GEOLOGY OF THE BEYPINARI-KARABABA AREA (SİVAS PROVINCE)

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ABSTRACT.— The serpentinites of the Beypınarı region are thrust over Maestrichtian - Lower Paleoccne limestones and Eocene flysch, which are folded along WNW-ESE axes; patches of Middle Eocene Nummulitic limestone lie disconformably on the serpentinites. The direction of tectonic movement is to the north. The ophiolitic mass is very fragmented, and brecciated serpentinite is widespread, particularly in the frontal part of the thrust, where there are also gabbro, basalt, radiolarite and exotic blocks of Mesozoic limestone and of metamorphic rocks. The available evidence suggests that: the ophiolites had began moving north by gravity sliding in the Upper Cretaceous; in the Lower and Middle Eocene their instability produced olistostromes in the flysch; the flysch is syn-volcanic, rather than syn-tectonic; finally, folding and overthrusting occurred in the Upper Eocene. Followed unconformably a typical post-geosynclinal series made of elastics, evaporites and limestones.

INTRODUCTION

This article describes the geology of the area of the Gürlevik and Bozbel Dağları and of the upper Karabel valley, between Zara and Divriği (Fig. 1). It is an area of considerable geological interest, because it is underlain by masses of serpentinites thrust over Upper Cretaceous limestone and Eocene flysch, and it contains asbestos deposits of economic importance. The main problems are the origin of the ophiolites, the genesis of the asbestos, and the composition and provenance of the flysch.

The region is mountainous and is situated on the south slope of the divide between the confluents of the Kızılırmak, in the north, and those of the Çaltısuyu, in the south.

The main mountain range strikes about east-west, reaching elevations of 2700 m in the calcareous Gürlevik Dağı, 1800-2200 m in the Bozbel Dağları. The range rises 200 to 500 m above a general plateau situated at 1400-1600 m, into which valleys have been cut by 200-350 m (e.g. the Karabel valley below Beypınarı and at Sincan). The existence of erosional surfaces at 1600, 1400 and 1200 m is also clearly seen further south, in the valleys between Sincan and Divriği.

The highest erosional surfaces are certainly post-Miocene, as they cut across folded rocks of that age. Their development has produced numerous cases of stream deviation.

Ü. Artan mapped the Beypınarı area and studied the petrology of the ophiolites and the origin of the asbestos. G. Sestini examined mainly the flysch. The authors wish to acknowledge the financial and practical assistance of the M.T.A. Institute and would also like to thank Prof. C. Pirini-Radrizzani, for the identification of microfossils.

(Simplified from Sivas Sheet.)

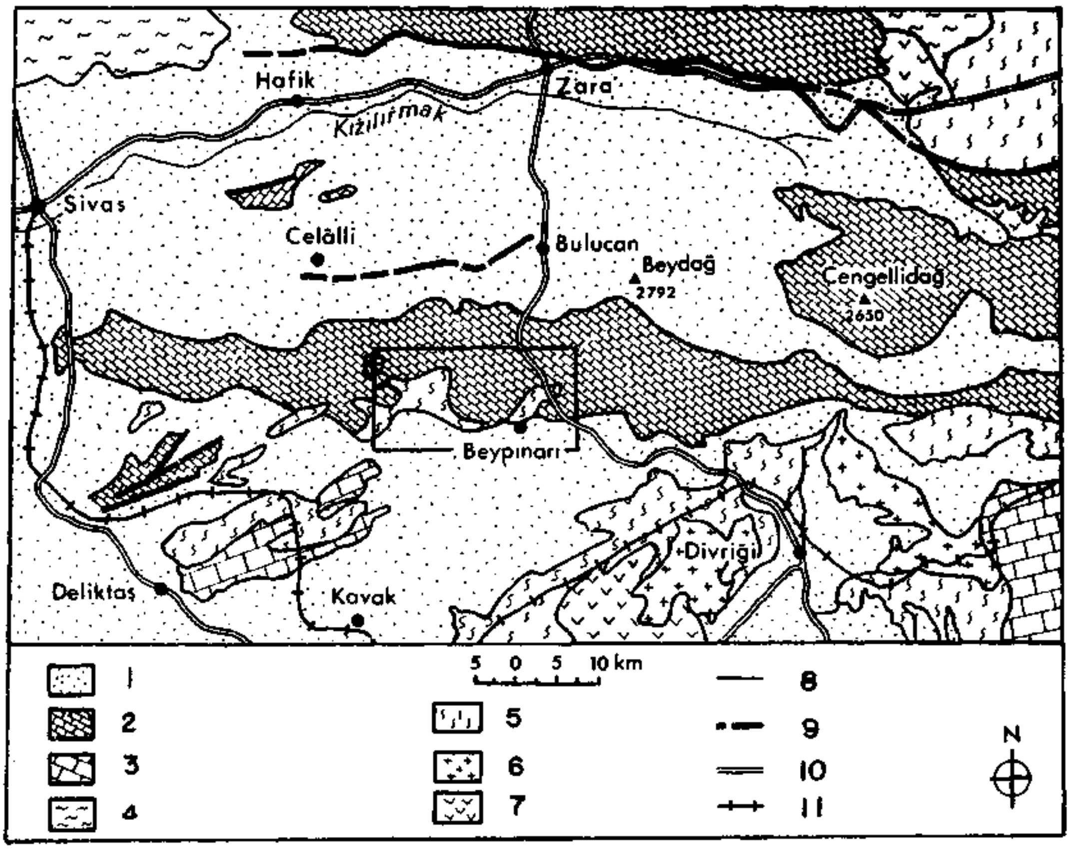


Fig. 1 - General geology of Central East Turkey.

1 - Neogene formations; 2 - Eocene formations; 3 - Jurassic, Cretaceous; 4 - Metamorphic rocks; 5 - Ultrabasics; 6 - Acid intrusives; 7 - Andesite, spilite; 8 - Formation boundary; 9 - Overthrust, fault; 10 - Road; 11 - Railway.

PREVIOUS WORK

The geology of the Sivas region around the Beypınarı area has been described by Blumenthal (1937), Stchepinsky (1938, 1939), Okay (1952), and Norman (1964); a summary is given in the explanatory notes of the Sivas Sheet (Baykal and Erentöz, 1966).

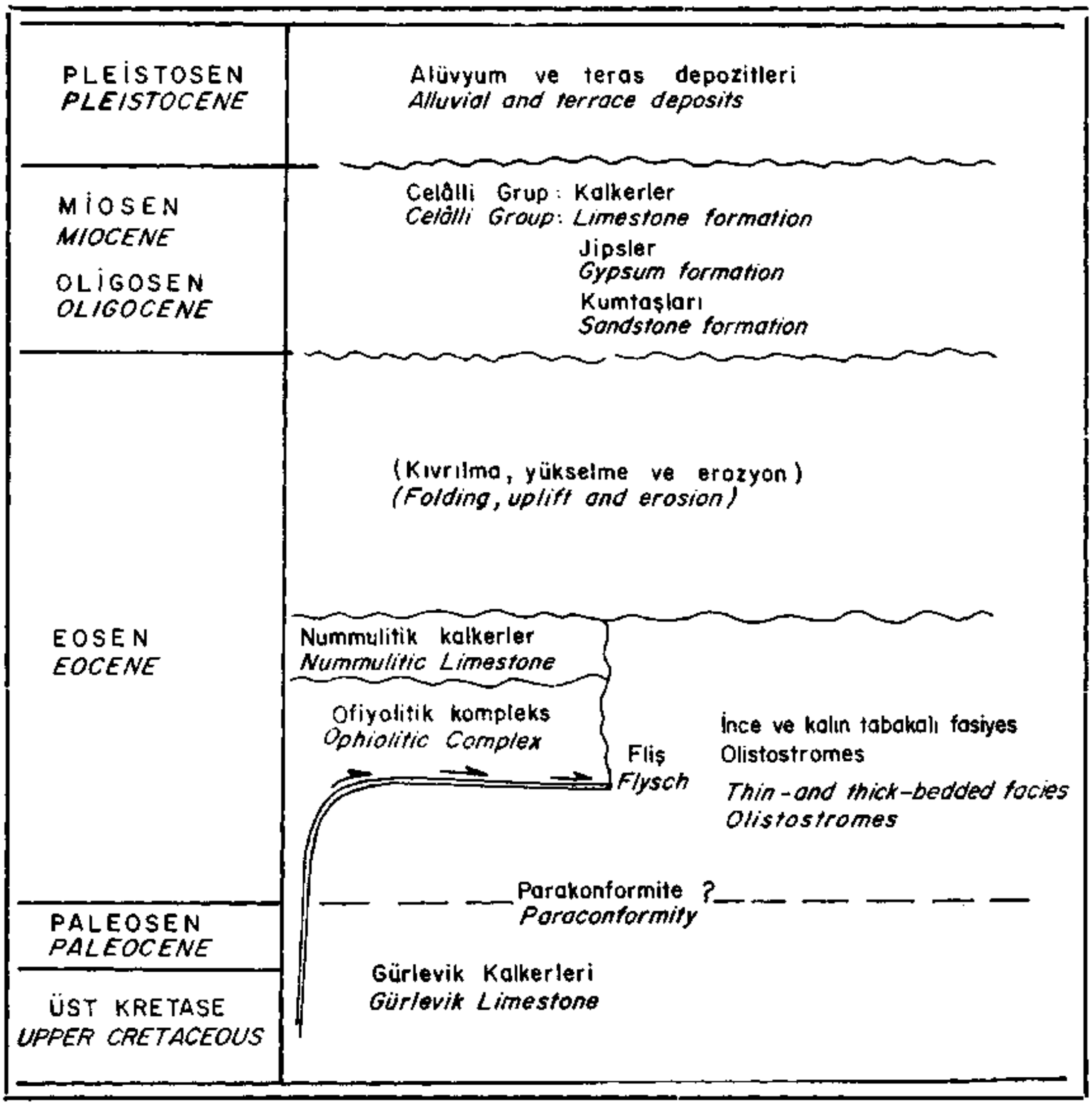
More particular studies of the Mesozoic limestones and the Eocene flysch, with an emphasis on petroleum possibilities, were carried out by Arpat (1964), Demirmen (1965), and Rathur (1965).

STRATIGRAPHY

A schematic column of the stratigraphy of the Gürlevik and Bozbel Dağları is given in Table 1. The Gürlevik Limestone, the oldest formation, is Maestrichtian to Paleocene and is overlain probably with a paraconformity, by the Eocene Flysch. Patches of Middle Eocene Nummulitic Limestone rest disconformably on the

Table - 1

Stratigraphy of the Beypınarı Area



and Dasycladacea), corals, mollusc and bryozoan fragments. The micrite matrix is mostly unrecrystallized, but there is a fair amount of scattered fine-grained authigenic quartz. The foraminifera are: miliolids, valvulinids, textularids and rotalids (e.g. *Periloculina* and *Rotalina* sp.; *Alveolina* cf. *glomalveolina primaeva)*. This faunal association indicates the uppermost Cretaceous to possibly the Paleocene.

THE FLYSCH

The Bozbel, Karababa, Gelin, Hocahanım and Yıldız Dağları are formed by an arenaceous flysch with minor amounts of graded limestones. The flysch presents three fades : thin-bedded sandy flysch, thick-bedded graded sandstones, and slump deposits (olistostromes).

Along a north-south section from the Karabel valley to the village of Çamözü, the first two facies follow in this order :

1. «Lower» thin-bedded flysch, Karabel valley and southeastern parts of the area; possibly 500 m exposed.
2. «Lower» thick-bedded sandstones and tuffites, forming the prominent ridge from Zeynelbaba to Gelin Dağı; 300 m, increasing northward to 800 m in the folds of the Bozbel Dağı (Plate I).
3. «Middle» thin-bedded flysch, in the area between the Gelin-Zeynelbaba ridge, the Bozbel and Karababa Dağları; up to 1000 m.
4. «Upper» thick-bedded tuffites and volcanic conglomerates; top escarpment of Karababa, about 200 m.
5. Thin-bedded and argillaceous flysch south and west of Çamözü (situated just north of the map area).

The «lower» thick-bedded sandstone disappears to the south where it grades rapidly into the thin-bedded flysch. In the valley of the Mezar Çay, south of Karyagan, there are thick lenses of thick-bedded sandstone within the thin-bedded flysch.

East (upper Ilıca and Erikli valleys) and west of the area (Elmalı and Çağlıyan valleys) the thick-bedded facies appears to thin out. In the west (Hocahanım Dağı) it is also possible that the two thick-bedded facies merge.

Rathur (1965) had named as Bozbel and Başyurt Formations the thin-bedded and the thick-bedded facies, respectively; and in the east, the Bozbel Formation had been called Nordun Formation by Demirmen (1965). As the relationships between the facies are known at present, we do not feel it is safe to give formal stratigraphic names to units that appear to be of variable extent and with enclosing reciprocal relations.

a. The thin-bedded facies

This facies is characterized by closely spaced graded siltstone and sandstone beds generally 5-10 cm thick, alternating with an average of 55% shale. Recurring at some intervals are sandstone beds up to 50 cm, occasionally 1-2 m. The percentage of shale also fluctuates, between 10% and 80% in some bands. Clusters of thick beds occur south of Karababa and in the «lower» thin-bedded flysch of the Karabel valley.

Characteristic are very thin beds, 1-3 cm thick, of coarse to fine-grained siltstone, which are generally ungraded and laterally discontinuous.

The sandstones are predominantly medium-grained, but there are even relatively thin 10-20 cm layers with coarse-grained sand. Most of the graded beds have parallel and current ripple laminations. Sole markings are rarely seen; flute casts are more frequent than groove casts and indicate currents from the east.

The sandstones of the thicker beds contain volcanic debris and are similar to the tuffites of the lower thick-bedded facies. The others are of three types:

a. Calcarenitic sandstones made of quartz, feldspar, volcanic fragments, quartzite, abundant detrital calcite, nummulites and rounded echinoid fragments.

b. Calcareous sandstones with quartz, feldspar and muscovite.

c. Calcarenites made of fossil fragments or micritic grains, with up to 15% of quartz sand.

Thin beds (5-15 cm) of gray, graded nummulitic calcarenites occur sporadically in the thin-bedded flysch. Conspicuous is only a band made of several graded-limestone beds, which occurs 60-70 in stratigraphically above the «lower» thick-bedded facies, between Zeynelbaba and the Bozbel Dağları. The band is extensive, but there are significant variations in the number, thickness and grain size of the component beds. In the east, north of Mehmetler, the band is 3 m thick and comprises nine graded beds with coarse calcarenite and conglomerate; 12 km to the west, at the Sincan-Zara road, the band is 2.5m thick and there are 14 graded beds largely of micritic limestone; 4.5 km south, on the south slope of Zeynelbaba, the thickness is reduced to 40 cm and there are only three beds. These variations from west to east suggest westward-flowing currents, as is also indicated by the flute casts in the sandstones. The graded limestones consist of calcarenite, fine to coarse-grained in the lower part of the beds, micrite in the upper part. The composition depends on grain size: the coarser calcarenites are largely made of whole nummulites and of nummulite fragments —in some samples largely substituted by algal, molluscan and echinoid debris— together with pelagic and benthonic foraminifera. There are also reworked limestone fragments with an Upper Cretaceous microfauna. In the finer-grained calcarenites, micritic pellets and/or mono-crystalline detrital calcite are common, together with miliolids. In all the calcarenites the matrix is micrite, with some secondary quartz (grains scattered in the matrix and partial replacement of microfossils).

The limestones contain *Discocyclina* cf. *discus,* Rutimeyer, *Alveolina* sp., *Num mulites* cf. *foliaini* Prever, *N. globulus* Leymerie, Ophthalmidiidae, *Valvulammina* sp., orbitoids, miliolids, textularids and rotalids. Their age is Eocene or Middle Eocene.

The micro-foraminifera of the shales of the thin-bedded facies are generally scarce and poor, sometimes pyritized. They are Eocene *Globorotalia* and *Globigerina.* In some samples, however, there are Lower Eocene assemblages: *Globorotalia* cf. *venezuelana* Hedberg, *Gl.* cf. *velascoensis* Cushman, *Gl.* cf. *wilcoxensis, Gl.* cf. *angulata* White, *Globigerina* cf. *aragonensis* Nuttall, *Gl,* cfr. *onachitaensis* Howe & Wallace, *Cibicides* sp., *Gyroidina* sp.

The base of the flysch is not well exposed. Most of the contact with the Gürlevik Limestone is tectonic; only at one place on the south limb of the Gürlevik anticline there is a poorly sorted conglomerate with pebbles and cobbles of limestone, serpentinite, brecciated serpentinite, limestone-serpentinite conglomerate, and shale (including twisted and boudinaged shale beds). The matrix is a calcareous sand. The overlying flysch sandstones are made of serpentinite and volcanic fragments; both contain nummulites.

Similar «basal» conglomerates are said to occur beneath the Eocene flysch between Yozgat and Çorum (Ketin, 1959). Since the Gürlevik Limestone reaches the Lower Paleocene, and the flysch is Eocene, if not entirely Middle Eocene, the contact with the Gürlevik Limestone must represent an unconformity, probably a paraconformity. The serpentinite and limestone conglomerate does not appear to be a true «basal conglomerate», rather a slump deposit.

b. Olistostrome

A large lense of chaotic boulder-clay is intercalated in the thin-bedded flysch, possibly 100-150 m below the «lower» thick-bedded facies, in the area between Sincan, Tepehan and Mehmetler.

The facies is typical of olistostromes (Abbate *et al.,* 1970) : abundant contorted shales enclosing ball-like to lenticular and tabular clasts of greatly variable size and lithology. Represented here are:

1. Dark-gray marlstone and micritic limestone; generally 5-15 cm clasts, occasionally blocks;
2. Pebbles of volcanic rocks;
3. Lenses of andesite agglomerate, a few tens m wide, with angular elements up to 40 cm in diameter;
4. Blocks of a conglomerate made of rounded serpentinite pebbles with a sandy matrix;
5. Rare blocks (30-50 cm) of radiolarite breccia;
6. Small cobbles to large chunks of tuffitic sandstone with nummulites;
7. Occasional large blocks of serpentinite (5-10 m across);
8. Packets of bedded flysch made of fine-grained sandstone and marlstone layers with Eocene micro-foraminifera.
9. Cobbles to large boulders (up to 5 by 5 m) of nummulitic limestone; the larger blocks are unbedded but show a lenticular nodular structure, and some have a chaotic structure. The limestone varies from a biocalcarenite with nummulites to a biostromal limestone with algae, corals and large pelecypods and gastropods.

The abundance and size of these components varies from place to place. In the northeast, near Mehmetler, serpentinite is absent, and the clasts are mainly micritic limestone, andesite, and large chunks of conglomeratic tuffite; in the Mezar valley the association is andesite agglornerate, serpentinite and nummulitic limestone; in the southwest, near the road, the predominant clasts are micritic limestone and marlstone, flysch packets and nummulitic limestone blocks.

The olistostromc is conformably underlain and overlain by the thin-bedded flysch. At the road, the base is characterized by a number of thick layers of soft, coarse, graded sandstone with a channelled base and abundant marlstone clasts. They are interbedded with 2-4 m lenses of boulder claystone with clasts of marly limestone and nummulitic limestone. At other places the flysch beds below the olistostrome are deformed, but those above are not. In the Mezar and Ilıca valleys, immediately above the olistostrome, there is a 10-30 m lens of tuffite, at places conglomeratic (limestone and andesite clasts).

The shales of the olistostrome matrix and those in the flysch beds at the base contain a Lower Eocene assemblage *(Globigerina* cf. *onachilaensis* Howe & Wallace, *Gl.* cf. *aragonensis* Nuttall, *Gl.* cf. *bulbrooki* Bolli, *Gl.* cf. *angulate* White). On the other hand the blocks of nummulitic limestone are Middle Eocene. A discrepancy occurs also in the thin-bedded flysch with Middle Eocene nummulites in the graded limestones; and Paleocene-Eoccne, sometimes definitely Lower Eocene micro-foraminifera in the shales. It is possible that most of the microfossils are reworked, because they come from the shales in the upper part of graded beds, i. e. shale deposited by turbidity currents.

The diversity of sources of the olistostrome clasts is also problematic. From the south, i. e. the Ophiolitic Complex, probably came the serpentinites, serpentinite conglomerate, radiolarite breccias and nummulitic limestone; on the other hand, the andesite and tuffite sandstone, which are similar to the sandstone and the clasts of the thick-bedded flysch, should have a northern origin, because the outcrops of Eocene volcanics are located north of Zara (Fig. 1).

c. The thick-bedded flysch facies

The thick-bedded facies of the flysch consists of graded to poorly graded layers of dark greenish-gray sandstone. The average thickness of the layers is 1 m, beds 2 to 5 m are common, and some reach 21 m. There are considerable lateral variations in the number and thickness of the layers. Shale is very subordinate. Most beds over 1 m are without shale partings; where present, these are up to 10 cm. One half of the beds between 0.3 and 1 m have shale at the top, with a shale thickness up to 20 cm. At irregular intervals there are small bands (0.15-1.7 m) composed of 10-60 % shale and 3-20 cm sandstone or siltstone beds.

In the thick-bedded sequence of the Gelin-Zeynelbaba ridge there are vertical cycles of average layer-thickness, with peaks every 50 m, and a general upward increase in the thickness of the layers (Sestini, 1970).

Most of the sandstones are medium to coarse-grained, but grain size is positively related to bed thickness: the beds over 1 m are made, in the lower part, of coarse sand or fine-grained conglomerate (1-2 cm pebbles). There are one to three bands of conglomerate with clasts up to 50 cm. One of the bands is graded, with a transition at the top to coarse sandstone, then to siltstone. The base is channeled, the top is wavy. The thickness and grain size of the band increases from south to north within a distance of 3 km; there is a change in thickness from 15 to 30 m, in boulder size from 0.5 to 2 m. The conglomerate phenoclasts are well rounded; mainly they are of andesite, mixed with some serpentinite and a very variable number of limestone pebbles microcryetalline, dark-gray limestone and nummulitic limestone). At places there are also granite and sandstone. The conglomerate matrix contains, nummulites.

Part of the sandstones are tuffites, with abundant grains of prismatic, zoned plagioclase, which are barely rounded at the edges; and scattered pyroxene. In other sandstones the feldspar is mixed with volcanic fragments, serpentinite, and minor amounts of quartz and pelagic micro-foraminifera. There are no metamorphic rock fragments.

The sandstone beds are graded, but grading is not well developed and in some cases it is not immediately obvious. Monofractional grading is common: a rapid decrease in grain size occurs in the upper $^1/_{10}$ or less of the bed, where parallel and ripple lamination become visible. In the ungraded part of the bed there are no current structures, only abundant shale clasts. Several of the thicker beds have a channelled base.

Sole markings are rare, there are a few flute and groove casts. These, and elongated carbonized plant fragments, are oriented about east-west, the flutes indicating currents from the east.

The elongated pebbles of the conglomerate band are also oriented, but measurements vary from E-W with an embrication to NE and SE, to NNW and NNE with an embrication to SW and SE.

NUMMULITIC LIMESTONE

Patches of light-cream limestone containing nummulites are scattered disconformably over the ophiolites in the southern half of the area. The surface of contact is quite irregular, locally it dips up to 35 degrees; it is overlain by calcareous sandstones rapidly passing to pebble conglomerates and pebbly limestones. The sand grains and pebbles are of serpentinite. In thin-section the sandstones are sorted and are cemented by calcite; the grain composition varies between 50 and 90 percent serpentinite, the rest being foraminifera with algal and echinoid fragments. The serpentinite grains are angular to fairly well rounded.

Over the basal elastics there are massive biocalcarenites of variable thickness and with no apparent bedding. They are poorly sorted biomicrites with at least two common microfacies: one, coarse-grained, characterized by abundant nummulites (whole and very fragmented), without other fossils or with micro-foraminifera (miliolids, rotalids), Melobesiae and pelecypod fragments; another, finer-grained with an association of whole corals, calcareous algae and micro-foraminifera. The matrix is micrite, partly recrystallized. Characteristic is the presence of angular serpentinite grains of very fine-sand size (0.05-0.200 mm), making about 2-3 percent of the thin-sections.

The macro-foraminifera are: *Nummulites* cf. *aturicus, N.* cf. *globulus* Leymerie, *Alveolina* sp., *Orbitolites* sp., *Discocyclina* sp., *Sphaerogypsina* sp. The age is Lutetian (Middle Eocene).

The thickness of the Nummulitic Limestone can be estimated at about 50 m.

CELALLİ GROUP

This name was given to the evaporftic series by Norman (1964), after the town of Celalli in the Kızılırmak basin. Three rock units are present in the Beypınarı - Sincan area: gypsum; sandstone and marls; limestones. They were not mapped in detail and their relationships are not clear.

The gypsum formation is the most widespread and the thickest. At places interbedded with the massive, white, finely crystalline gypsum, are thin beds of limestone. Reddish sandstones and marls are found in the southeast corner of the map area; near Sincan, these rocks contain *Cibicides* sp. and Rotaliidae *(R.* cf. *viennoti)* suggestive of an Oligocene age, and are associated with Cream-colored sandy limestones made of calcareous algae and foraminifera.

The third unit, the limestones, outcrops west of Körpınarı. It is a poorly sorted biomicrite with a small and variable amount of feldspar, serpentinite and quartz. The faunal association includes *Lithothamnium* sp., *Rotalia* sp., *Amphistegina* sp., Textularidae, *Miogypsinoides* cf. *complanata,* and *Miogypsina* cf. *guntheri.* The age is Aquitanian-Burdigalian. Other grains in the biomicrites are echinoid and mollusc fragments; in some they are mostly calcareous algae. Other limestones are unfossilifereous micrites. The environment of deposition appears to have been moderately deep neritic.

THE OPHIOLITIC COMPLEX

The ophiolites are mostly serpentinite, which is massive or fragmental. The massive serpentinite is in fact very fractured, with blocks or slabs not more than 2 km long, separated by faults and slickensided surfaces, or by fragmental serpentinite. The frontal and basal parts of the complex, exposed for a width of 2-3 km, have a chaotic structure, and mixed with the brecciated serpentinite are masses of basalt and gabbro, basic fine-grained «dykes», beds of radiolarian chert, tabular slabs of limestone, and boulder-beds with limestone and metamorphic rocks. The largest masses are the basalt (1.5 by 3 km), and the tabular limestone blocks (0.2-0.5 km). All the contacts are tectonic.

SERPENTINITE

The massive serpentinite probably originated as peridotite, but no remains of this are now visible. There are numerous small fractures and many veins of cross-fibre chrysotile asbestos and picrolite, generally 1 mm wide. The composition is characterized by a very high percentage of serpentine (lizardite and chrysotile, no antigorite), together with chlorite and accessory magnetite and chromite. Under the microscope, thorn and random-flame textures are common; in some samples there are also mesh, bastite and asbestiform textures, but there are no relicts of olivine nor orthopyroxene. The clinopyroxene has been transformed into bastite. Tremolite and brucite are absent. The lizardite is consistently richer in iron than chrysotile.

The average chemical composition of 17 samples is given in Table 2, the normative mineral composition in Table 3. In respect to harzburgites and peri-

Table - 2

Chemical analyses of the Beypınarı ophiolites

	Serpentinites (17 analyses)		Basic dykes (15 analyses)		Basalts (2 analyses)	Rodingites (5 analyses)	
	Average	Range	Average	Range	Range	Averaga	Range
SiO_2	39.73	38.1 - 43.1	49.94	43.6 -53.2	46.3 -48.8	39.13	32.5 -46.1
TiO_2	—	—	0.96	0.6 - 1.3	2.2 - 2.5	1.01	0.4 - 1.8
Cr_2O_3	0.8	0.06- 0.28	—	—	—	—	—
Al_2O_3	0.5	0.1 - 1.6	13.90	10.1 -14.7	15.2 -14.5	8.90	7.8 -10.7
Fe_2O_3	5.6	2.8 - 7.4	4.8	2.4 - 6.1	5.5 - 7.1	5.73	2.4 - 9.3
FeO	1.5	0.8 - 2.64	6.3	4.0 - 8.0	4.6 - 5.2	4.77	1.8 - 6.8
MnO	0.11	0.08- 0.14	0.18	0.15- 0.2	0.13- 0.17	0.21	0.16- 0.29
NiO	0.54	0.34- 0.72	—	—	—	—	—
MgO	38.55	38.1 -40.0	8.4	4.6 -13.1	6.92- 4.34	14.27	9.5 -19.8
CaO	0.06	0 - 0.7	8.2	4.4 -17.4	6.5 - 8.7	29.89	18.4 -23.80
Na_2O	0.05	0.04- 0.1	3.9	0.9 -5.6	2.5 - 4.7	0.14	0.08- 0.25
K_2O	—	—	0.4	0.05- 1.5	1.2 - 2.6	0.04	0 - 0.2
H_2O+	13.36	12.1 -14.8	1.8	0.6 - 3.2	2.1 - 3.0	3.59	0.8 - 6.8
H_2O^-	0.36	0.1 - 0.9	0.9	0.4 - 1.7	1.1 - 1.2	0.57	0.4 - 0.7
P_2O_5	—	—	0.12	0.07- 0.17	0.03- 0.5	0.16	0.09- 0.17
S	0.03	0 - 0.2	0.04	0 - 0.22	0 - 0.14	—	
Total	**100.53**		**99.28**			**99.41**	

dotites (Green, 1964) these serpentinites, differ only in having more water, but less alumina and calcium. The content of minor elements (Cr, Mn, Ni, Na, Al, S, Ca) is low, but in agreement with data from other serpentinites (Table 4). On a water-free basis the composition of the serpentinites appears to be very uniform; on an AFM diagram they concentrate near the MgO corner (Fig. 2). SiO_2, MgO, Fe_2O_3 and $A1_2O_3$ plotted against H_2O^+ remain approximetely constant (Fig. 3).

The fragmental serpentinite is of two types, brecciated and conglomeratic. The first contains angular clasts of serpentinite, a few cm to 15 cm in diameter, largely stretched and bounded by slickensided surfaces. The matrix is a mush of sheared serpentinite. In thin section one sees textures typical of tectonic breccia, but the components are not exclusively serpentinite; there are also gabbro, dolerite and small but significant quantities of crystalline limestone.

The breccia is widespread and the massive serpentinite grades into it without much order, but in some parts «layers» of massive serpentinite appear to be interposed between sub-horizontal bands of brecciated serpentinite (Pl. I). This is a situation similar to that described by Boccaletti *et al.* (1966) in the Ankara Melange, and by Abbate *et al.* (1970) in the ophiolites of the Northern Apennines. The «layers» of massive serpentinite could be interpreted as flat blocks that moved horizontally between shear zones, or as slide blocks intercalated with slump deposits (olistoliths within olistostromes). But here, as in the Ankara Melange, the quantity of sedimentary rocks is small, and there are no features indicative of slumping, such as graded ophiolitic sandstones with microfossils (cf. ophiolitic olistostromes in the Northern Apennines, Abbate *et al.*, 1970; detrital serpentinites in California, Moseyvev, 1970). A tectonic origin of the breccias is possible, although their texture can

Table - 3

Normative minerals composition of the Beypınarı ophiolites

Serpentinites (17 analyses)		*Basic dykes (15 analyses)*		*Basalts (2 analyses)*	*Amphibolites (2 analyses)*	*Pyroxenite (1 analysis)*
Average		Average		Average	Average	
Chromite	0.29	Cordierite	0.08	--	—	—
Pyrite	0.08	Quartz	0.27	0.07	—	—
Magnetite	6.27	Orthoclase	2.47	11.38	10.02	—
Hematite	1.19	Albite	30.46	30.51	8.97	0.85
Tremolite	0.41	Anortite	18.87	18.64	18.65	3.29
Cl. pyroxenite	0.44	Nepheline	1.48	0.07	4.59	—
Clorite	2.51	Diopside	16.96	13.72	29.21	79.33
Olivine	0.53	Hypersthene	13.05	3.97	0.69	2.79
Serpentinite	83.49	Olivine	4.72	2.75	13.78	11.09
Brucite	0.31	Magnetite	6.04	9.06	6.55	1.52
Orth. pyroxenite	1.47	Ilmenite	1.83	4.56	4.57	0.04
H_2O^-	0.36	Apatite	0.28	0.59	0.98	0.14
Excess H_2O^+	2.08					
Excess MgO	—					
Excess SiO_2	1.16					

be formed otherwise than by tectonic shear : it has been reported in subaerial «flows» of serpentinite (Cowan & Mansfield, 1970).

The other type of fragmental serpentinite is conglomeratic, containing a large proportion of more or less equidimensional clasts, up to 50 cm across, with rounded margins; there is a sandy matrix or a calcite cement. This type occurs along the frontal part of the complex (e.g. south side of Gürlevik Dağı), and in its geometrically higher parts, especially under the disconformity with the Nummulitic Limestone. The texture of the conglomerate is suggestive of a certain amount of aqueous transportation, as stream or steep shoreline gravel.

Table - 4

Range of minor elements in the serpentinites of the Beypınarı and other areas, in ppm

Elements	*I*	*II*	*III*
Cr	1 600	2 400	400-1800
Mn	1 620	1 040	500-1100
Ni	2 000	1 500	1 800-5700
Na	4 200	1 040	300-700
Al	20 000	10 000	0-8600
S	300	—	0-2500
Ca	25 000	—	0-5400

I = Turekian and Wedepohl (1961)
II = Goles (1968)
III = Beypınarı area (17 samples)

OTHER OPHIOLITIC ROCKS

Dyke-like bodies of dark fine-grained rocks are common amongst the serpentinites. Their size varies from about 1 m to 1 km in length, and 50 cm to 125 m in width. The contacts with the serpentinite are usually sharp, but sheared, and both dykes and serpentinite are often brecciated. The strike of most dykes in the northeastern part of the Ophiolitic Complex is parallel with that of the fault contact with the flysch.

The main constituents of the dyke rocks are plagioclase, amphibole, chlorite and opaques (Table 3). The texture and plagioclase composition indicate that many are diorites and dolentes; other are tonalites and gabbros.

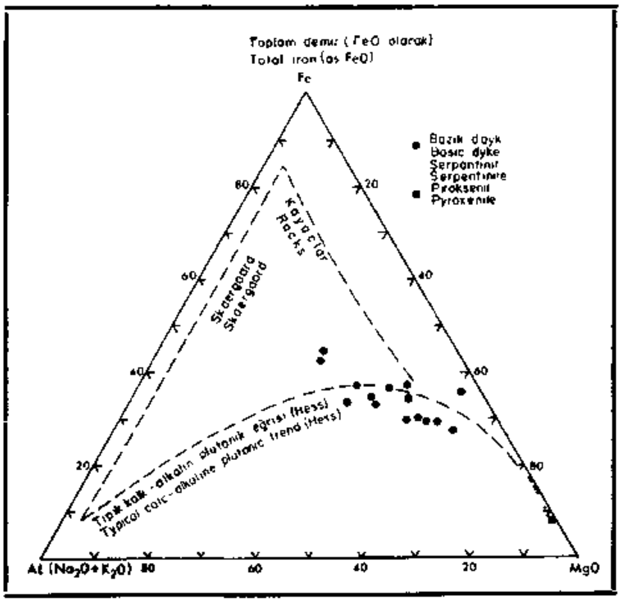


Fig. 2 - AFM diagram of basic and ultrabasic rocks of the Beypınarı area.

In the vicinity of these rocks there are often tabular to subspherical masses of rodingite. This rock, fine-grained and light green in hand specimen, under the microscope shows all gradations from partially altered gabbro with ophitic texture to a completely amorphous material. The less altered types are composed of chlorite, amphibole and granular to columnar aggregates of epidote and clinozoisite. The mafic minerals are altered to chlorite and tremolite. The composition of the rodingites is characterized by a lower silica and a higher calcium and magnesium content than the «basic rocks» with which they are associated (Table 2).

Basalt outcrops in the frontal part of the complex, across the Karabel valley. It forms an elongated vertical mass with a NW-SE strike parallel with that of the ophiolite-flysch contact. The rock is very jointed and brecciated, and shows no pillow structure, as could be expected from the association, at the northern margin, with thin vertical beds of radiolarite.

The basalt is made of plagioclase, generally very altered, clinopyroxene and chlorite, with accessory magnetite and hematite; the composition is that of a normal tholeiitic basalt (Table 2).

CHRYSOTILE ASBESTOS VEINS

The principal economic occurrence of asbestos in the Beypınarı area is situated near Davutyaylası (Pl. I), in the chaotic front of the Ophiolitic Complex.

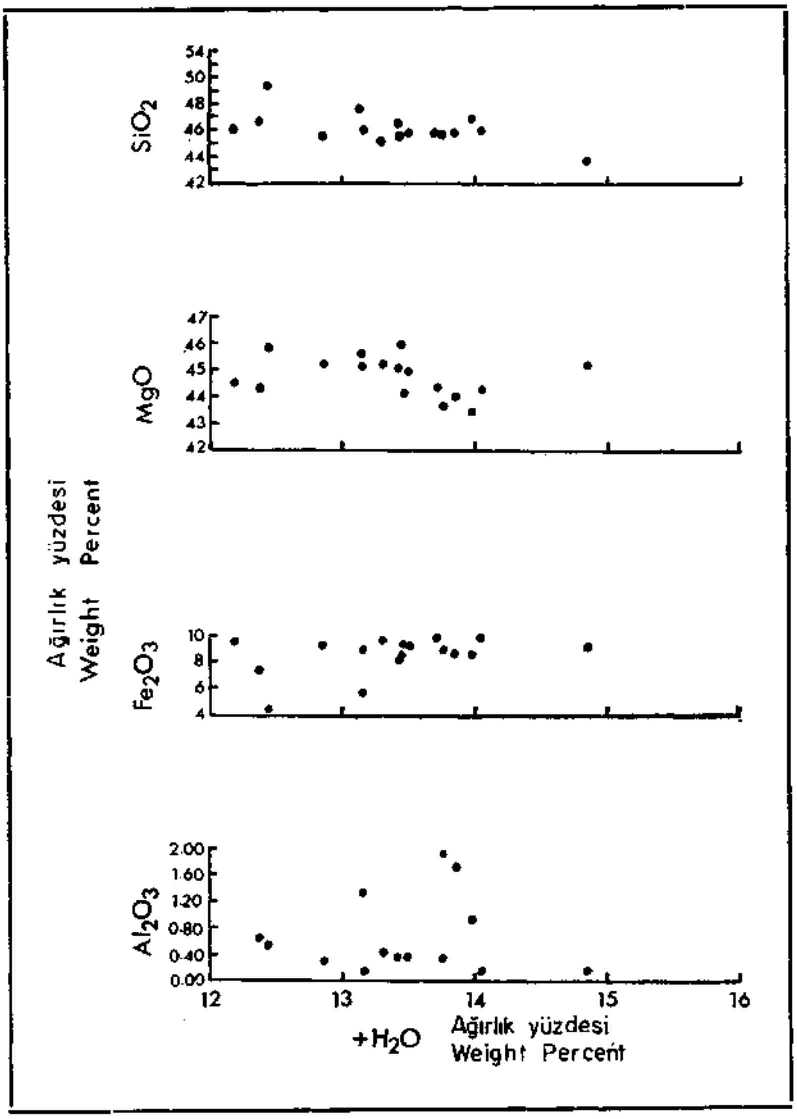


Fig. 3 - Correlation of Al_2O_3, Fe_2O_3, MgO and SiO_2 on a water free basis, against H_2O^+

There are single veins, 1 mm to 3 cm wide, and minor groups of veins in the massive and the brecciated serpentinite, following randomly oriented joints. More important are zones, 15-40 cm wide, made of numerous parallel veinlets (1.5 to 2.5 cm), at the contact between brecciated serpentinite and brecciated dolerite dykes. Almost all the dykes are oriented E-W, parallel with the ophiolites-flysch contact. The zones are very steeply inclined and extend for 250-300 m. The veinlets are straight or wavy, with margins usually very sharp. Most of them are composed of cross-fibre asbestos; slip-fibre asbestos is seen in zones where the deformation appears to be more intense.

The origin of the crysotile asbestos could be related to the process of serpenlinization, because its composition reflects that of the serpentinite of the vein walls, with an increase in magnesia and silica; there is also picrolite, a possible intermediate phase between lizardite and clinochrysotile. However, the occurrence of the groups of veins is definitely controlled by fractures that are related to the movement of the ophiolitic thrust front, and the asbestos veinlets are not deformed. This tends to suggest that the asbestos was formed after serpentinization. This problem is worthy of further attention, because in the region between Divriği and Zara there are various examples of asbestos in the vicinity of the flysch - ophiolites contact.

BOULDER BEDS

A first type of boulder-bed is found at the base of some of the tabular limestone blocks in the ophiolites not far east of Davutyaylası (Pl.I). The limestones are massive, crystalline and devoid of fossils. Beneath their fractured and brecciated soles and above the thin-bedded flysch, there are few to several meters of deformed shale with pebbles of serpentinite, chert, mica-schist, and fine-grained limestone; some blocks of this limestone are thin-bedded and very deformed.

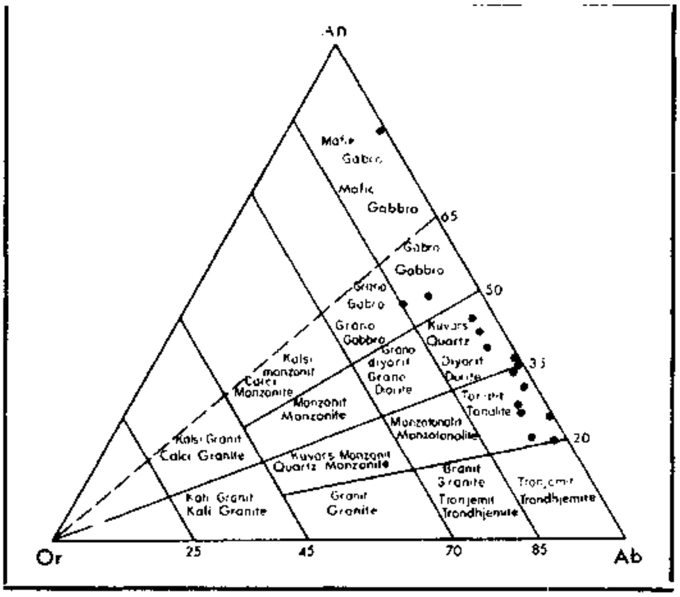


Fig. 4 - An-Or-Ab diagram of the Beypınarı area.

The second occurrence lies on the southern margin of the basalt outcrop. The matrix here is crushed serpentinite, and most of the phenoclasts are ophiolitic (they are fairly rounded at the margins). But there are also large blocks ,of micaschist, chlorite-schist, muscovitic quartzite and amphibolite, with completely random distribution. Amongst all this are a few cobbles of microcrystalline limestone.

STRUCTURE

The flysch is folded into a system of synclines and anticlines with a general WNW-ESE direction; the fold axes tend to turn to the southeast in the eastern half of the area. Most of them are asymmetric to the north, and the northern limbs are 10-15° steeper than the southern ones. The amplitude of the folding is related to sedimentary facies. In the south, the folds of the thin-bedded flysch are more numerous and compressed, with wave lengths below 500 m; minor folds, bed-slipping and crumpling occur in the cores of the anticlines. In the thick-bedded flysch the wave length" of the fold increases northward to over 3 km. Overturning has developed in this facies where it is not continuous, as along the Gelin Dağı-Zeynelbaba ridge, in the valley of the Mezarçay, and north of Mehmetler.

The anticline west of Zeynelbaba is symmetrical at first (PL II, 5), the crest being in the thick-bedded facies. As the lateral gradation to the thin-bedded facies becomes more rapid, the line of transition becomes the axial plane of the fold and the competent sandstones of the northern limb rapidly change from steep dips to vertical and to overturned (Pl.II, 4). In the Gelin Dağı the degree of overturning has increased, and the axial plane of the anticline has developed into a thrust fault; part of the «lower» thin-bedded flysch is also overturned (Pl.II, 2, 3).

The Gürlevik Limestone is folded like the flysch; the Gürlevik anticline is somewhat asymmetric to the north, and the northern limb is cut by thrust fault hading south 60°. Where the limestones are not exposed, their folds are presumably concordant with those of the flysch in the north, but in the south there must be disharmonic folding under the thin-bedded facies.

The Ophiolitic Complex rests on the sedimentary rocks with a structural discontinuity. On the south side of the Gürlevik Dağ the contact is conformable (Pl.II,1). except that its dip is 20° greater than that of the limestones. Between the Göller and Karabel valleys the contact generally dips 40° to 60° to the southwest, and at places it follows the strike of the flysch beds. But windows and re-entrants show that the plane of contact south of the Ophiolitic front dips only 15°-20°, and it cuts across the structure of the flysch (Pl.II, 3, 4). This situation is repeated in the various serpentinite outliers between the Karabel and the Ilıca valleys (e.g. Zeynelbaba Tepe, Pl.II, 5, 6).

The ophiolites therefore appear to be thrusted over the flysch. They are at least pre-Eocene, because serpentinite is present in the conglomerate at the base of the flysch, in the olistostrome and in some of the flysch sandstones. There are no intrusive contacts, nor signs of contact metamorphism. A minimum distance of overthrusting can be estimated from the relative positions of the flysch olistostrome that contains nummulitic limestone, and that of the patches of the same limestone that are on the Ophiolitic complex; taking folding into account, such distance should be no less than 10 km.

An even greater distance is suggested by the exotic blocks of limestone and of metamorphic rocks in the chaotic front of the complex. The limestones are as yet undated, bu they are of Mesozoic type. The nearest outcrop of metamorphic «schists» (Baykal & Erentöz, 1966) is 30 km to the south (west of Kangal, Fig.l), amidst Jurassic-Cretaceous limestones and large bodies of massive serpentinites. These are not so tectonized as the Beypınarı ophiolites, but their margins are faulted (e.g. between Curek and Sincan).

Within the massive serpentinites near Beypınarı there are several faults, mainly with an east-west direction, and many fractures with slickensides showing movement to the north and northeast; that is, parallel with that of the main thrust. With the exception of a few basic dykes within the serpentinite, the contacts between the different rock types of the complex are tectonic. This and the abundant matrix of fragmental serpentinite, makes the complex similar to a giant olistostrome, but on the whole we think that the process of formation was tectonic, of gravity sliding, rather than of sedimentary slumping.

GEOLOGIC HISTORY

During the uppermost Cretaceous the area was the site of marine, shallow-water carbonate deposition. In the south the ophiolites had started slumping, dragging with them metamorphic rocks and Mesozoic limestones. The detachment of the upper part of *in situ* massive ophiolites is indicated by the present occurrence at the front of the complex, of basaltic lavas and radiolarites, rocks that are commonly the roof of the ultrabasic massifs (Aubouin, 1965; Brinkmann, 1968; Bortolotti & Passerini, 1970).

On the age of emplacement of the large serpentinite bodies between Kangal and Divriği, there are no certain data; they are associated with Jurassic-Cretaceous limestones and to some extend with Paleozoic rocks, but the contacts are faulted. In other parts of Central and Eastern Anatolia the beginning of the ophiolitic magmatism ranges from Middle and Upper Jurassic to Lower Cretaceous (Albian-Cenomanian), from the age of limestones and marlstones interbedded with, and overlying the pillow lavas (Boccaletti *et al.,* 1966). The gravity sliding of the ophiolites took place at the same time as the subsidence of the Upper Cretaceous flysch troughs. The time of slumping is given by the flysch, marlstones and limestone exotics of the allochthonous «Mesozoic Ophiolitic Formation» (Mof) : pre-Maestrichtian in North - Central Anatolia (Bortolotti and Sagri, 1968), Upper Cretaceous inclusive of Maestrichtian, in the Konya region (Passerini & Sguazzoni, 1966), Campanian to early Maestrictian in the eastern Taurus (Rigo de Righi & Cortesini, 1964).

The flysch basin developed in the Eocene, but deposition was not continuous with the Gürlevik carbonates. Since the conglomerate at the base of the flysch is a slump deposit, there is at least a paraconformity due to a rapid subsidence of the basin. The serpentinite clasts of the conglomerate could be attributed to the advancement of the ophiolites, whereas the sandstones reflect the start of more active erosion at the margins of the basin.

By the Middle Eocene the situation could be imagined as follows: The serpentinites had emerged and had been eroded, then they were invaded by the sea (widespread Middle Eocene transgression, Erentöz, 1966), and carbonate muds and sands with nummulites and calcareous algae were deposited on them. The ophiolitic front was still unstable, because some of its components slumped into the flysch basin, interrupting deposition and forming the olistostrome. Slumping appears to have heralded the massive clastic influx of the thick-bedded tuffitic flysch, and therefore the Onset of volcanic activity.

The thick-bedded facies represents high energy turbidites deposited in channels (Sestini, 1970b), and a progressive increase of volcanicity may be seen in the upward thickening of the average turbidite thickness. The agglomerates and the graded tuffites of the Karababa thick-bedded facies indicate a second volcanic phase.

The composition of the thin-bedded flysch sandstones reflects at least three sources : volcanic, quartz-feldspathic and bioclastic, but too little is yet known on paleocurrents to be able to locate the source areas. Only for the sandstones at the southwestern margin of the flysch basin (south of Sivas), a western source can be safely assumed (the Yozgat massif), on the basis of composition and of current sedimentary structures.

Part of the thin-bedded flysch is a lateral, non-channel equivalent of the thick-bedded facies; the remainder, i.e. the «middle» thin-bedded flysch, could represent a period of reduced volcanic activity, or at least one when the volcanic edifices were destroyed, the pyroclastics reworked, mixed with bioclastic grains, and periodically carried off by turbidity currents, to be interbedded with non-volcanic deposits.

The flysch was folded in the Upper Eocene (Pyrenaic phase). It is most likely that folding was a gradual process, tied to the gliding of the Ophiolitic Complex : the wave of deformation proceeded northward in the flysch, brought the ophiolites onto the flysch, then the thrust plane itself was folded.

It is not envisaged that the Upper Eocene folding produced emergent lands of great relief. In the Oligocene and the Miocene there was probably a scattering of islands in a shallow sea. The deposits of the «evaporite series» include reddish marine elastics with detritus from the ophiolites and the flysch, evaporites, and bioclastic and muddy carbonates. There are considerable vertical and lateral variations of facies. The situation is very similar to that of the Upper Miocene, post-geosynclinal sediments of the western part of the northern Apennines (Sestini, 1970a). Lacustrine deposition may have obtained in some parts of East-central Anatolia, but there is no evidence of it in the Beypınarı region.

Manuscript received March 23, 1971

REFERENCES

ABBATE, E.; BORTOLOTTI, V. & PASSERINI, P. (1970) : Olistostromes and olistoliths. *Sedimentary Geol.,* v. 4, 3-4.

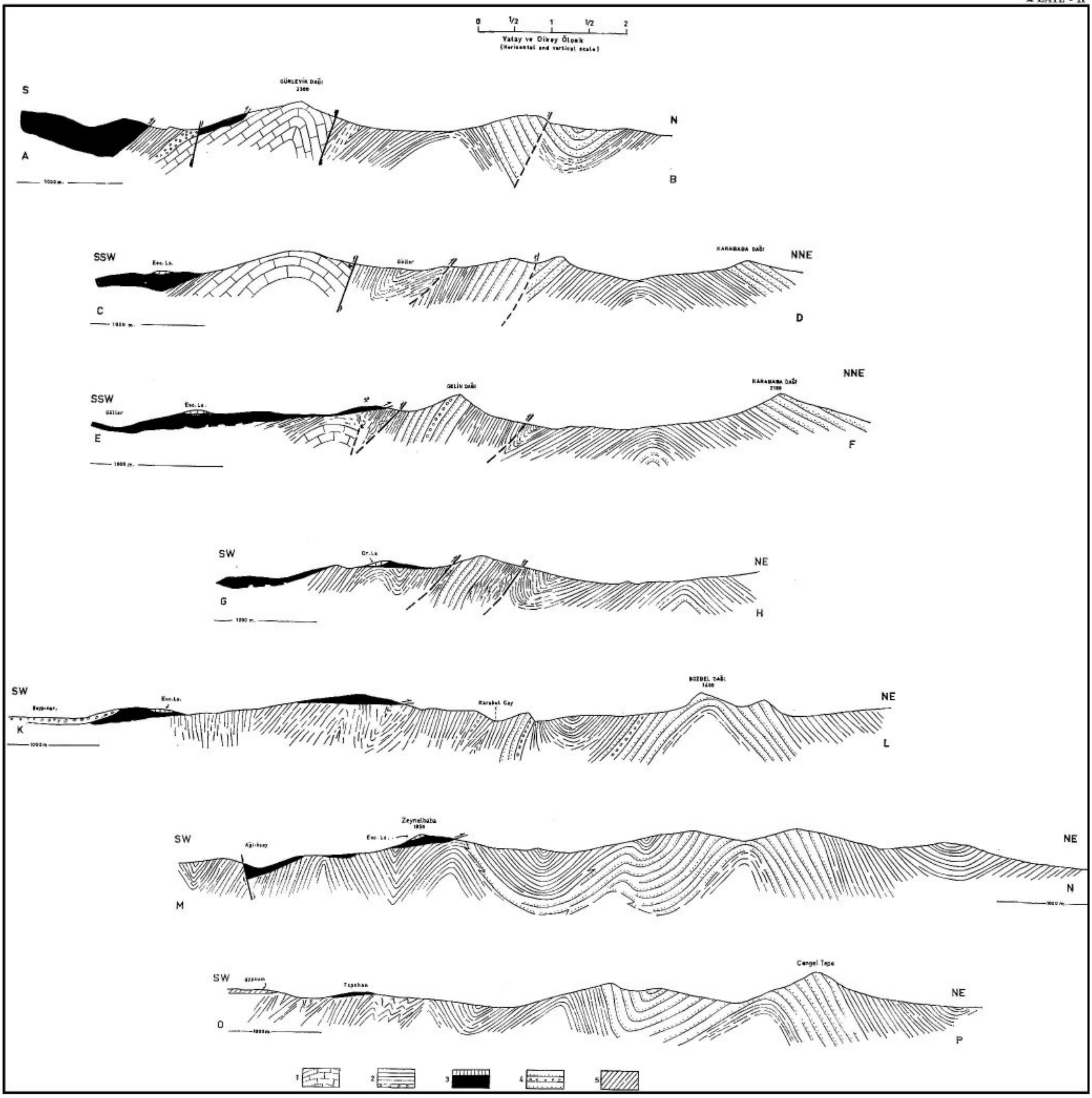
ARPAT, E. (1964) : Gürlevik dağı bölgesinin ve kuzeyinin genel jeolojisi ve petrol imkanları. *M.T.A. Rep.* (unpublished), Ankara.

ARTAN, Ü. (1968) : Progress report on the Zara - Beypınarı area of East central Anatolia, Turkey. 72[th] *annmal report Earth Sciences Leeds.*

AUBOUIN, J. (1965) : Geosynclines, Developments in Geotectonics. I. *Elsevier,* 335 p.

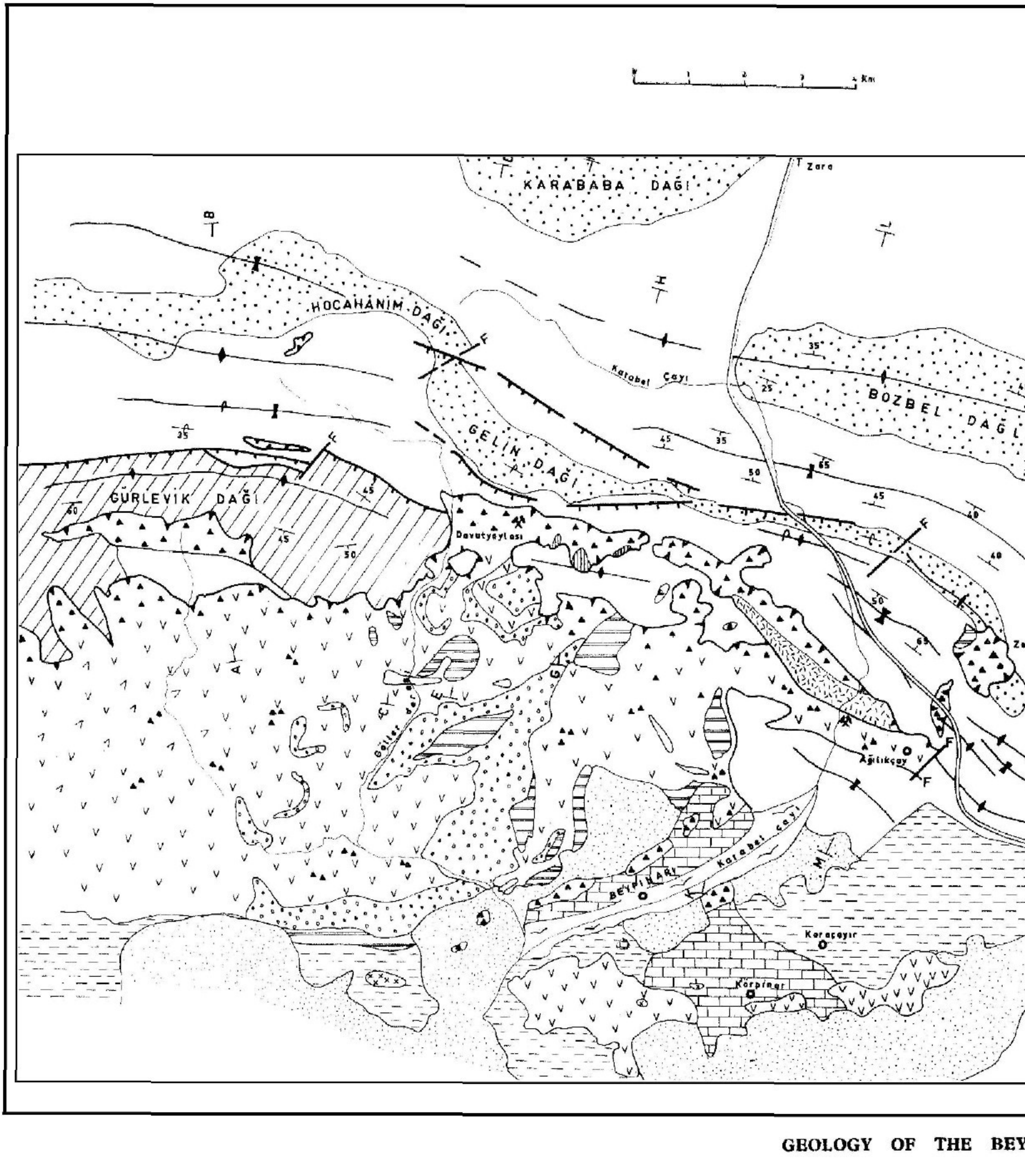
BAYKAL, F. & ERENTÖZ, C. (1966) : Explanatory Text Geol. Map of Turkey, Sivas. *M.T.A. Publ.,* Ankara.

BLUMENTHAL, M. (1937) : Kangal ile Divrik arasındaki mıntıkanın başlıca jeolojik hatları. *M.T.A. Rep.,* no. 568 (unpublished), Ankara.



CROSS-SECTIONS OF THE BEYPINARI AREA

1 - Gürlevik Limestone; 2 - Thin-bedded flysch with «basal» conglomerate; 3 - Ophiolites overlain by Nummulitic Limestone; 4 - Thick-bedded flysch with conglomerate; 5 - Gypsum.



GEOLOGY OF THE BEY

BOCCALETTI, M.; BORTOLOTTI, V. & SAGRI, M. (1966) : Ricerche sulle ofioliti delle Catena Alpien. I. Osservazioni sull, Ankara Melange nella zona di Ankara. *Boll. Soc. Geol, Ital.,* v. 85, p. 485-508.

BORTOLOTTI, V. & PASSERINI, P. (1970) : Magmatic activity. *Sedimentary Geol,* v. 4, 3-4.

———& SAGRI, M. (1968) ; Ricerche sulle ofioliti delle Catene Alpine. 4. Osservazioni sull'eta e sulla giacitura delle ofioliti tra Smirne ed Erzurum (Turchia). *Boll. Soc. Geol. Ital., v.* 87, p. 661 -666.

BRINKMANN, R. (1968) : Einige geologische Leitlinien von Anatolien. *Geologica et Palaeont.,* v. 2, p. 111-119.

COWAN, D.S. & MANSFIELD, C.F. (1970) : Serpentinite flows on Joaquin Ridge, Southern Coast Ranges, California. *Geol. Soc. Amer. Bull., v.* 81, p. 2615-2628.

DEMİRMEN, F. (1965) : Sincan bölgesi genel jeolojisi. *M.T.A. Rep.* (unpublished), Ankara.

ERENTÖZ, C. (1966) : Stratigraphic evolution of Turkey *M.T.A. Bull.,* no. 66, Ankara.

GOLES, G.G. (1968) : Trace elements in ultramafic rocks. *In:* Ultramafic and related rocks, *John Wiley & Sons, p.* 352-362.

GREEN, D.H. (1964) : The petrogenesis of the high-temperature intrusion in the Lizard area, Cornwall. *Journ. Petrol.,* v. 5, p. 134-188.

MOSEYVEV, A. N. (1970) : Late serpentinite movements in the California Coast Ranges; new evidence and its implications. *Bull. Geol. Soc., Amer.* v. 81, p. 1721 - 1732.

KETİN, İ. (1959) : The orogenic evolution of Turkey. *M.T.A. Bull.,* no. 53.

NORMAN, T. (1964) : Celalli (Hafik) bölgesinin genel jeolojisi. *M.T.A. Rep., (unpublished),* Ankara.

OKAY, A.C. (1952) : Sivas 62/2 paftası lövesi raporu. *M.T.A. Rep.,* no. 1996 *(unpublished),* Ankara.

PASSERINI, P. & SGUAZZONI, G. (1966) : Ricerche sulle ofioliti delle Catene Alpine. 2. Giacitura delle ofioliti nella zona a sud-ovest di Konya (Anatolia Meridionale). *Boll. Soc. Geol. Ital.,* v.85, p. 424-509.

RATHUR, A.Q,. (1965) : Genera geological report of the Divriği sheet I-39-d3 and about the possibilities of petroleum. *M.T.A. Rep., (unpublished),* Ankara.

RIGO DE RICHI, M. & CORTESINI, A. (1964); Gravity tectonics in foothills structure belt of Turkey. *Bull. Amer. Assoc. Petrol. Geologists, v.* 48, p. 1191-1937.

SESTINI, G. (1970a) : Post-geosynclinal sedimentation *In:* evolution of the Northern Apennines Geosyncline. *Sedimentary Geol.,* v. 4, 3-4.

———(1970b) : Vertical variations in flysch and turbidite sequences. A review. *Journ. Earth Sciences, Leeds, v.* 1.

STCHEPINSKY, V. (1938): Sivas vilayetinin merkezi kısmında bulunan muhtelif cevherler hakkında rapor. *M.T.A. Rep.,* no. 770 *(unpublished),* Ankara.

———(1939) : Sivas vilayeti merkezi kısmının umumi jeolojisi hakkında rapor. *M.T.A. Rep.,* no. 868 *(unpublished),* Ankara.

TUREKIAN, K.K. & WEDEPOHL, K.H. (1961) : Distribution of the elements in some major units of the Earth's crust. *Bull. Geol. Soc. Amer., v.* 72, p. 175-192.