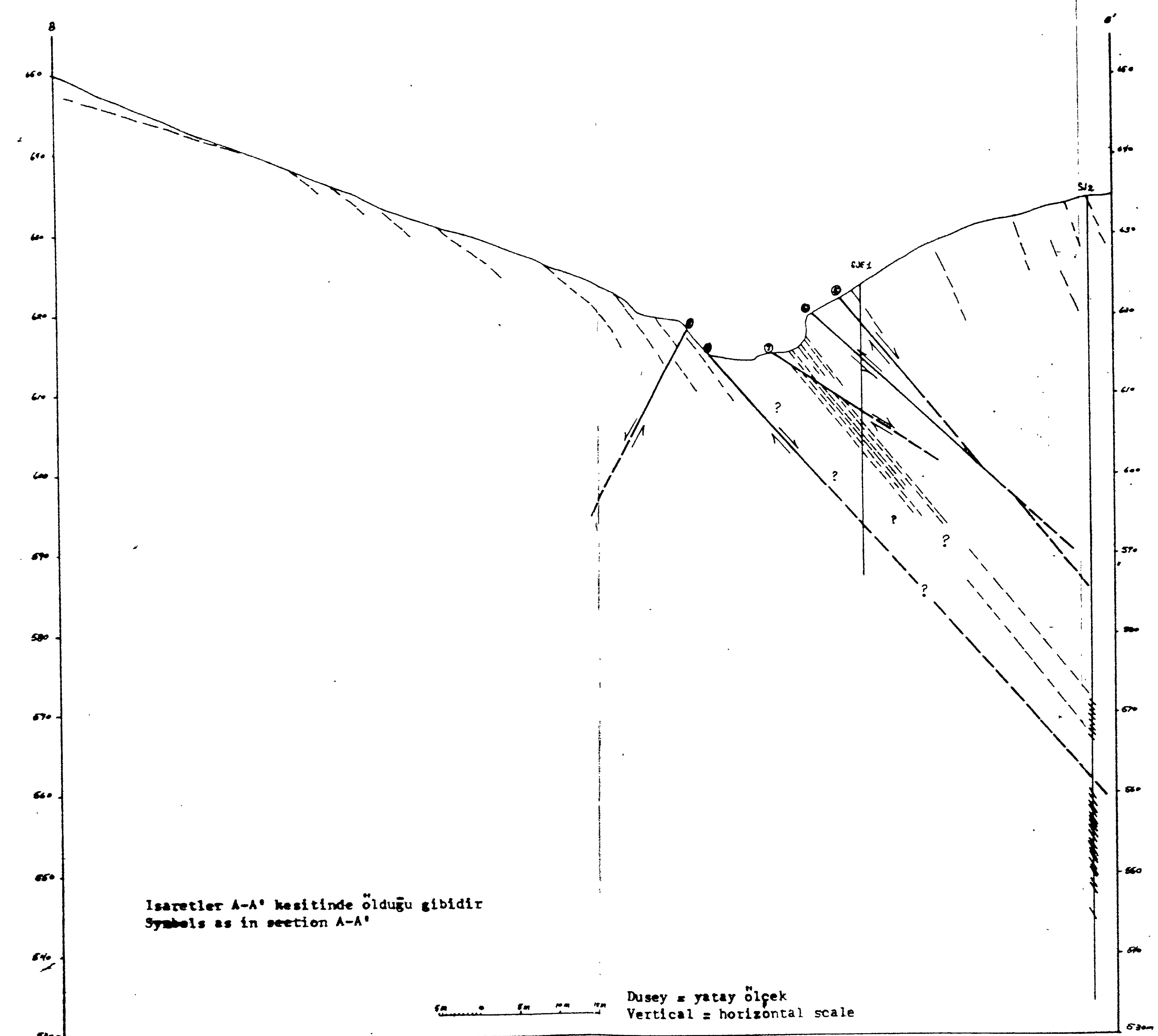
Sekil 2--Bağirkaç ocağinin guney kisminin ve Balikesir I 18 d_2 paftasinin NE çeyreğine ait pusula ve çelik metre ile yapilan jeolojik harita

Figure 2--Geologic tape and compass map of the southern part of the Bağirkaç Mine, northeast quarter of the Balikesir I 18 d_2 quadrangle

Geology by
R. D. Krushensky
Y. Akçay and
E. Karaege



Sekil 3--Bagirkaç ocağinin A-A' kesiti
Figure 3--Section A-A' of the Bagirkac Mine



Sekil 4--Bağirkaç ocağinin B-B' kesiti
Figure 4--Section B-B' of the Bağirkaç Mine

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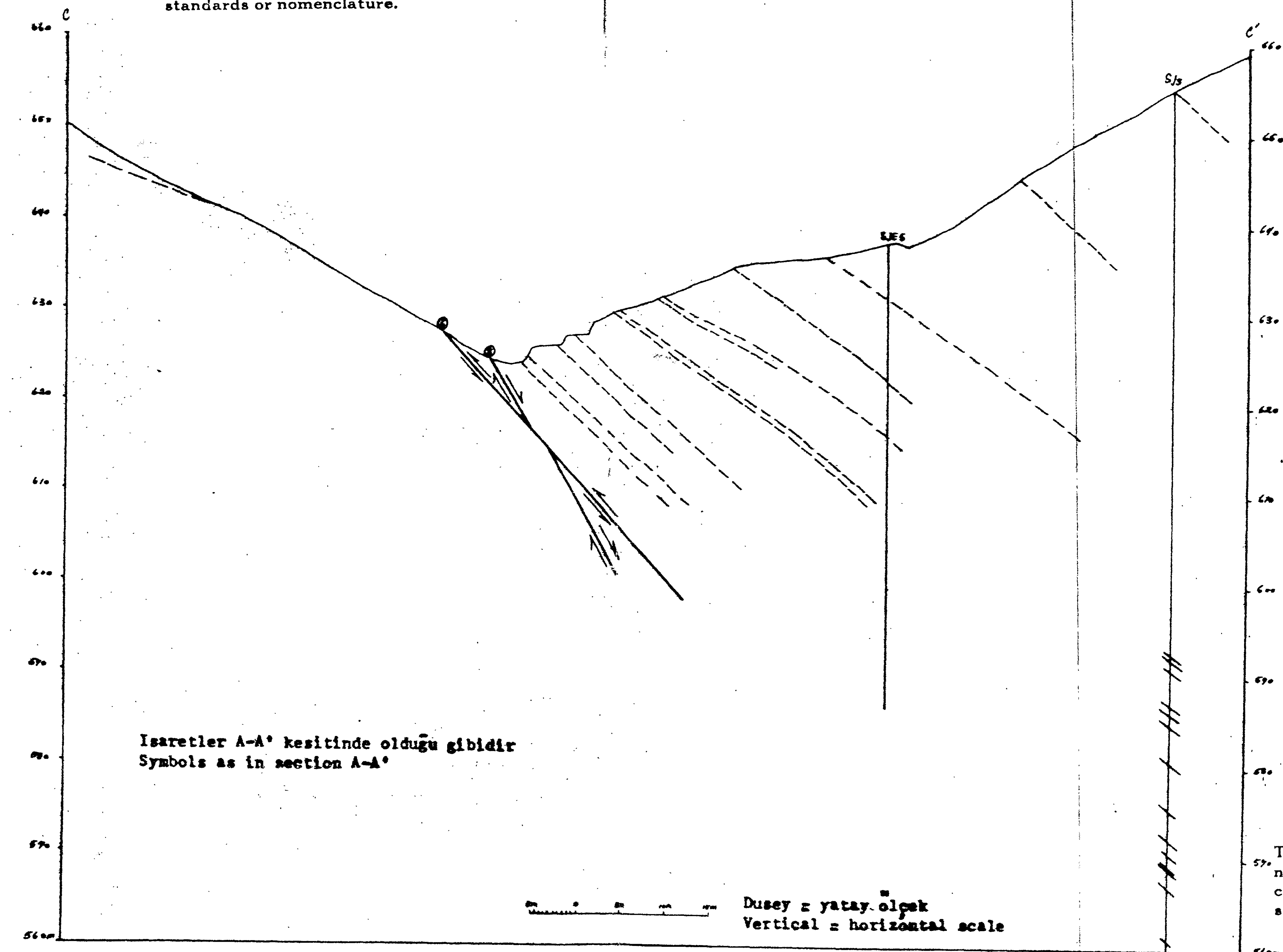

Isaretler A-A' kesitinde oldugu gibidir
Symbols as in section A-A'

Dusey = yatay olçek
Vertical = horizontal scale

Sekil 5--Bağirkaç ocağinin C-C' kesiti
Figure 5--Section C-C' of the Bagirkac Mine

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