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GEOLOGIC INVESTIGATION OF THE İZMİT-HEREKE-KURUCADAĞ AREA

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ABSTRACT. — An area of over 450 km^2, spreading over five topographic sheets to a scale of 1 : 25,000, has been mapped by distinguishing lithogenetic units. 16 Measured Stratigraphic Sections total a distance of over 20 km in the field. Their names and locations figure on the Sample Map. They contributed to the Generalized Stratigraphic Section, as well as to the Stratigraphic Table. One group, eight formations and seven members are differentiated and named. Application forms were submitted to the Stratigraphic Commission of Turkey to solicit their approval in order to capitalize the second of the given names.

The micrographic descriptions of over 300 thin sections accompany either the text of the original report or follow the pertinent columnar sections. The carbonate rocks are named after Todd rather than Folk, and the detrital ones after Williams, Turner and Gilbert. The volcanics, as well as most of the fossils, were determined at the M.T.A, laboratories.

This paper is a digest of a detailed geologic investigation sponsored by the Mineral Research and Exploration Institute of Turkey (M.T.A. is its short form in Turkish.)

GEOGRAPHY

The investigated area is situated within Kocaeli Province, and to the W of İzmit City. Geographically it lies within the Kocaeli District of the Marmara Region. Kocaeli Plateau (peneplain) exhibits similar physiographic features from the Bosphorus to Sakarya River.

Eren-Çene watershed lies at a distance of 10 km from the coast in the E, and comes within 4 km of it in the W. It is winding due to the headwards erosion of the streams. Serçe-Teke, Ağa-Dikmen, Toylar-Kuruca Secondary Transverse Divides, as well as Kayalı-Çulcular, Kirazkaya-Kuyulu and Dikmen-Çataklar Longitudinal Divides are figured on the Orographic and Hydrographic Map. There exists a very rough rectangular drainage network. The streams over the southern slope are larger in the E but smaller in the W. Only the headwater portions of the perennial streams headed to Black Sea lie within the mapped area. The upper stretches are of dendritic pattern, but the middle and lower sectors are fairly straight. The tributaries are parallel to the ridges or cross them at places, so that junctions at right angles do exist. Waterfalls are scarce and located at the sites of abrupt lithologic change.

In the main the coast is submerged, and appears to be in its youth stage. Degradational features lie in the E, while the aggradational ones are common in the W. Pleistocene and Recent forms are bound to young disturbances, the lineage of which is not yet known.

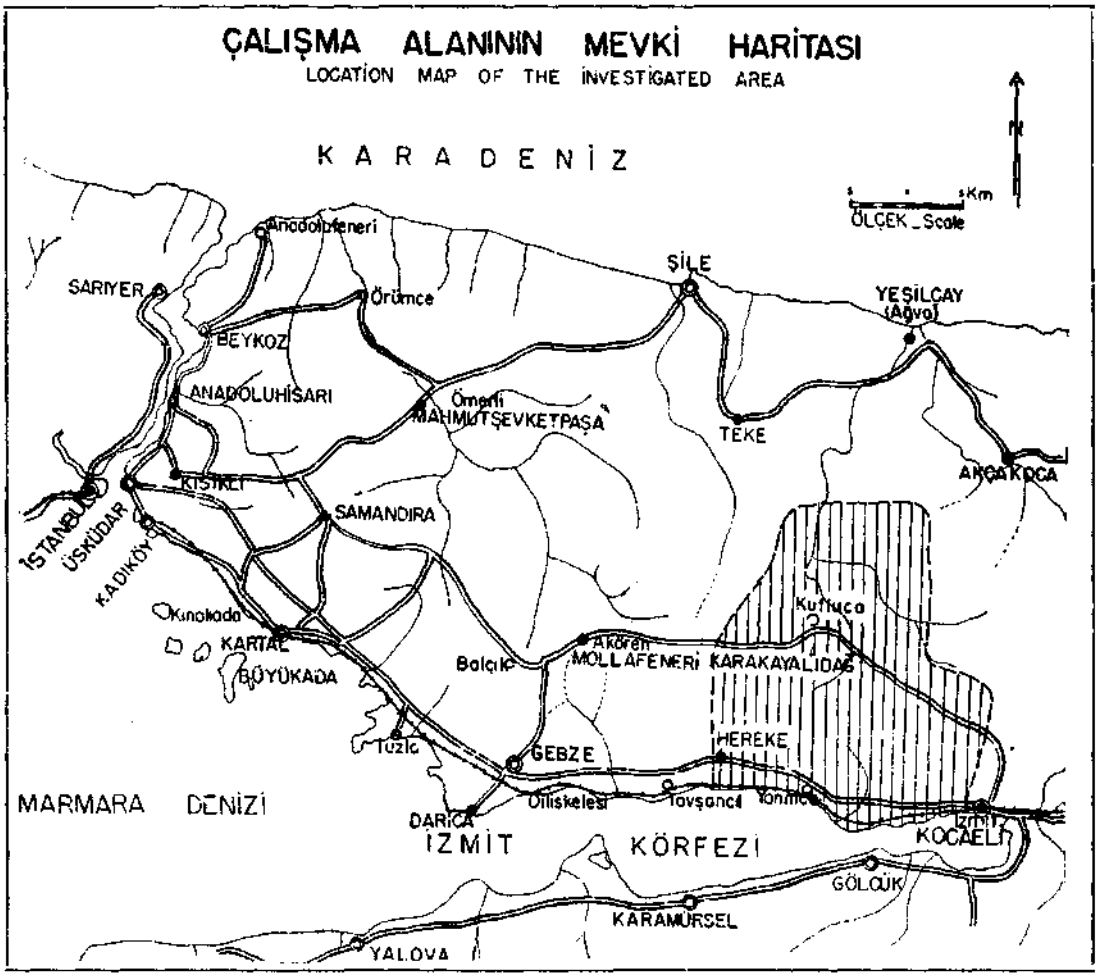

Fig. 1

The Mean and Extreme Values of the Meteorological Bulletin for a period of 29 years were processed by Thornthwaite formula to find out the climate class, which is $C_2B'_1S_2b_3'$. These letters mean successively, semi-arid, mesothermal, high summer water deficiency and third degree maritime. Other pertinent data are as follows : mean precipitation 76.20 cm, PE 77.76 cm, actual PE 53.94 cm, water deficiency 33.86 cm, water surplus 22.26 cm. The yearly variations of these are shown on the Monthly Change of Groundwater Inventory of İzmit. According to the precipitation efficiency indices, the total of the yearly indices is 39.3, which means a semi-humid park-looking forest for the area.

A mediterranean type of vegetation is displayed in S, while in N pontic types appear, such as rhododendron, hazelnut, etc. Deep and inaccessible creeks contain taller thicket more or less mixed with stands. Timber forests lie in N, and the dwindled ones in S provide combustible fuel. Forests and woods are dwindling near the villages, and so the thicket thins out to a vanishing point where tillable land replaces it. The uncovered soil is prone to swift erosion, especially over the slopes. There are no more «impassable forests» as it is marked on the topographic sheets made a few years ago.

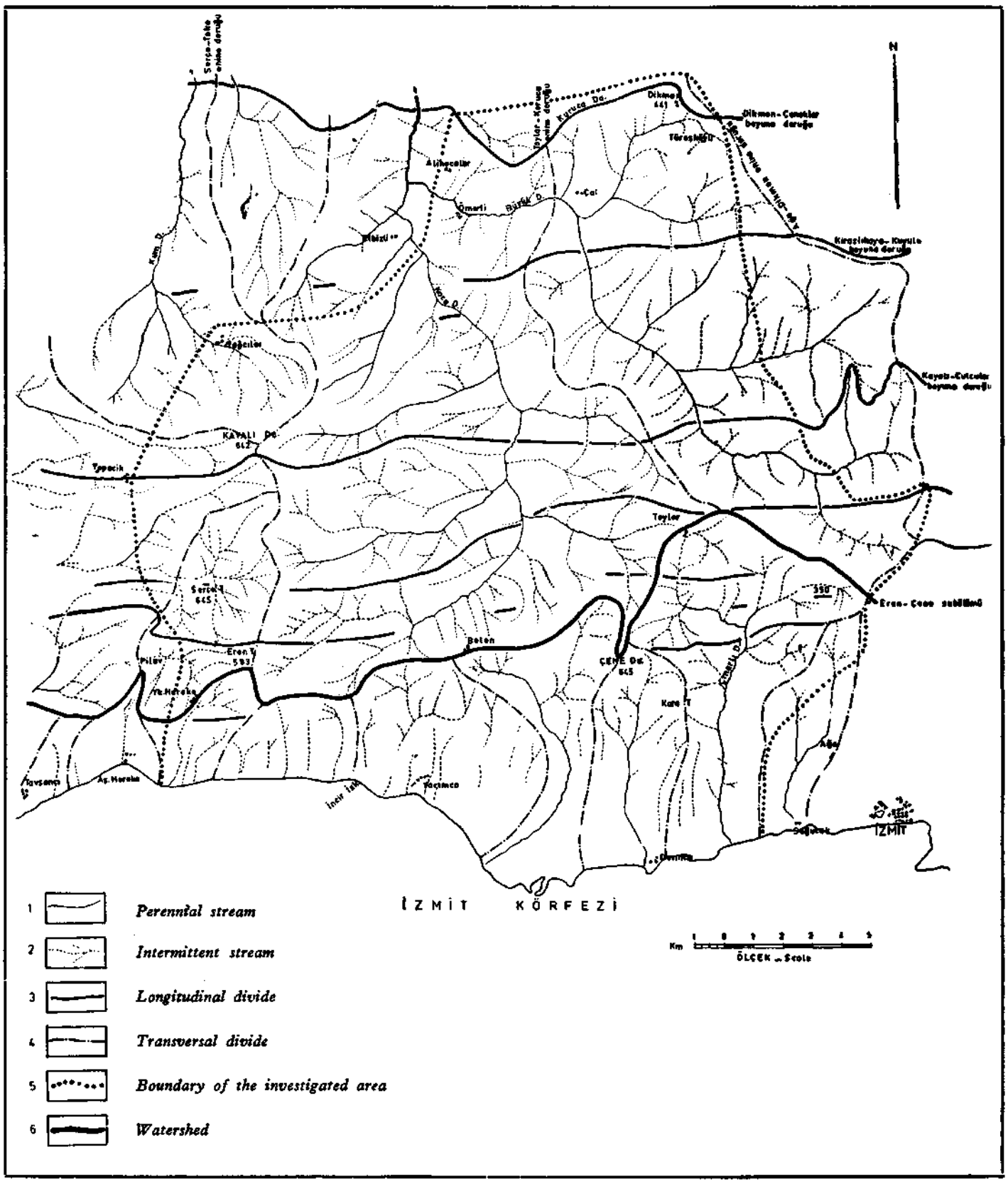

Fig. 2 - Orographic and hydrographic map of the İzmit - Hereke - Kurucadağ area.

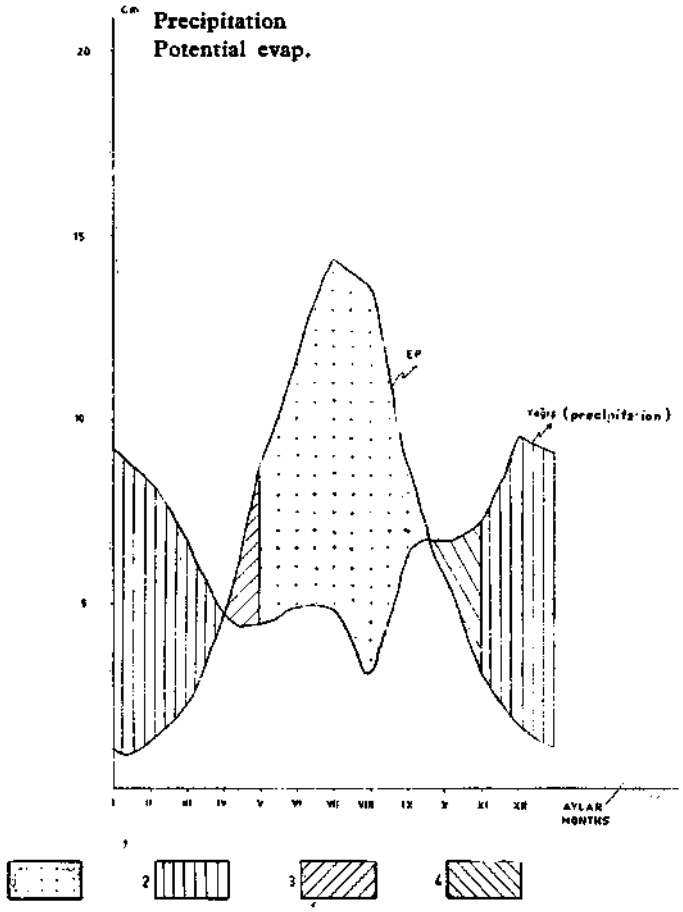

Fig. 3 - Graph showing montly change of İzmit.
1 - Water deficiency; 2 - Water surplus; 3 - Soil moisture utilization; 4 - Soil moisture recharge.

The main artery is the new Istanbul-Ankara highway and the railway. The old Istanbul-Ankara highway in the middle of the mapped area follows the main divide and it is nearly derelict. Transverse branches are few in number and are in poor condition. Maritime transportation along the coast is lacking.

PREVIOUS INVESTIGATIONS

With the exception of special purpose mapping for oil, the former geological investigations were based upon the geochronological subdivisions rather than on rock-stratigraphic units; since a close collaboration between field geologist and stratigraphic paleontologist has not yet been realized, refinements in biostratigraphic units and rock units are not proportionate with the field efforts. Systematic fossil collections, especially along the measured stratigraphic sections, are most needed.

In 1849 Tchihatcheff mentioned the- boundary of the Devonian with the Triassic near Gebze. He correlates the white limestone at Hereke with the Upper Cretaceous one at Ereğli.

In 1890 Toula reported the Triassic for the first time; distinguished the Ladinian and published the Paleontology of the Anisian.

In 1898 Fitzner discussed the Lower, Middle and Upper Triassic.

In 1909 Kessler considered the red sandstone and conglomerate as the representatives of Rothliegende.

In 1910 Endriss published the geology of İzmit-Kandıra area, and submitted two cross-sections beneath his map. In 1926 he edited the Rhynchonellidae which he discovered along with the sandstone and conglomerate.

In 1914 Arthaber established the Ladinian and the Carnian through fossils sent to him by Freeh. For him, lower Middle Triassic overlaps the regional Paleozoic. He cited 101 species. In 1915 he discussed further the local paleontology, and wrote about the mediterranean-looking Anisian and Ladinian fauna from the vicinity of İzmit. He determined the absence of Rhetian in Kocaeli.

In 1917 Arabu wrote about the Anisian and the Carnian he discovered besides Muschelkalk, and stressed the absence of Norian and Rhetian. He claims to find Mediterranean, Anatolian and Himalayan types at Tepecik (Tepe) village.

In 1919 Penck made comments about the geomorphological evolution of İzmit Gulf and its vicinity.

In 1943 Baykal mentioned Lower Devonian crystallized limestone and the transition beds, which are followed by Middle Devonian sandy and clayey schists cropping out over Adapazarı-Kandıra area. For him, Dikmen Mountains are made up of Paleozoic volcanics, being covered by Triassic beds. A Tertiary tuff overlies the Lutetian limestone. Turonian is made up of flysch facies. Senonian exhibits limestone and marl interbeds, Paleocene is a flysch, while the unconformable Lutetian is a limestone.

In 1949 Erguvanlı failed to draw definite contacts between his stratigraphic subdivisions and marked them with overprints on his geologic map. He submitted lists of fossils, and compared his area with the neighboring ones. His lithologic subdivisions do not comply with the rules of stratigraphic nomenclature.

In 1963 Abdüsselamoğlu revised 21/1 and 38/1 sheets to a scale of 1: 500,000 for the compilation of the Geologic Map of Turkey. He used «series», as, for example, Arkose series, for a large rock unit. He maintains a Silurian age for the quartzite, greywacke and upper feldspathic quartzite. Halysites limestone stands at the boundary of Silurian with Devonian, and it is overlain by the richly fossiliferous Lower Devonian (in fact, Halysites limestone intertongues with the subfeldspathic wacke and so both are contemporaneous). He mentions Middle and Upper Devonian to the NW of İzmit; and the Carboniferous greywacke to the SE of Gebze. Halobia schist overlying Virglorian and Ladinian might belong to Rhetian. A flysch with volcanic intercalations belongs to Senonian. The area in the middle of Arızlı and Karakütük exhibits a sequence of Upper Paleocene - Lower Eocene. The Caledonian and Hereynian trends are N-S directed. A thrust run at the foot of the mountain and another one which is directed to NE lies to the S of Çene Mountain. These are younger than Eocene.

STRATIGRAPHIC GEOLOGY

SEDIMENTITES

Kocaeli Paleozoic lies along the trend of Istanbul Paleozoic, and these are followed by Sakarya Paleozoic further E. All of them display similar features. The main characteristics are given in a condensed form on the Generalized Stratigraphic Section and the Stratigraphic Table. The overall thickness of the columnar section lies between 2,500 and 7,500.

The following rock units are differentiated, mapped and named according to the Stratigraphic nomenclature: Sopalı formation (Os), Çene formation (05) — Ordovician; Cmarh group (Dç) —Devonian; in S Kapaklı formation (TRk) together with its Gıcık conglomerate member (TRkgı), Gözlü limestone member (TRKg), Afaklar sandstone member (TRKa) and in the N Dümbüldek formation (TRd)— Lower Triassic; Hereke roundstone (Kh) together with its Eren conglomerate member (Khe), Kutluca limestone member (Khk) — Campanian; Şemsettin limestone (Kş) and Koruca formation (K-Pk) Upper Cretaceous - Paleocene; Tepetarla marl (Qt) and Şirintepe sand (Qş) —Pleistocene; alluvium, terrace, slope waste, alluvial cones and aprons, travertine-Recent.

Sopalı formation (Os)

Rather uniformly purplish-reddish arkose (subfeldspathic lithic wacke, feldspathic wacke, arkosic wacke, etc.) make up most of the southern slope of coastal ridge. It is similar to the one exposed in Istanbul. Paeckelmann called it «Arkose Horizon»; Baykal and Kaya «Arkose Formation», but without complying with the requirements of the Stratigraphic nomenclature.

Sopalı Measured Stratigraphic Section shows a thickness of 1290 m, but a higher or lower value is possible. No older lithologies are known here, nor in Istanbul. The trail from Sopalı hamlet to Çene Mountain is taken as a type locality, and there also lies the type section. The name is borrowed from Sopalı hamlet. The columnar section starts with subfeldspathic lithic wacke, continues with an alternance of it with subfeldspathic wacke, and ends with feldspathic wacke.

The bedding surfaces are distorted due to repeated orogenic activities. Its sedimentary features, and even its identity are hard to surmise. The true bedding is differentiated through either minor features (lamination, cross-lamination, change in texture, etc.) or by finding out a perpendicular surface to two sets of joints nearly at right angle. The bedding is rather unevenly thin to medium. The texture is either uniform, or gradationally uneven in both horizontal and vertical directions. Pebbly sandstone, and sandstone with conglomeratic streaks are more usual than conglomerates. There are discontinuous quarzt veinlets. The interfingering and lensing are ill-defined. No fossil is yet detected. Physical disintegration is eased through rock cleavage, joint sets, shears and non-geometrical breaks. Mass movements toward valleys are continuous, especially over the naked slopes. Alluvial cones are steep at the mouth of side creaks. Arkose is a weak type of rock, and the unpaved roads over it are grooved and transient.

No clue is of avail for subdivision. -The top of the sequence shows flat lensing quartzite, which is a precursor of a new sedimentary cycle and change of the environmental conditions. There is a definite vertical transition with the overlying conglomerate, which is observable either through a decline in the feldspar content or the advent of a quartz and arkose pebbly conglomerate. The latter is assigned to the new sedimentary cycle because of the reworked arkose pebbles, such as the one cropping out over the southern slope of Çene Mountain. The absence of limestone interbeds within the arkose sequence is helpful to differentiate purplish-scarlet Devonian beds, such as those exposed along the cuts of the old Istanbul-Ankara highway. The Ordovician age is inferred from field relationships by applying stratigraphic principles, and by identity with the rock unit in Istanbul.

Immature arkose is accumulated within a low energetic environment undergoing mild disturbances. The lithologic peculiarities are the impacts of the tectonic control. The source area underwent more a physical disintegration rather than a chemical weathering. The high feldspathic content reflects the tectonic activity. This is a tectonic arkose brought up under humid climate.

Çene formation (Oç)

Paeckelmann's Hauptquartzit, Baykal and Kaya's Orthoquartzite formation designate a steady sequence of quartzite in İstanbul, but these names are not given in compliance with the stratigraphic nomenclature. Williams, Turner and Gilbert suggest restricting quartzite and orthoquartzite to the metamorphics, and reserve quartz arenite for the sedimentaries.

The Çene-Sopalı Measured Stratigraphic Section affords a thickness of 60 m, but the sequence at Çene monadnock in the E is much thicker than this figure. Rather older erosions reduced it to a mere marker in the W, where it may even be discontinuous. It is useful to differentiate arkose from Lower Devonian greywacke where both are of similar aspect. The sequence is better exposed over the southern slope of Çene Mountain, where a section is also measurable. The names of the type section and the type locality are derived from that prominent hill top. There the occurrence of a basal conglomerate is local, and a definite contact with the underlying arkose is hard to locate because of the vertically transitional beds.

Repeated deformations make it hard to decide which is the bedding and the same criteria used for arkose are also applied to quartzite. The bedding is rarely steady. Lamination and cross-lamination are either rubbed out or are infrequent. Admixture of unlike lithology to the steadily uniform sequence is not known, but the color changes from light grey to green to purple, etc. Until the present time no fossil has been detected. Hydrothermal alterations caused red and brown colors, and also brought in iron, copper, etc., mainly through the various kinds of breaks.

As magmatic, metamorphic and volcanic types of quartz are common in thin sections, the basement should be similar to the present Istranca Mountains, which are made up of granite, granodiorite, gneiss, mica-schists, etc. This basement complex has been leveled off, and during a quiescent and humid period dunes, bars, etc. deposited seawards. Mature quartz arenite lagged behind, while feldspars were removed in total.

Çınarlı group (Dç)

In 1936 Paeckelmann differentiated Pendik beds (Upper Coblentzian) into Lower Pendik beds and richly fossiliferous Middle and Upper Beds. The latter is subdivided into Pendik facies made up of marly limy beds, and Bosphorus facies constituted by limy greywacke, limy greywacke shale and limestone. Intermediate facies lies in between these two. Just N of the new Istanbul-Ankara highway and Pendik, the basal limestone of Pendik Facies overlaps, successively, Aydos quartzite, the unconformable greywacke and the overlying subfeldspathic wacke which interfingers with Halysites limestone.

In 1963 Baykal and Kaya submitted the following sequence in order of growing age: Arkose formation, Orthoquartzite formation, Siliceous shale formation (together with its Feldspathic greywacke member and Protoquartzite member), Subarkose formation and Coralline limestone formation. Lower Devonian displays limestone and greywacke, while the Carboniferous exhibits greywacke and clayey shale.

Kocaeli Devonian resembles the much better known one at Istanbul. The former, like the latter, deposited over a highly uneven shelf area. It has overlapped either arkose or quartzite. Contemporaneous disturbances interfered with undaclino-and fondo-conditions. No turbidite is noticed. Either forest or thicket hindered the differentiation into formations and members. The outcrop pattern of the system draws a V, which is pointed to SW; besides in N, there are SW-NE trending erosional windows at Kutluca, Taşköprü and Cuma.

The Çınarlı Measured Stratigraphic Section totals 2855 m. In the absence of a better exposed itinerary, Çınarlı together with its Geyikduran tributary is taken as a type locality, and a type section is measured along it. The basal beds, even over arkose and quartzite, are not alike. Especially thick lensing feldspathic arenite bodies are striking, and somewhat similar to the one exposed to the S of İçerenköy in İstanbul. Besides, there are crystallized limestone and even marble interbeds. Intricate lateral and vertical intertonguing and lensing are common.

Along with the northern foot of Çene Mountain a light grey-cream, evenly fine textured, brittle and thin-bedded second generation quartzite resembles the one over the southern slope of Aydos Mountain in Istanbul. The latter also exhibits an altered tuff. This distinct quartzite is in lateral transition with silty and then clayey greywacke. The subfeldspathic wacke lens extending from Dolayba to Kurt and intertonguing with Halysites limestone is absent within Kocaeli Devonian. Again in Istanbul and to the NNE extension of Çamlıca, only Halysites limestone lies directly over the Çamlıca quartzite.

As a whole, the sequence is coarser at the base (feldspathic arenite, feldspathic lithic arenite, subfeldspathic lithic wacke, arkosic wacke and shale). There are finer textured detritals (laminated quartz wacke, shale) in the middle. The top displays thin-bedded black radiolarian chert and laminated-flatly nodular limestone in close alternance with greywacke. Usually the lensing of very many varieties of limestones deposited either at shallow depths or at positive phases. Lamination and amygdaloid limestone reflects cyclic sedimentation. Dark-colored, sterile, clayey shales are deposited within the basins. Life was prolific along with shallow, clear,

aerated stretches, but the usually hard limestones failed to submit guide fossils. Highly coarse or very finely textured lithologies are poorer in fossils.

The environmental conditions, such as nearby Kayalı Mountain, favored the deposition of a sequence not unlike the nearby arkose. The differentiation can be seen when walking along the direction of bedding until recognizable greywacke or an intercalation of limestone is encountered. Again within the same sector the whitish kaolin-like alternation product along with greywacke is due to intermingling of reworked volcanic products, such as tuff, to the depositing detrital. Porphyrite is also present there.

Carbonates consist mostly of micrite, biomicrite, bioclastite, bioclastic oolitic micrites. These are mostly bound to clinoforms, which are swept by weak currents. Sparite and dolomicrite are nearly wanting. The recrystallization is more or less advanced.

The greywackes are of unlike color and texture, and even composition. They all weather in yellowish-brownish hues. The finest grained variety is black inside.

The subfeldspathic lithic wacke may alternate with quartz arenite. It is more frequent than the feldspathic wacke and it is only occasionally laminated. The bedding is less conspicuous with finely textured varieties. There are slaty sectors and trends, but no schist is evolved. Rock cleavage, shear, joint, foliation, etc. directed hydrothermal alternation and guided weathering.

There are only subsidiary magmatic and volcanic bodies and even tuff, tuffite, tuffisite.

The collected fossils, determined by Dr. C. Kırağlı and A. Baysal, are of the Lower Devonian age span :

Favosites sp.
Michelinoceras sp.
Anoplia nucleata (Hall)
Rhipidomelloides cf. *musculosa* (Hall) *Solaris* (Clarke)
Platyorthis planoconvexa (Hall)
Megastrophia cf. *hemisphaerica* (Hall)
Brachyspirifer carinatus Schnur
Hysterolites hystericus (Schlot.)
Dalmanella cf. *verneuili* (de Koninck)
Eotonia cf. *medialis* (Vanuxem)
Strophodonta cf. *kozlowskii* (Caster)
Brachyspirifer carinatus (Hall)
Septathyris cf. *aliena* (Dreverman)
Amphipora ramosa (Phillips)
Hysterolites hystericus cf. *pachypleura* Solle

The sedimentation over a highly uneven shelf and under unsteady conditions makes intricate group which is basically made up of greywacke together with later-

al and vertical lithologic types bound to local setup and environmental conditions. Clino-unda-fondo-themes, under tectonic instability, manifested wedging and lensing relationships. The greywacke is not a flysch, and there is no molasse to correspond to it. There might have been an epicontinental geosyncline. Only slate is produced by dynamic effects; otherwise no metamorphism is induced.

TRIASSIC

A transgressive sea advanced anew over a rough country. The general outcrop pattern makes a V pointed to SW. The basal detritals to the NE of Tepecikköy, which alternate with lavas and their reworked products, are taken as representative and accordingly given the name of Kapaklı formation. This is laterally transitional with the Gıcık Conglomerate Member, the Gözlü Limestone Member, and the Afaklar Sandstone Member. Their correspondence in age awaits paleontological detailing.

A highland, situated to the N of the map area, is made up predominantly of volcanics and their pyroclastics. Both the detritals and the volcanics are red in color and fine in texture, so that their differentiation in the field is hard, and made more difficult by a thick forest soil and closely grown tall timber. This outstanding sequence is called Dümbüldek Formation.

Kapaklı formation (TRk)

Along a creek starting from the Devonian area to the NE of Tepecik village and heading NW a sequence is beautifully exposed. It is called Kapaklı formation after a spring of that name. This itinerary affords both a type section and a type locality.

The Kapaklıpınar Measured Stratigraphic section shows an alternation in which the volcanics exceed the detritals only at intervals. But this typical sequence does not contain the volcanics in S, and even there the onlapping beds vary laterally. So the Lower Triassic is uneven in its lithologic distribution, and only the broad lithologic associations are given specific names. The main body is a thick-bedded, eventually pebbly, occasionally friable sandstone.

At Kızpınarı a conglomerate is made up of uneven, unequilateral, unsorted granules, pebbles and blocks. The matrix is silty at the bottom, but limy at the top. The thick beds contain also reworked and fragmented Brachiopods. It is overlain, successively, by a reddish-yellowish marl; dark grey, thick-bedded, angular breaking limestone; light grey, laminated-thin-bedded and occasionally pebbly limestone. At Çırçırpınarı a yellowish subfeldspathic lithic wacke is used as whetstone by peasants. This is overlain by another reddish and less pure variety.

At Velidede Pınarı an alternation of laminated conglomeratic sandstone and pinkish, laminated-thin-bedded siltstone lies directly over Sopalı formation (i.e. arkose). At Kadıkuyusu of Yukarıhereke a coarse pebbly quartzite is well exposed. At Kabakuz arable fields a red, indurated basal conglomerate made up of even pebbles lies over the Devonian basement made up of greywacke holding limestone lenses. At places local basal limestone is overlain by an alternating series of limestones and marls. This suite is observed . in vertical transition with the younger

Hereke formation, which is made up of a steady sequence of grey, middle to thick-bedded limestone. Feldspathic wacke, quartz wacke, recrystallized oolithic and volcanic dolomicrite make up the outstanding lithologic association of the Lower Triassic.

Gıcık conglomerate member (TRkgı)

At Gıcık Creek, which lies to the S of Yukarıhereke, and still better along the highway to the E of Aşağıhereke, a coarse, uneven, unsorted, ill-bedded conglomerate and sandy conglomerate contains laminated sandstone streaks and even lensing recrystallized limestone interbeds. The limits of that basal conglomerate are not adequately exposed due to a thicket, cover and soil. No section of it is yet measured.

Gözlü limestone member (TRkg)

At Gözlü sheep barn, which lies to the SE of Yukarıhereke a uniform sequence of originally grey-black but now pink-red through subsequent hydrothermal alteration, hard, compact, angularly breaking, thick-bedded limestone is exposed, but no section of it is yet measured,

A slight unconformity is observable in between the underlying alternance of marl and limestone and the overlying Hereke Formation, which is made up of an easily recognizable limestone succession. The outset of the system to the N of Yukarıhereke is marly. At Alibeyköyü arable fields, a limestone overlies the Devonian basement. The quartzite along Duraklı dirt road is overlain successively by a conglomerate and then by a thin to thick-bedded limestone. The purple quartzite to the S of Eleşli village is directly overlain by a limestone.

Afaklar sandstone (TRka)

Although the Kuşakçı-Afaklar Measured Stratigraphic Section is chiefly made up of feldspathic wacke, it contains sandy sparitite and oolitite interbeds. It is 716 m thick. Along that road lie both the type section and type locality.

Küçükasmaca Measured Stratigraphic Section is but 186 m thick. There, a feldspathic lithic wacke is successively overlain by Hereke formation's quartz wacke, quartz arenite, shale and recrystallized Ostracod micrite. There are good outcrops over the northern and southern slopes of Sarp Creek, over Keçiyatağı hill and between Belen-Erikli hamlets. A large reddish pebble taken from a conglomerate cropping out at Uzunburun is a quartz porphyrite.

Over the western slope of Adatepe a reddish-purplish, and occasionally white speckled sandstone is evenly and steadily thin to thick-bedded, here and there uneven pebbly, soft to hard and seemingly unfossiliferous. Along Istanbul-Ankara highway, to the western end of İzmit City, a sample of it shows all through the cut.

At Belen hamlet and its vicinity a reddish-yellowish, evenly fine-textured, occasionally small pebbly, laminated-cross-laminated and also thin-bedded sandstone is noteworthy through mica specks paralleling the bedding. There are a few limestone lenses to the S of this old village.

The sandstone at Erikli hamlet is light grey, loose-textured, with repeating conglomerate streaks to a degree that suggests a cyclic sedimentation. Although it

resembles arkose, such features as steadily even and conspicuous bebding, stratigraphic position, and delimitation of the arkosic basement are helpful for differentiation.

The sandstone of psammitic type displays wedging type lamination, ripples, etc. Typical quartzite is noticeable through its steadily thin bedding, laminated and cross-laminated structure, evenly red color, and prominent ledge. Such an outcrop nearby the mouth of the Çınarlı Creek is exploited in an impermanent quarry. Elsewhere along that creek the sequence may exhibit shaly and dolomitic interbeds.

Dümbüldek formation (TRd)

Kurucadağ is a highland made up of closely alternating red detritals and grey to brown intrusives, extrusives and possibly pyroclastics. The latter could have been mingled with the depositing sediments. The predominant subfeldspathic lithic wacke is mostly fine-textured, and the bedding is rather thin. The differentiation of the volcanics from the sedimentaries is hindered by thick forest and soil cover. Although Dümbüldek spring area is a type locality, no type section is yet measured, because of lack of a suitably exposed itinerary. It is contrasted with Kapaklı formation in S, and hence a new name is given to this variant.

Hereke formation (TRh)

The road from Aşağıhereke to Yukarıhereke affords both a type locality and a type section. There the measured stratigraphic section is 950 m thick. The sequence is steady, and it is made up of lithologic varieties not readily distinguishable in the field. The columnar section shows from bottom to top crinoidal recrystallized limestone, dolomitic limestone, dolomite, sandy limestone, dolomitized crinoidal sparry pseudo-oolitite, dolomitized micrite.

Eleşli reference section measures 480 m, and displays from bottom to top dolomitic micrite, dolomitic crinoidal bioclastic micrite, micrite, dolomitic micrite, recrystallized and dolomitized micrite, fine to medium crystallized dolomite, and bioclastic micrite.

Along the sea slope a dark grey-bluish, hard, compact, thick-bedded limestone, but landwards a light grey, rather soft and then flat and small lensing spalling limestone is common. But this is a minor and unsteady lateral transition. As these might alternate no distinct unit is in question. In N there also appear grey marl and red shale interbeds. Other noteworthy lithologic varieties are marly limestone; dark red-pink, laminated and thin-bedded, compact limestone; schistose limestone, tiny nodular limestone; ripple marked sandstone and siltstone.

To the NW of the mapped area and between Kozluca-Alihocalar villages the limestone sequence is identical with the sequence between Yukarı- and Aşağıhereke, and there it overlies Dümbüldek formation. In the NE corner of the map area and along Sarp Creek the sequence is less steady, and there appear quartz wacke shale or shale interbeds, which might be thicker, as along the Küçükasmaca Measured Stratigraphic Section.

The dolomitization is detected by dyeing thin sections. The dolomite is not directly precipitated; and the existence of a thick sequence of it is not yet de-

tected; neither rock salt or gypsum accompany the formation. An irregular invasion affected both the allochems and the orthochem.

The dolomization phenomenon is repeated, as Campanian limestone also is dolomitized but at a much smaller scale.

Solutions emitted after the main volcanic phase penetrated along the various breaks rather than through the pores, so the substitution is controlled tectonically. Detritals are nearly unaffected by this process. Future needs might lead to delimit commercial dolomite and dolomitized limestone.

UPPER CRETACEOUS -PALEOCENE

The transition from Mesozoic into Tertiary, as ideally exposed at Şemsettin village, is a gradational one. There the top Şemsettin limestone (mainly Maestrichtian) interfingers with an embayment of grey-green, thin to unbedded, soft marl, and this is topped first by conformable transitional beds of alternating marly limestone and marl, and then by interchangeable soft beds of fine detritals and marls. No unconformity is in sight but a detailed stratigraphic paleontology is imperative.

The local outcrop pattern is controlled through Dere-Çal Axial Low. At a regional scale a SW-NE trend is observable, as for example on The Geologic Map of Turkey to a scale of 1:500,000. Smaller outcrops lie nearby İzmit and Çardakbayırı-Heybeli Axial Low. The onlapping beds are of unlike lithology, because the transgressive sea advanced over a hilly country. So the following formations together with their members are here differentiated: Hereke conglomerate with its Eren conglomerate member and Kutluca member; Şemsettin limestone and Korucu formation.

Hereke conglomerate (Kh)

Hereke-Küllüktepe Measured Stratigraphic Section is 83 m thick. Its lower 45 m is large pebbly, its middle 9 m is an evenly textured limestone, and its higher 39 m is small pebbly. The columnar section is made up, from bottom to top, of dolomitized pseudo-oolitite, pebbly dismicrite, coarse conglomerate, recrystallized dismicrite and dolomitic pebbly micrite. There exists a band of outcrop trending NW from SW corner of the map area and outwards. The uneven pebbles which were derived from Hereke formation are tight through pink, grey or variegated limy cement. *Hippurites* are found where pebbles are either scarce or wanting. The sequence is somewhat changeable both laterally and vertically.

Eren conglomerate member (Khe)

At the head of Kangal Creek to the N of Yarımca, overlying unconformably the arkose, Cretaceous starts with an odd conglomerate, called Eren conglomerate member, after the nearby hill to the W. The outset of the Belen measured stratigraphic section displays 30 m of grey, thick-bedded, cliff-making conglomerate. Eastwards it includes cross-stratified sandstone, marl, etc., which occasionally and locally gain thickness. Characteristically the conglomerate is grey-greenish, the pebbles of which are mostly flat, uneven and unsorted, bound together with a medium amount of sand and silt. Cut and fill structure, cavernous

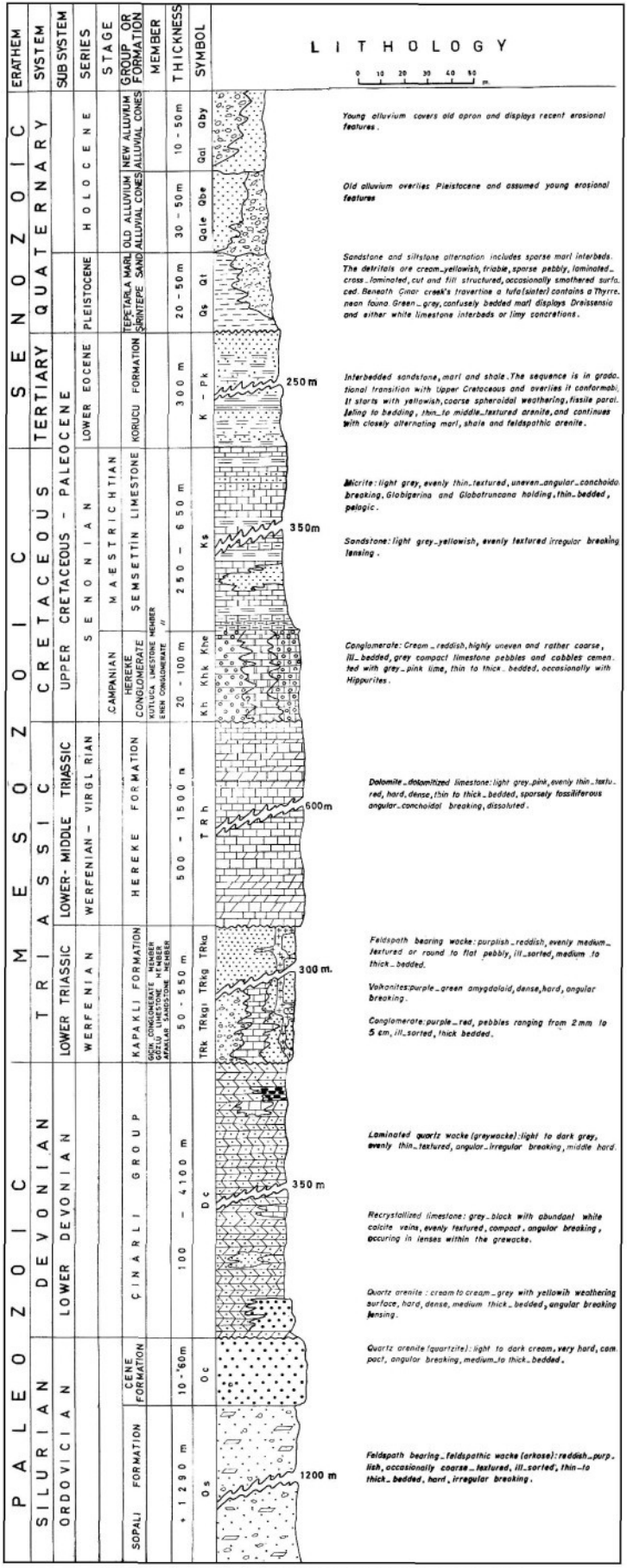

Fig. 4 - Generalized stratigraphic section of the İzmit - Hereke - Kurucadağ area.

weathering, etc. are noticeable. It is overlain by marl spalling in flat lenses. Over Yarımca-Belen dirt road the overlying marl and nodular limestone alternance is identical with the one exposed along the old Istanbul-Ankara highway to the W of Kıyırlı directly over the Devonian basement. This shows the hazards of cursory correlations.

A basal conglomerate at Alioren overlaps arkose, and it is overlain by a cliff-making, scanty pebbly sandstone. The latter may display repeating but upwards finer growing conglomerate streaks. At Belen the sandstone beds overlying the conglomerate contain rounded arkose pebbles. Nearby there, even Şemsettin limestone directly overlies Sopalı arkose. At Bali hamlet a pink, pebbly stratified sandstone resembles the Lower Triassic one. Similarly, at Sopalı hamlet a reddish-brownish sandstone with conglomerate streaks looks like the Lower Triassic one, and there it is overlain by Cretaceous limestone. At Elmacık hamlet a basal grey conglomerate is exhibited, the pebbles of which are uneven, subrounded and unsorted but well-indurated by a sandy matrix. A grey sandstone and siltstone with some lignite streaks is the base of local Cretaceous beneath the Kutluca limestone member.

At Yağcılar village a noteworthy basal conglomerate is finely exposed at both sides of the creek, and extends nearly 2 km on the village side. The uneven pebbles and the blocks of over 30 cm are bound by a sandy-silty matrix at the base but a limy cement at the top. The thick beds carry large Actaeonella, Ostrea etc. Along the new road cut a higher sandstone bed is exposed with a smothered surface. Along the derelict dirt road marl is observed beneath the conglomerate.

Over the road from Küçükasmaca to Beşdoğan the basal red to green, pebbly, ill-bedded, friable sandstone is overlain by another grey, even-textured, fine, evenly bedded one.

Marl and even an alternance of greyish-bluish sandstone and greenish marl might start the Upper Cretaceous sedimentation. Marl is more common over the Devonian greywacke, and limestone more usual over its limy tracts.

To the E of Aşağıhereke the Upper Cretaceous starts over Hereke formation by an alternance of grey marl and dark-colored, steadily medium bedded limestone (i.e. bioclastic micrite, biomicrite, and intraclastic biomicrite).

Kutluca limestone member (Khk)

A tract of over 10 km long and 1-2 km wide, extending in a SW-NE direction from Kıyırlı village to Büyükdere Brook, and wrapping around a similar Devonian high, is made up of a biostromal limestone (micritic bioclastite). It is thick-bedded in contrast to the overlying thin-bedded Şemsettin limestone of Maestrichtian age. The former makes ledges and canyons in opposition to cuesta, escarpment together with dip slope producing the latter. A type section is measured from sandstone at the head of the Kömürlük Creek to the S of Duranlı hamlet and the hillside is the type locality. The name is borrowed from Kutluca hamlet, where for a long time stone quarries are in exploitation. The limestone shows minor variances both in color and fossil content, and the quarry men keep looking for the marketable kind. Basinward it is onainly overlain by Maestrichtian Limestones, but both kinds might be locally interfingering.

A striking exposure is noticeable from the old Istanbul-Ankara highway at the entrance of Bıçkı Canyon; but possibly through onlapping conditions it is no more observable within similar creeks further S. Şemsettin limes-tone starts at the base of Şemsettin Measured Section with a richly megafossiliferous *(Dicyclina schlum bergeri* Mun. & Chalmas), unbedded, coarse-textured, white, limestone. The same is thinner to the E of Kalburcu village, but it is wanting towards Yarımca, where a grey to black, hard, evenly medium to thick-bedded, sparsely fossiliferous lime-stone is present.

Nearby Yusufunkuyusu over the old Istanbul-Ankara highway a brick-red thick-bedded, hard, richly fossiliferous *(Hippurites* and others) fancy-looking lime-stone is unexploited because of its badly broken state. It is overlain by a light red marly limestone, and then by typical Şemsettin limestone. Further E along the same highway, and beneath a red, coarse, unsorted, ill-bedded conglomerate ap-pears an alternation of greenish marl and blackish, very coarsely nodular limestone which is similar to the one exposed along Yarımca-Belen road, mentioned under the heading of «Eren conglomerate member». At Yılanlıkaya a white, thick-bedded limestone interfingers and even alternates with a stratified, light-colored limestone. *Echinocorys* cf. *conicus* Agassiz (Campanian) is found at Önezli and Duranlı. There are also *Stegaster* sp. gr. s. *novoi* Lambert (Campanian) and *Inoceramus balticus* Böhm at the second locality.

Şemsettin limestone (Kş)

A readily recognizable steady sequence is a white, thin-bedded, fine-textured, microfossilliferous, angular breaking, competent limestone stands high in either cuestas or escarpment together with dip slopes. The overall outcrop pattern makes a V which is pointed to SW. The outset is dissimilar and might be either bio-stromal or not, while the top grows marly. The transitional beds with the overlying Korucu Formation of Paleocene age embody marl interbeds.

Şemsettin Measured Stratigraphic Section amounts to 633.50 cm. There are also reference sections: Korucu, Belen, Kalburcu, Arızlı-Kayapınarı.

Together with the biostromal fauna of the base, the following species were determined (determination by: Dr. E Meriç, M. Serdaroğlu, N. Karacabey, Y. Sez-ginman, A. Oral, E. Öngüç):

Hippurites (Vaccinites) aff *inaequicostatus* Münster
Radiolites endrissi Böhm
Plesioptygmatis aff. *atschadjurensis* Pchel.
Actaeonella immanis Böhm
Actaeonella gigantea d'Orb.
Phyllocoenia exsculpta (Reuss)
Echinocorys sp.
Echinocorys cf. *ovatus* Leske
Stegaster sp.
Holaster sp.
Globotruncana stuarti (de Lap.)
Globotruncana area Cush.

Globotruncana rosetta (Carsey)
Globotruncana lugeoni Tilev
Globotruncana cf. *conica* White
Globotruncana lapparenti tricarinata (Quer.)
Globotruncana lapparenti lapparenti Brotzen
Globotruncana contusa (Cush.)
Globotruncana calcarata Cush.
Globotruncana coronata Bolli
Globotruncana fornicata Plum.

To the N of Arızlı village the Maestrichtian limestone is ill-bedded and even massive. It is exploited at small scale for local needs. Further N a grey to pink, nodular looking limestone is of the same age and strict differentiation is based upon the comparison with the resembling Devonian limestone along the packway crossing the creek to the E of Asmacaaltı. At Çiftlikpınarı an evenly bedded reddish limestone dips underneath the nodular looking limestone. A few samples from that sector were determined in thin sections as bioclastic micrite, and the slaty rocks as shale and clayey shale. The former is grey, steadily fine-textured, uneven to angular breaking and high standing in topography.

At Kozluca in the NW corner of the map area, a white, evenly thin-bedded limestone containing Hippurites, Inoceramus, Echinid, etc. overlaps an old high made up of Dümbüldek formation. Over the NE sector of the mapped area, at Türeş and Karaarmutbeli a similar sequence is built up of a white to cream - colored, medium to fine-textured, rough to angular-breaking siderolites bioclastite. The outcrop to the west of Türeş hamlet is made up of closely alternating white competent limestone and greyish-greenish marl.

An odd feature of Şemsettin limestone is the occurrence of lensing sand bodies, such as the one at Kalburcu village's cemetery, two smaller ones to the NW of Kozluca village, and a huge one to the E of Şemsettin village which is shown over the columnar section of the Şemsettin Measured Stratigraphic Section. At exposure it is weathered and discolored. The fresh one is cream to brown, fine or small pebbly, crudely stratified, and seemingly unfossiliferous.

Korucu formation (K-Pk)

There are convincing field observations which concur to an inference about the continuity of sedimentation from Mesozoic into Cenozoic. Söğütlü trough is a SSW-NNE-directed synclinorium filled in by a soft formation, which in the main is made up of closely alternating fine detritals with marl and marly limestone. The overall age is Paleocene, which is used here in the sense of Eonummulitic by Haug. It makes a depressed lowland of arable fields which stands in contrast to the forested highlands of Şemsettin limestone. The largest outcrop stretches along Kocadere, and everywhere it is continuously covered either with crop fields or woods. So, a thick soil cover together with fine slope waste merges with alluvium, hence the difficulty of laying a definite boundary between them. Bare rock and suitable exposures lie along the road cuts, and at the foot of highland which are dissected by streams. So, measuring a complete Stratigraphic section, either a single

or composite one, is not practicable. Korucu type section displays a small fraction of it, and the type locality lies along the dirt road by that village, the name of which is used for the formation. Korucu Measured Stratigraphic Section displays a thickness of 257 m, but in the future longer sections would contribute to a better understanding of Korucu formation and eventually might lead to differentiation of members.

Arızlı-Kayapınarı Measured Stratigraphic Section is especially undertaken in order to prove the inexistence of an overthrust. Along the section line the dips are normal; i.e. Korucu formation does not dip beneath the ,Şemsettin limestone as along the dirt road to the N of Arızlı village. There only a local fault is to be inferred, and it does not continue into the flanking deep creeks. Here, only a thickness of 105 m is measured, as mass movement, slope waste, creep, etc. hinders the outcrop further S.

In the vicinity of Kamilbakar sheep barn of Şemsettin village the typical Maestrichtian limestone obviously interfingers with a greenish, thin-bedded, soft, seemingly unfossiliferous marl filling in an embayment of the former.

To the S of Kalburcu village no such embayment is present, but there the normal Maestrichtian limestone becomes first marly, then starts to interbed with soft marl. After these transitional beds closely alternating fine detritals and marl make up the definite Cenozoic. Occasionally the sandstone shows flow marks casts over the lower face. Only competent sandstones suit for measurements. Marl, when dry, is hard and brittle but upon wetting may run by solifluction. There are wide apart bioclastic Globigerina micrite, spicule micrite, etc. The quartz arenite is the common type of sandstone.

Along Yarımca-Kalburcu and Kalburcu-Değirmenbayırı trails and further E, the white, fine-textured, thin-bedded limestone is hard to differentiate in the field from a younger sequence built up of alternating limestone and marl; and although a light-bluish, evenly thin-bedded, angularly breaking marly limestone zone makes the transition, the boundary line is approximate.

Spot samples' thin sections yielded Paleocene microfossils, but a paleontological approach is needed for better delimitation of biozones. At Belen hamlet's Kozal ridge a light grey, brittle, angular breaking, fossiliferous bioclastic micrite is transitional between Upper Cretaceous and Paleocene. To the S of that hamlet's cemetery, alternating greenish marl and greyish fine sandstone dip underneath the uniformly red Lower Triassic sandstone, and a fault is inferred. A red to pink, evenly thin-bedded limestone overlapping the arkosic basement is overlain by a cliff making white limestone. Along Belen-Erikli ridge dirt road the Triassic red sandstone is in fault contact with Şemsettin limestone. Orbitoides marly limestone lies over the Devonian to the N of Belen. Small Nummulites containing micritic bioclastite crop out along the trail from Erikli to Obruk Creek. The cream-colored limestone to the S of Kaynarca spring of Hacı village is in gradational transition with Paleocene grey and angular breaking marl. A bioclastic micrite exposed to the S of that village contains Upper Paleocene microfossils.

A ridge extending from Mantarlık to Kertil to the W of İzmit displays a white, thin-bedded limestone which is in gradational transition with Paleocene marl. A grey, angular breaking marl exposed to the E of İğnediler village contains

small Nummulites. Over the road to İshakçılar there are wide apart interbeds of fine-textured, muscovite flakes-bearing sandstone. A steady sequence of marl to the SW of that village is hard to observe because of its spheroidal weathering.

The following is a list of Paleocene fossils determined by Dr. E. Meriç and M. Serdaroğlu:

Nummulites sp.
Operculina sp.
Discocyclina sp.
Gastropod
Globigerina soldadoensis Bron.
Globorotalia pseudomenardii Bolli
Globorotalia velascoensis (Cush.)
Globorotalia aequa Cush. & Renz
Globorotalia angulata (White)
Globorotalia acuta Toul.

QUATERNARY

Neither Miocene nor Pliocene are known through their outcrops, but reworked Miocene Foraminifera from a Pleistocene sand deposit indicates the former presence of that series within the investigated area.

Tepetarla Marl and Şirintepe Sand, although inadequately exposed either along road cuts or sea cliffs, are taken as formations here, their mutual relationship is not directly observable.

There are noteworthy Recent aggradational and degradational features.

Tepetarla marl (Qt)

At the far end of İzmit and nearby Çınarlı Creek, the former Istanbul-Ankara road, cut to the N exhibits a greenish, ill-bedded, weathered, soft *Dreissensia* marl. The new highway cut further W, exposed thin-bedded, greenish and whitish, seemingly unfossiliferous marl with eventual chalky concretions. Tepetarla is a name of nearby hill, totally covered with sculptured apron materials, which assumably hindered the overlying Şirintepe sand, as attested by some scattered Pecten, Ostrea, etc. A tiny outcrop of that formation lies to the SE of the hill. According to G. Chaput, *Dreissensia buldurensis* d'Arch., which she determined, indicates a brakish Pleistocene lake. A measurable section of Tepetarla marl is failing.

Şirintepe sand (Qş)

At about 750 m to the SW of the exposure of *Dreissensia* marl and at the southern foot of Şirintepe, an abandoned sand quarry displays a face of nearly 20 m high. Şirintepe, is similarly covered by sculptured apron deposits. There were similar hills nearby Yarımca, but they were erased to get necessary tracts for the projected industrial plants. So the mentioned sand quarry is the type locality, and there exists no better section than the quarry face. There the sequence is made up of laminated or cross-laminated, thin to thick-bedded, yellowish, friable, occasionally small pebbly sandstone and siltstone, which contains wide

apart streaks of greenish marl and shale. Some of the bedding surfaces are smothered with white, brittle megafossils, which assuredly are similar to the Yalova deposit investigated by Erinç and Chaput.

A widespread travertine deposit "overlies a white, friable spring tuff which includes a Tyrrhenian faunule determined by G. Chaput : *Cerithium (Thericium) vulgatum* Bruguiere, *Cardium (Cerastoderma) edule* var. *lamarcki* Reeve, *Mytilus galloprovincialis* Lamarck, *Pecten glabra* Linne var. *pontica* BDD.; no Foraminifer is present.

At Hünkar Çiftliği sand quarry the following Miocene Foraminifera were determined also by G. Chaput : *Globigerina bulloides, Globigerina inflata, Globigerinoides triloba, Globigerinella* sp., *Lagena williamsoni* and *Entosolenia sp., Cibicides.*

An interfingering relationship between Tepetarla marl and Şirintepe sand is inferred from mutual outcrops. The former's brackish lake could have been repeatedly invaded by transgressing sea.

Among the Recent features the Karst area of Hereke limestone in its first stage is noteworthy for its sinks, swallow holes, dry and blind valleys and a few vauclusian springs.

VOLCANITES

Volcanic activities are restricted to Devonian and Triassic. In the field thick vegetation cover hindered to trace all the manifestations.

Devonian is poor in intrusives and extrusives. There are diabase, volcanic glass, epizonal crystal tuff, etc. Also reworked pyroclastics have been incorporated into the settling deposits, and these are manifested through white kaolin-looking weathering of some greywacke.

There were suites of contemporaneous volcanic sills, dikes, flows, and also their reworked products which together with pyroclastics mingled with the settling detritals of Lower Triassic. These are scanty in S, but plenty in N. All the manifestations are affected by autometamorphism (anchimetamorphism), i. e. during the cooling and crystallization stage of the magma the residual hydrothermal solutions autohydratation caused ion change, and so a partial modification of volcanic rocks' minerals ensued. Through this metamorphism, i. e. autometamorphism, the plagioclase albitized.

Within the albite porphyrite domaine to the NE of Tepecik village a dike of green epidotfels is observed. There are purple, red, black porphyrites with either white specks or amygdules.

Over Kuruca Mountain in N the volcanics outweigh the detritals as flows, wedges and flat lenses. A Lower Triassic conglomerate near Uzunburun (near Sarp Creek), among others, contains blocks of over 1/2 m^3 of albitized porphyrite. Among the varieties determined by Dr. Elgin there are albite porphyrite (albitized porphyrite), autometamorphic keratophyre, keratophyre spilite, autometamorphic quartz-natron keratophyre, autometomorphic albite porphyrite, autometamorphic quartz keratophyre and epidotfels (olivine diabase totally transformed into epidote).

STRUCTURAL GEOLOGY

REGIONAL PATTERN

In order to disclose the local structural pattern, a tectonic analysis is conducted on the Geologic Map of Turkey's Istanbul sheet. On this map, Istanbul, Kocaeli, and Sakarya Paleozoic formations lie on the same trend. They are made of bundles of anticlinoria and synclinoria. They are separated through axial highs, toward which the fold axes plunge. So there exist noses and bays.

Kocaeli Paleozoic makes a wide angle with İstanbul Paleozoic, due to Şile Recess. It is noteworthy that these Paleozoics stud the trend of the basement complex exposed at Istranca Mountains.

In the entrenched epigenetic Sakarya valley between Bilecik and Alifuatpaşa an Appalachian relief is splendidly exposed, İzmit Gulf is one of the observable synclinoria, and served as a channel for the advances and retreats of the Pleistocene sea. Its constrictions are due to opposingly directed talus and aluvial cones or the axial highs. Its eastern extension is directed to Adapazarı rather than to Sapanca Lake, while its western continuation might lie at Büyükçekmece. Large depressions, mostly filled in with lakes are situated at the intersection of syncline with an axial low, and bound by axial highs. The basement complex's trends are either exposed or reflected by the overlying Paleozoic.

The strike-slip faults noticeable through sag pond, offset stream, wind gap with the occurrence of devastating earthquakes were traced from Bolu to Erzincan. The one at Adapazarı is shown en echelon with the North Anadolu Seismic Line, but it is not extended towards İzmit Gulf. İzmit Gulf area is a first-degree seismic zone, a second-degree one lies to the N of Gebze latitude; the Black Sea shore is not seismic.

Söğüt synclinorium filled in by Cenozoic deposits is a synclinorium trending N 70°E; it is lodged within the anticlinorial bundle of the underlying Devonian. It may be considered as an epigeosyncline. It is rimmed by Upper Cretaceous from inside, but Triassic from outside. The renewed tectonic control is noticeable through the variance of the onlapping deposits of the systems. Often a shelf environment was ready at the outset of many sedimentary cycles.

The investigated portion falls within the Anatolids, and lies over the path of Istanbul Axial High.

LOCAL LAYOUT

The whole of the structural evolution is pictured through a Structure Map, the background of which is differentiated - according to the Structural Stages. So a layer-cake geology is efficiently pictured.

While drawing the fold axes the weight is given to the undulated E-W trends, not without some bias. The measurements leading to S-N trends should derive from pre-existing sedimentary troughs and erosional depressions' initial dips caused by an ever repeating Appalachian relief.

For Istanbul area a N-S trend is fyrthered both for Caledonian and Hercynian orogenies, the E-W oriented alpine trend being stronger. The small-scale interference folds observed, for example, to the near E of Anadoluhisarı, were not encountered during the field investigation at Kocaeli. Atwartn outcrops to the trends of folds might be due to such a feature at a large scale, or to the predominance of alpine orogenies.

Folds

As will be noticed over the cross-sections most of the folds are en echelon, undulose and asymmetrical to S. All of them are drawn by considering the bedding measurements. Kocayarma along the old Istanbul - Ankara highway shows an intricate structure with overfolds, shears, rock cleavages affecting the Devonian. There is disharmonic folding between greywacke and the included limestone. Besides the former is tightly, while the latter is openly folded. Only slate is present, assumably along the disturbed zones. The radiolarian chert and the amygdaloidal limestone interbedded with greywacke are rather wrinkled.

The Triassic competent limestone is rather openly folded. The thin-bedded Şemsettin limestone yielded by small folds, especially where marly interbeds are present. The soft Korucu formation is not tightly folded.

Faults

The faulting, which is subsequent to folding, is scarce and not well exposed. The longitudinal, branching overthrusts drawn on both 1 : 100,000 and 1: 500,000-scale sheets failed to be conspicuous to the author, even over the aerial photographs to a scale of 1 : 35,000, the scale of which is decidedly unsuitable for such diagnosis.

A subsidiary fault is inferred by dipping Korucu formation beneath the Şemsettin limestone to the N of Arızlı village, which does not extend to the deep carved creeks in E and W. It is the same with the alternating detritals and marls dipping underneath the Afaklar sandstone at the cemetery of Belen village. Erikli - Belen fault being not exposed is thus inferred. Şirintepe's sand quarry displays beautifully the small-scaled step faults toward the sea.

Axial highs and axial lows

The following axial highs and lows from E to W are drawn over the Structure Map :

Hatip-ÇaltarlaEAAmbartarla-ÇınarlıEY
Çene- Toylar EA Bali - Aktaşlar EY
Dere- Çal EA Çelikli - Kozluca EY
Çardakbayırı - Heybeli EA Kayalı- Dedebayırı EY

DIASTROPHIC HISTORY

An angular unconformity in between quartzite and greywacke discloses the Ardenian phase. The specific Hercynian which was active is not detectable because of the absence of the related stratigraphic stages. The recognized phases of alpine orogeny are Şile, Cimmeric, Van, Attican, Wallachian and Pasadenian. The faultings date from the middle or the late alpine cycles.

ECONOMIC GEOLOGY

As metallics there are iron and copper; as manufacturing industrial mineral barite; as fuel lignites; as construction materials limestone, tile and brick earth; as water resources springs and groundwater.

Autometamorphism, e.e. residual solutions derived by the recrystallization through the cooling of the magma, yielded metallic ores through ionic change. The products are due to phase changes and alterations by action and reaction in between the hydrothermal solutions and the rocks.

Yukarıhereke's Maden Creek, Kızılcıkpınarı, Fındıkpınarı, etc. exhibit, at places, hydrothermal siderite, ankerite, pyrite, blende (sphalerite), chalcopyrite, galena, quartz, etc.

Chalcopyrite, malachite, azurite, quartz, etc., are present at Alataşlar, Yumrukaya, Longurday, etc., where a few test pits still persist.

Karaağaç barite mine is of hydrothermal origin, and the magmatic emanations through fissured greywacke deposited barite veins and veinlets. They are tested through numerous pits; neither actual exploitation nor shipping has ever been undertaken.

There are thin and discontinuous lignite seams along with the basal sandstone of Upper Cretaceous age at Bıçkı Creek and at Kocacobul of Kutluca village.

Kutluca village's biohermal limestone has long been known in the market as «bez mermer», because of its tint close to that of cotton material. Hereketaşı is a decorative architectural stone. Şemsettin limestone is in flags, and so it is preferred for rustic masonry. Its marly variety disintegrates by weathering, so it is imperative to plaster the walls for their endurance. Afaklar sandstone is used only as an emergency material when others become hard to get. Occasionally whetstone is obtanied by local people from Lower Triassic sandstone to the E of Tepecik village.

Çene spring's water is highly appreciated since long, and recently it is conducted to a loading station on the right side of Çınarlı Creek nearby İstanbul-Ankara highway. There are either exploited or hitherto unexploited, ı..ostly karstic springs issuing from Devonian limestone, Hereke conglomerate, Şemsettin limestone, etc. Besides the alluvial valley fills the Şirintepe sand bodies afford interfingering or lensing aquifers to be reached by shallow drillings. The intricate stratigraphic relationships necessitate geophysical exploration beforehand.

The following types of soil are present: alluvial, brown non-limy soil of rough lands, redzina, red terra rossa.

GEOMORPHOLOGY

Over the investigated portion of Kocaeli a close relationship exists between the land forms, lithology and tectonics. The present topographic features are but a stage of an intricate geomorphological evolution. These were guided through the fluctuations of the base levels of İzmit Gulf and Black Sea. ′

Looking around from a clear summit area of Kuruca Mountain, a strikingly even and steadily inclined surface which is deeply carved by the fluviatile network is noticeable. There exist numerous smooth profiled hills (old topography), and entrenched valleys (young topography). Arkose is worn readily, and its physical disintegration is more swift than its chemical weathering, especially when bereft of its vegetation cover and soil. Mass movements in the direction of valley is striking, and the talus cones at the mouth of deep gullies are prominent. The quartzite outcrops either in single mounds (monadnpcks) or along the steady escarpments together with occasional dip slopes. The greywacke is exposed either in smoothly rounded ridges or the deeply carved valleys. Its limestone beds and lenses make ledges and steps with waterfalls.

The Lower Triassic detritals lend to dendritic carving, and lack the steady slopes of competent beds. There are a few cuestas along with the gentle dips. The volcanic intercalations fail to show by specific forms. Over Kuruca Mountain's highland, possibly through the thick forest, no single feature is detected. There are long escarpments and wide dip slopes over the land made up of Hereke limestone. Over it a dry land is established with various features belonging to the first stage of karstification, such as sinks, swallow-holes, dry and blind valleys and occasional karst springs.

There are ledges and sheer canyons along with Kutluca limestone. The pure limestone variety of Şemsettin limestone is rather competent, but becomes incompetent with admixture or intercalation of marl. Cuesta, sharp ridge, escarpment, canyon are usual features with the former, and buckling accompany the latter. Korucu formation's soft lithologies occupy at present a huge depression, and there the smooth ridges and slopes make either crop lands or woods.

The drainage network is epigenetic. There are narrow creeks along with hard lithologies but widely alluviated valleys over the soft ones.

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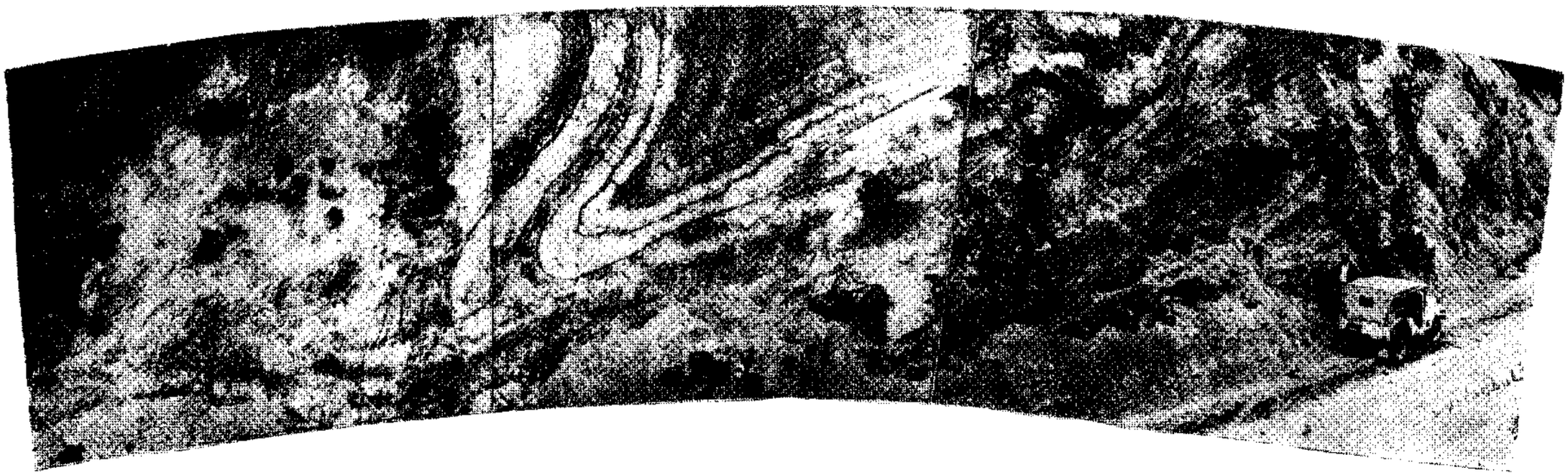
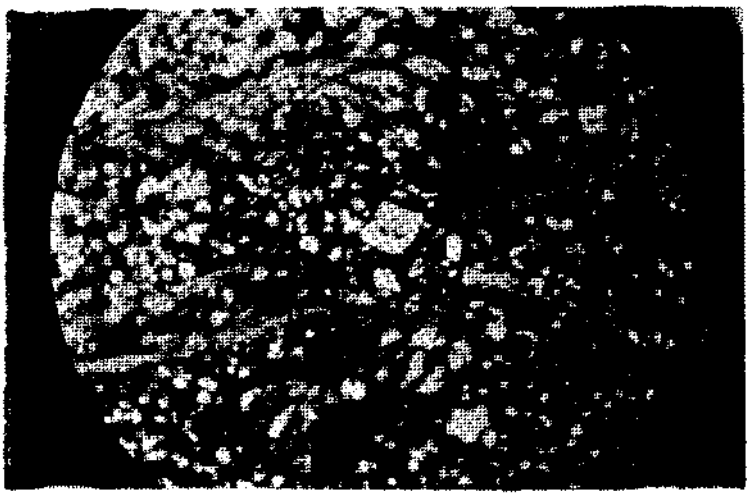


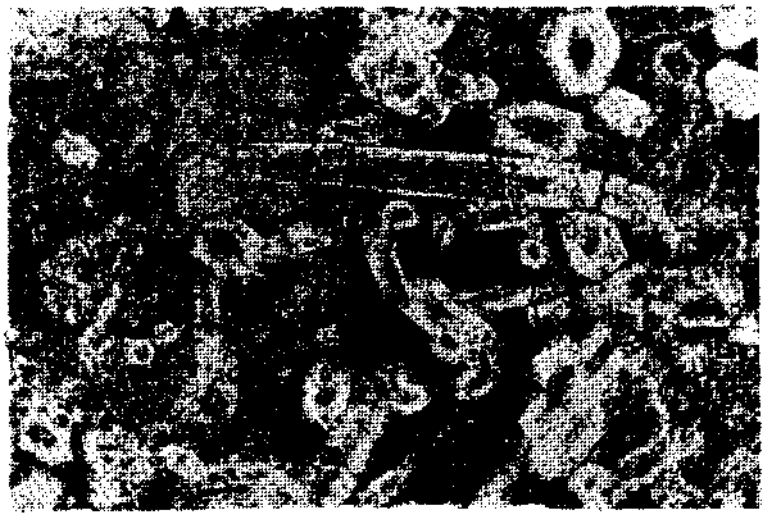
I - 48 Similar-type complex overfolding of the Devonian greywacke as seen along the biggest cut of the old İstanbul-Ankara Highway to the west of Kıyıklı hamlet.

II - 31 Şirintepe sand quarry as seen in a NW direction : The fossiliferous Tyrrhenian is made up of laminated-cross-laminated to thin-bedded, occasionally pebbly, smothered surfaced, friable sand and silt. The step faults are in descent towards İzmit Gulf.



K13A Korucu Formation : Nummulites, Assilina feldspathic arenite. × 40

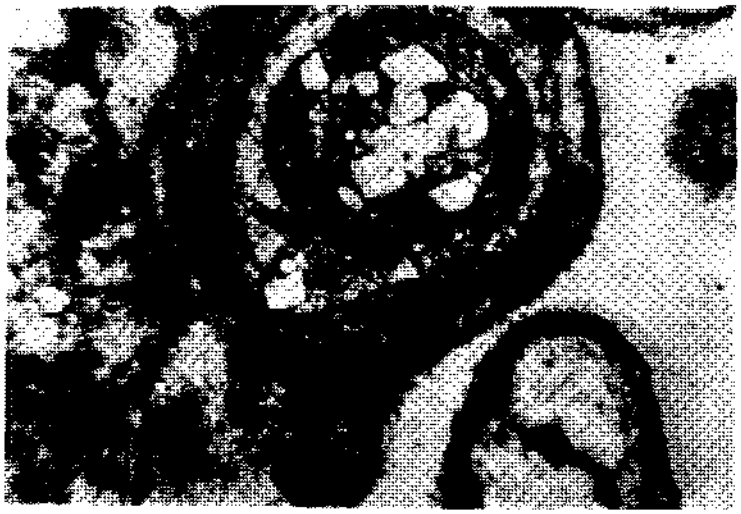
65 Pebbly arkose. Crossed Nicols. × 80



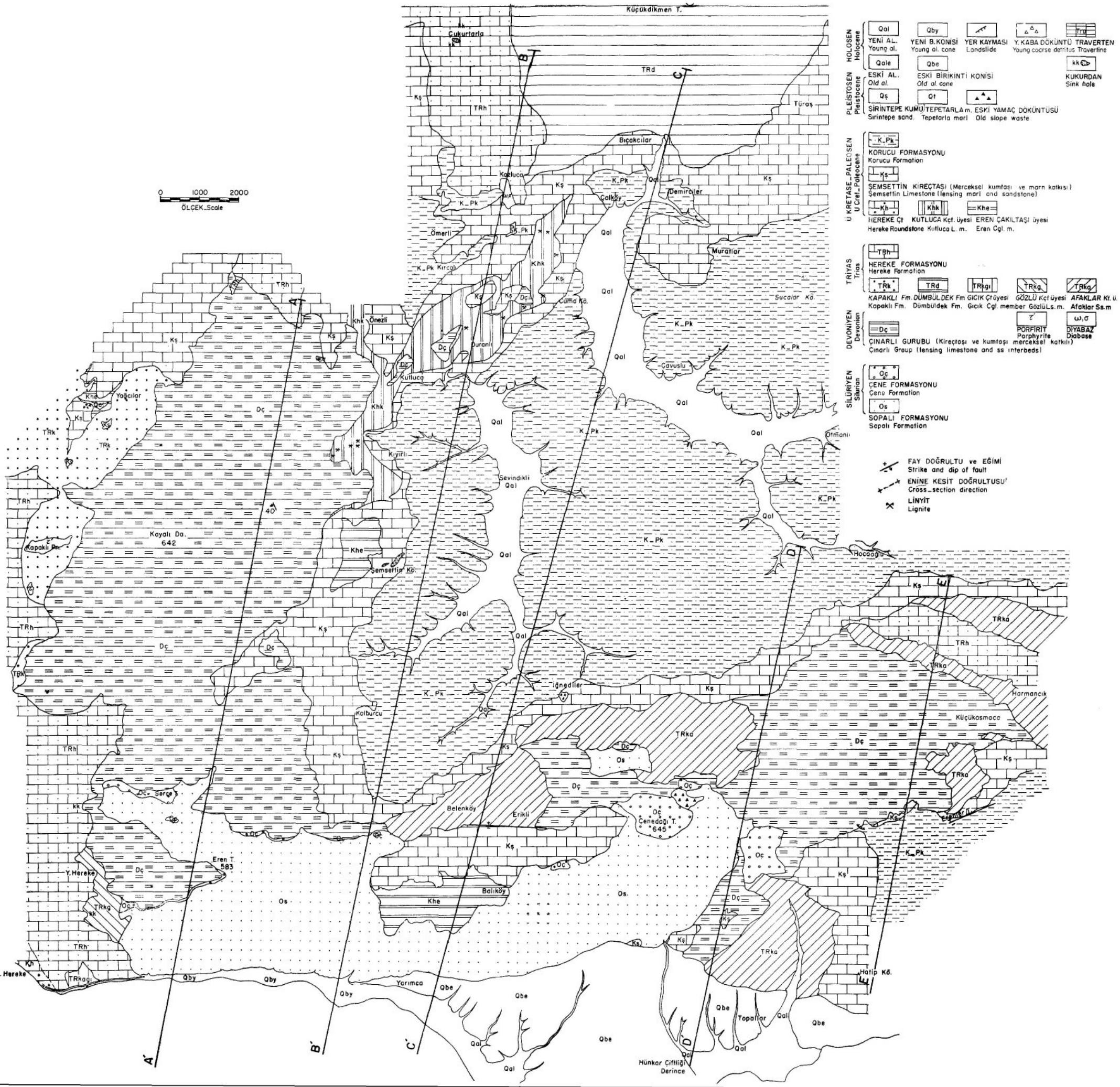
28 Spicule micrite. × 220

D19 Devonian shale with slant false cleavage. × 40

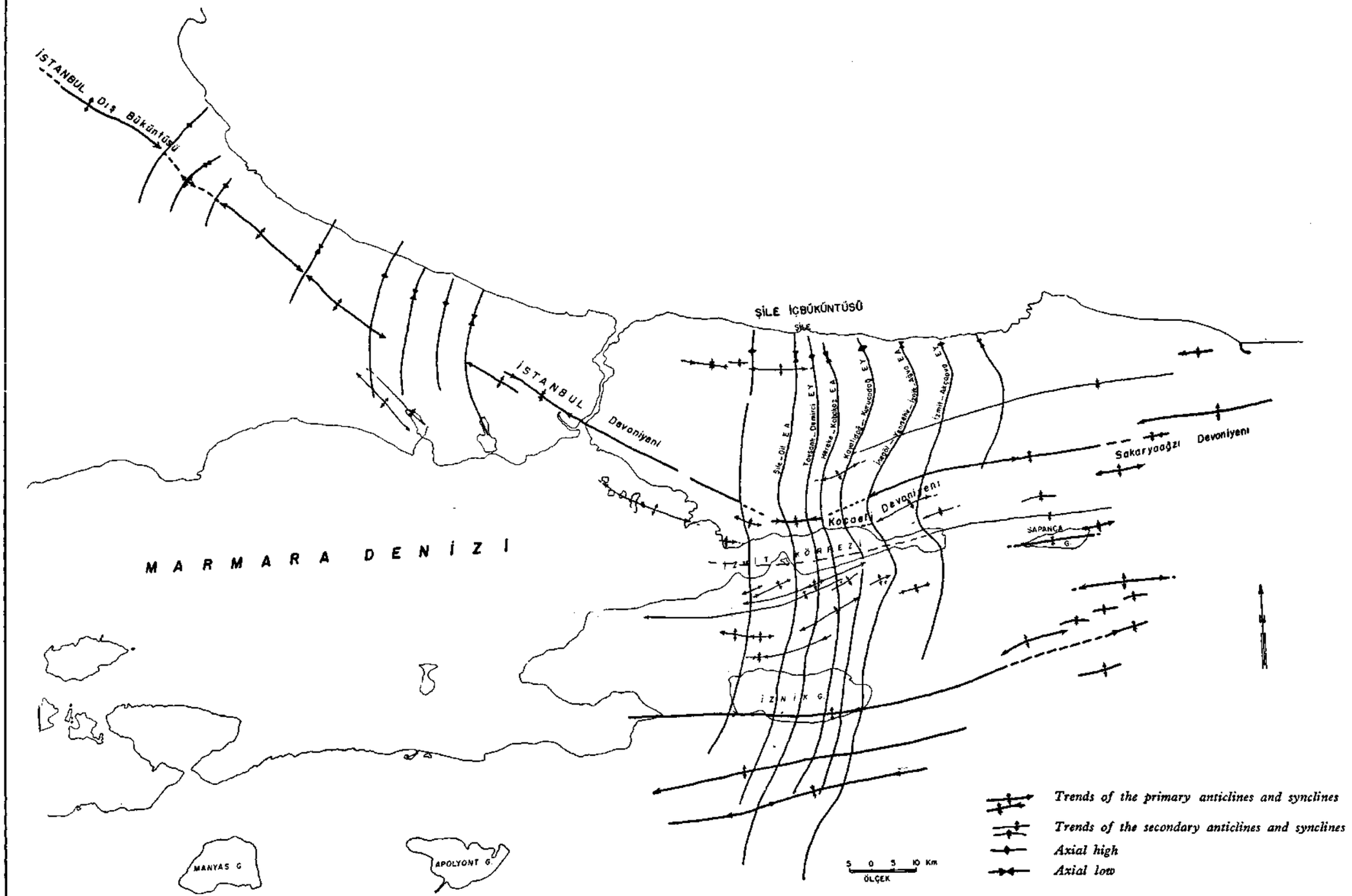
IV8 Dolomite crystals along the walls of a vug. Crossed Nicols. × 40



IV24 Dolomitized pseudo-oolites. × 80



GEOLOGIC MAP OF THE İZMİT - HEREKE - KURUCADAĞ AREA



TECTONIC MAP OF ISTANBUL REGION

1. Enver ALTINLI

0 1000 2000 m
ÖLÇEK_Scale

ALP KIVRIMLANMASI BÖLGESİ
REGİON OF ALPINE FOLDİNG

PASADENİK FAZI Pasadenic Phase
Valakik " Valachic "

A_3 ÜST YAPISAL KAT
Upper Structural Stage

Attik " Attic "

eA_2^2 ORTA YAPISAL KATIN ÜST ASKATI
Middle Structural Stage's Upper Substage

VAN " Van "

eA_1^2 ALT YAPISAL KATIN ÜST ASKATI
Lower Structural Stage's Upper Substage

SİMMERİK " Cimmeric "
Şile " Şile "

eA_1 ALT YAPISAL KATIN ALT ASKATI
Lower Structural Stage's Lower Substage

ALBİT PORFİRİT, Vb
Albite Porphyrite, etc

VARİSK KIVRIMLANMASI BÖLGESİ
REGİON OF VARİSCAN FOLDİNG

eV_2 ORTA YAPISAL KAT
Middle Structural Stage

VARİSK FAZLAR Variscan Phases

KALEDONİYEN KIVRIMLANMASI BÖLGESİ
REGİON OF CALEDONİAN FOLDİNG

eC_2 ORTA YAPISAL KAT
Middle Structural Stage

KALEDONİYEN F. Caledonian "
(Başlıca Ardenik f.) (Namely Ardenic)

DİYABAZ
Diabase

ANTİKLİNAL ve DALIMI
Anticline and its plunge

SENKLİNAL ve DALIMI
Syncline and its plunge

FAY (yarılım)
Fault

EKSEN YÜKSELİMİ
Axial high

EKSEN ALÇALIMI
Axial low

ÇELİKLİ-KOZLUCA E.A.

KAYALI-DEDEBAYIRI E.Y.

ÇARDAKBAYIR-HEYBELİ E.A.

DERE-ÇAL E.A.

ÇENE-TOYLAR E.A.

AMBARTARLA-ÇINARLI E.Y.

BALI-AKTAŞLAR E.Y.

HATİP-ÇALTARLA E.A.

STRUCTURE MAP OF THE İZMİT - HEREKE - KURUCADAĞ AREA