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STRATIGRAPHY OF THE PRE-JURASSIC BLOCKY SEDIMENTARY ROCKS TO THE SOUTH OF BURSA, NW TURKEY

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ABSTRACT.—Two of the major pre-Jurassic units of northwest Turkey consist of blocky sedimentary rocks (Dışkaya formation in this report) and low-grade metamorphic rocks (glaucophanitic) greenschist facies . In the study area, the Dışkaya formation is divisible into laterally continuous stratigraphic units of olistostromes and shale-lithic sandstone sequences. The blocks include variably recrystallized limestones, some with Late Paleozoic faunal elements, marble-like recrystallized limestones, submarine mafic volcanic rocks, quartzo-feldspathic sandstones, gray and red bedded chert. The complex internal structure, which is characterized by large sandstone pseudo-boudins up to several meters across, is the product of soft-sediment deformation. The basal olistostrome unit of the Dışkaya formation rests with a slightly deformed contact on the metamorphic rocks, and contains at its base blocks derived from the immediately underlying metatuff unit. The Dışkaya formation has slope characteristics. It appears to have been deposited on an older structural system comprising primarily low-grade metamorphic rocks, which has also constituted source area. The field data is not directly indicative of an accretionary wedge origin for the pre- Jurassic blocky sedimentary rocks (the Dışkaya formation) which is suggested in all recent tectonic syntheses.

INTRODUCTION

The oldest four major rock units of the southern parts of northwest Anatolia and northern parts of west Anatolia (Fig.l) include:a- ultramafic rocks;b- medium -grade amphibolite-banded gneiss; c- low-grade metamorphic rocks, d- pre-Jurassic sedimentary rocks characteristically containing Late Paleozoic limestone blocks.

In early studies (Erk, 1942; Ketin, 1947; Brinkmann, 1976) the blocky nature of the pre-Jurassic sedimentary rocks was overlooked, and they were considered to be a regularly stratified graywacke-shale-limestone succession. The latter was generally designated the "Permo-Carboniferous graywacke series". This series was believed to lie unconformably on the low-grade metamorphic rocks, although no sound confirmation existed.

Özkoçak (1969) recognized the blocks in the pre-Jurassic sedimentary terrain in the study area, but he classified it as a Late Cretaceous megabreccia. Bingöl (1974) and Bingöl et al. (1975) were the first to recognize the blocky nature of the pre-Jurassic sedimentary rocks throughout their distribution in northwest and west Anatolia (Karakaya formation) and to establish a mainly Early Triassic age. However, they considered the blocky assemblage to be variably metamorphic and defined the Karakaya formation as consisting of metabasic rocks and metagraywackes, containing large blocks of limestone, and basic and ultrabasic rocks (Bingöl, 1978). It is said that associated schists often display the characteristic features of a medium pressure greenschist facies with glaucophane present only locally. Şengör et al. (1980) redefined the Karakaya formation as an ophiolitic melange consisting of "blocks of Permian limestones, various members of now-disrupted ophiolitic suit and blueschists jumbled in an extremely highly sheared meta-pelite matrix".

In all recent works, accepting plate tectonic implications, the ultramafic rocks, low-grade metamorphic

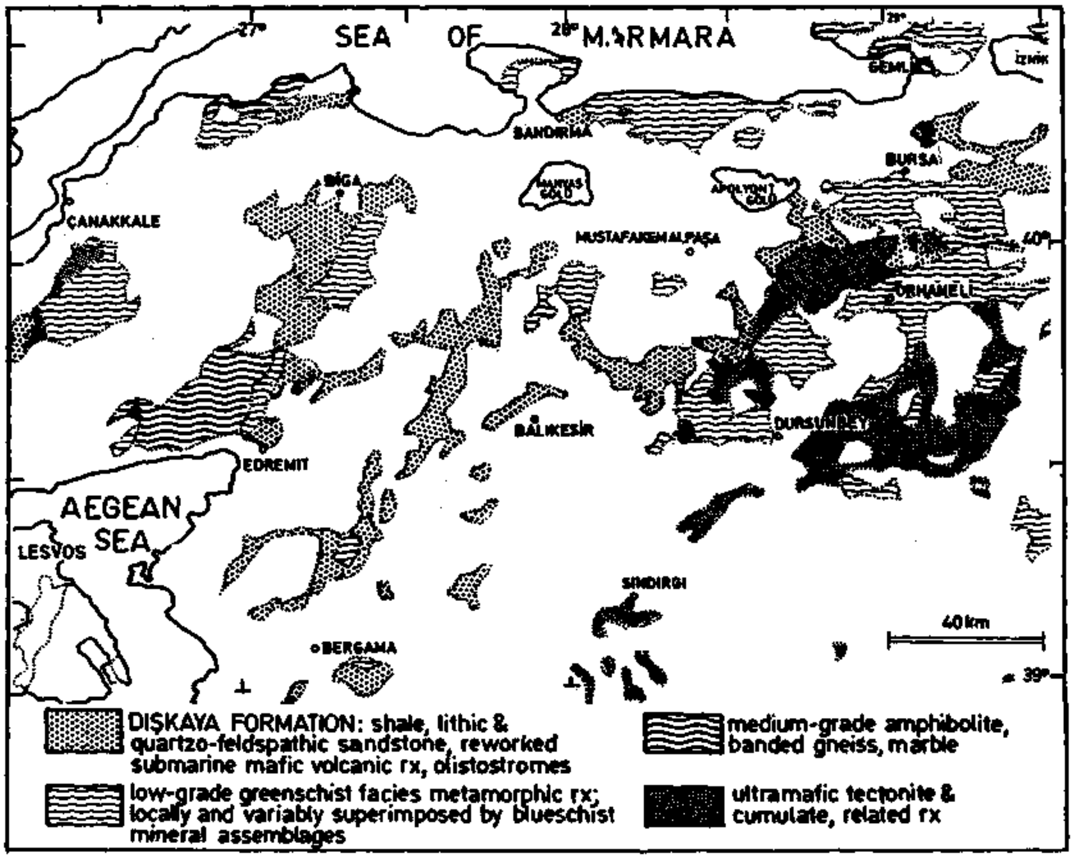

Fig. 1 — Distribution of the pre-Jurassic major units of northwestern and western Turkey. Modified after 1:500,000 scale Geologic Map of Turkey, and Bingöl et al. (1975). 1- Study area; 2- Dışkaya dağları.

rocks and blocky sedimentary rocks have been considered as coeval segments of the Late Palaeozoic and/or Triassic oceanic (or semi—oceanic) lithosphere which were incorporated into convergent margin deformation (Bingöl, 1974,1978, 1983; Şengör et al., 1980,1982; Şengör and Yılmaz, 1981; Tekeli, 1981; Üşümezsoy, 1987).

Kaya et al. (1986) have shown that the pre—Jurassic blocky sedimentary rocks were incorporated in stratigraphic successions; that their apparently complex internal structure is the product of the synsedimentary deformation; and that they rest unconformably on the immediately underlying low—grade metamorphic rocks. The name Dışkaya formation was proposed by Kaya et al. (1986) for the blocky sedimentary rocks to replace the Karakaya formation. Broadly, the Dışkaya formation corresponds to the blocky sedimentary part of the "Karakaya formation" suggested by Bingöl (1974).

This report presents further criteria to distinguish and delimit the Dışkaya formation.

UTHOSTRATIGRAPHY

The data on the ultramafic rocks and Tertiary igneous rocks are taken from Ldsenbee (1971,1972). The information about the Jurassic—Early Cretaceous rocks is adopted from Özkoçak (1969).

Ultramafic-mafic layered suit

The ultramafic-mafic layered suit corresponds to Özkoçak's (1969) "Massif ultrabasique d'Orhaneli" and Lisenbee's (1971, 1972) "Ultramafic-gabbro complex

(Orhaneli ultramafic complex) ". It consists of four major rock types which recur in vertical extent; dunite, harzburgite, gabbro and clinopyroxenite. Lherzolite and wehrlite occur in subordinate amounts. Dunite and harzburgite constitute over 90 percent of the layered suit . The mappable units range in thickness from 25 to 3500 meters. They recur in vertical extent several times at all scales, totalling nearly 13,000 m in thickness. The dominantly north-south and subvertical contacts of the major dunite, harzburgite and gabbro units are paralleled by an internal fabric of thin layers of clinopyroxenite and chromitite, and individual grains of elongate enstatite and chromite. Serpentinization has affected much of the primary units. Smaller amounts of jasperoid silica, silicified listwanite and magnesite are also present.

Tankut (1982) recorded the relict cumulative features of stratiform type, and chemical properties of Alpine-type complexes. Özkoçak (1969) suggested that the Orhaneli ultramafic massif was a Late Cretaceous intrusion. Lisenbee (1971, 1972) argued that the massif was emplaced as a solid mass during the Late Cretaceous.

The presence of detrital chromite in the nearby Late Jurassic basal clastic rocks (Özkoçak,1969) may suggest that the ultramafic-mafic layered suit is pre-Late Jurassic in age. The recent recognition of the Late Jurassic unconformity between a Late Jurassic slate unit and ultramafic rocks, which is defined by serpentinite-derived basal conglomerate and pebbly (slaty) mudstone, in Gemlik (Bursa) (Kaya and Kozur, 1987) and Almacıkdağ (Bolu) (Kaya, 1987), may support a pre-Late Jurassic tectonic setting for the ultramafic rocks.

Metatuff unit

This unit consists of bluish to olive-gray, homogeneous, fine to very coarse-grained mafic metatuff with subordinate interlayers of pervasively recrystallized limestone and metalava. The metatuff unit corresponds to Özkoçak's (1969) "Le serie metamorphique superieure" (The upper metamorphic serie). The unit exhibits a well developed foliation, which becomes more pronounced in the weathered-out exposures. The metatuff is apparently basaltic in composition, and consists of chlorite, albitic plagioclase, tremolite, actinolite, epidote, white mica, biotite, relict titaniferous augite, quartz, and glaucophane. Secondary minerals include clinozoisite, grossular-weighted garnet, sphene, apatite, tourmaline, magnetite and calcite. The marble-like recrystallized limestone interlayers are 5 to 100 m in thickness, light gray to reddish gray and fine to medium-grained, and have a gradational contact relationship with the metatuff. The thicker ones are traceable for considerable distances.

The metatuff unit represents the top of the low-grade (glaucophanitic) greenschist facies metamorphic sequence which is widely distributed in the southern parts of northwest Anatolia (Özkoçak, 1969, Lisenbee, 1971). Ketin et al. (1947), v.d. Kaaden (1959) and Brinkmann (1976) have suggested that the contact between the metamorphic rocks and overlying Permo-Carboniferous graywacke series is an unconformity. The only field evidence recorded for the unconformity is the presence of crystalline rock pebbles in the graywacke series, and the so-called rubefaction (weathering) of the metamorphic rocks at the contact, prior to the deposition of the graywacke series (Özkoçak, 1969).

In the study area, the blocky sedimentary unit (Dışkaya formation) contains blocks of metatuff which are identical in all aspects to the immediately underlying metatuff unit. The presence of these blocks at the very base of the Dışkaya formation is the most conclusive evidence so far for an unconformity bounding the metamorphic sequence at the top (Dışkaya formation, lower contact). Thus a pre-Lute Triassic age for the metamorphic sequence is evident.

Dışkaya formation

Stratigraphy .— The Dışkaya formation (Kaya et al., 1986) consists of shale (facies E and G), lithic sandstone—shale (facies C and D, and less commonly B and A), quartzo—feldspathic sandstone ("gully sandstone": Surlyk, 1987) and olistostromes. The latter include a matrix of the above rock types, reworked submarine mafic volcanic rocks and, typically, pebbly mudstone. The partial composite type section is exposed in the Dışkaya area, north of Bursa. In the study D

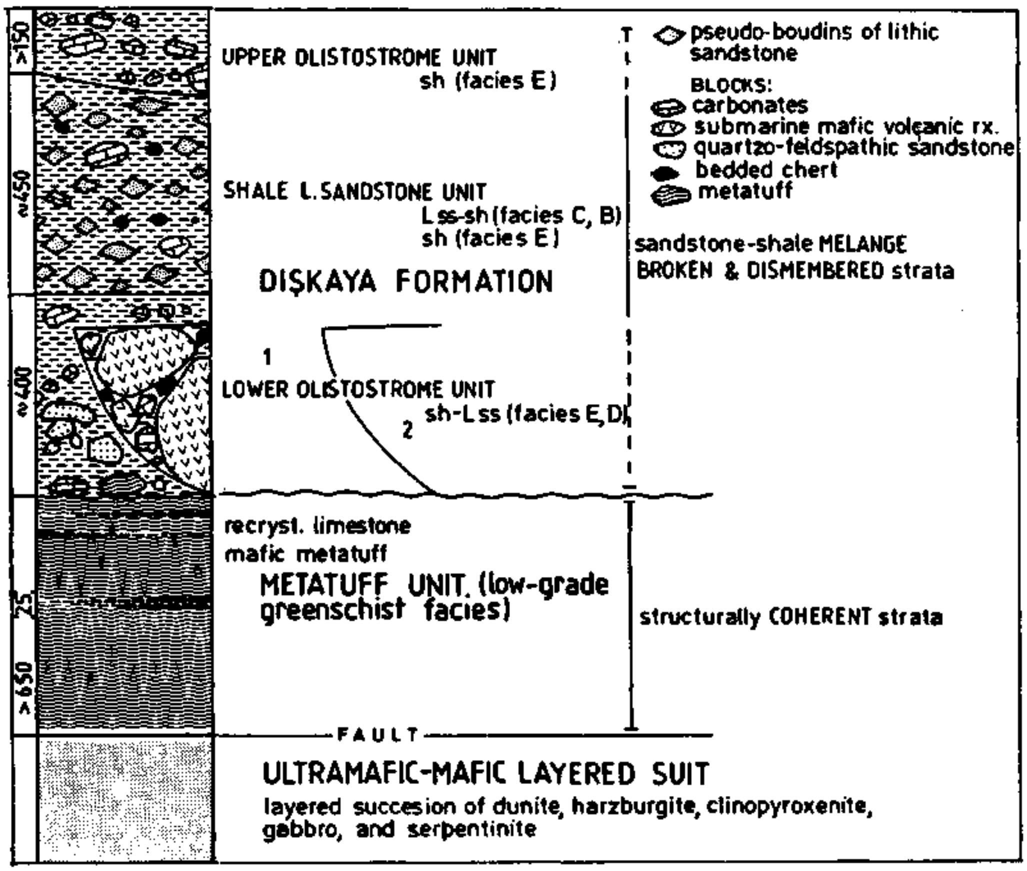

Fig. 2— Composite reference section of the Dışkaya formation exposed in the study area.

area the Dışkaya formation is divisible into three strattgraphic units (Figs. 2 and 3) in ascending order: a- lower olistostrome unit, b- shale-lithic sandstone unit, c- upper olistostrome unit. The units are delimited by arbitrary boundaries on the basis of the traceable distribution of blocks. Because many of blocks are probably undetected or covered by surface deposits, the boundaries may locally be subject to further modification.

Lower olistostrome unit: This unit consists, of isolated and intimately admixed blocks and a matrix of shale, and shale—lithic sandstone sequences primarily of facies C. With respect to the predominating types of blocks, it is divided into two parts: olistostrome 1A and olistostrome 1B.

The olistostrome 1A characteristically contains isolated blocks of gray and red-gray recrystallized limestone quartzo- feldspathic and Iithic sandstone, bedded cherts, submarine mafic volcanic rocks and minor metatuff, all floating in a matrix of shale and shale-sandstone (Appendix 1,1). The olistostrome is well exposed in the surroundings of Göktepe Köyü (Fig.3) where it was first recognized and mapped by Özkoçak (1969), who called it, however, a Late Cretaceous megabreccia.

The olistostrome 1B is dominated by chaotically admixed blocks of submarine mafic volcanic rocks (tuff, lava, reworked volcanic rocks with small limestone blocks, etc.) displaying differences in color, internal stratification and depositional structure. Other blocks are limestone, red and gray bedded chert and sandstone, which are interspersed among the volcanic blocks. The olistostrome is partly mappable in detail on the Belentarla Sırtı where favorable outcrops exist

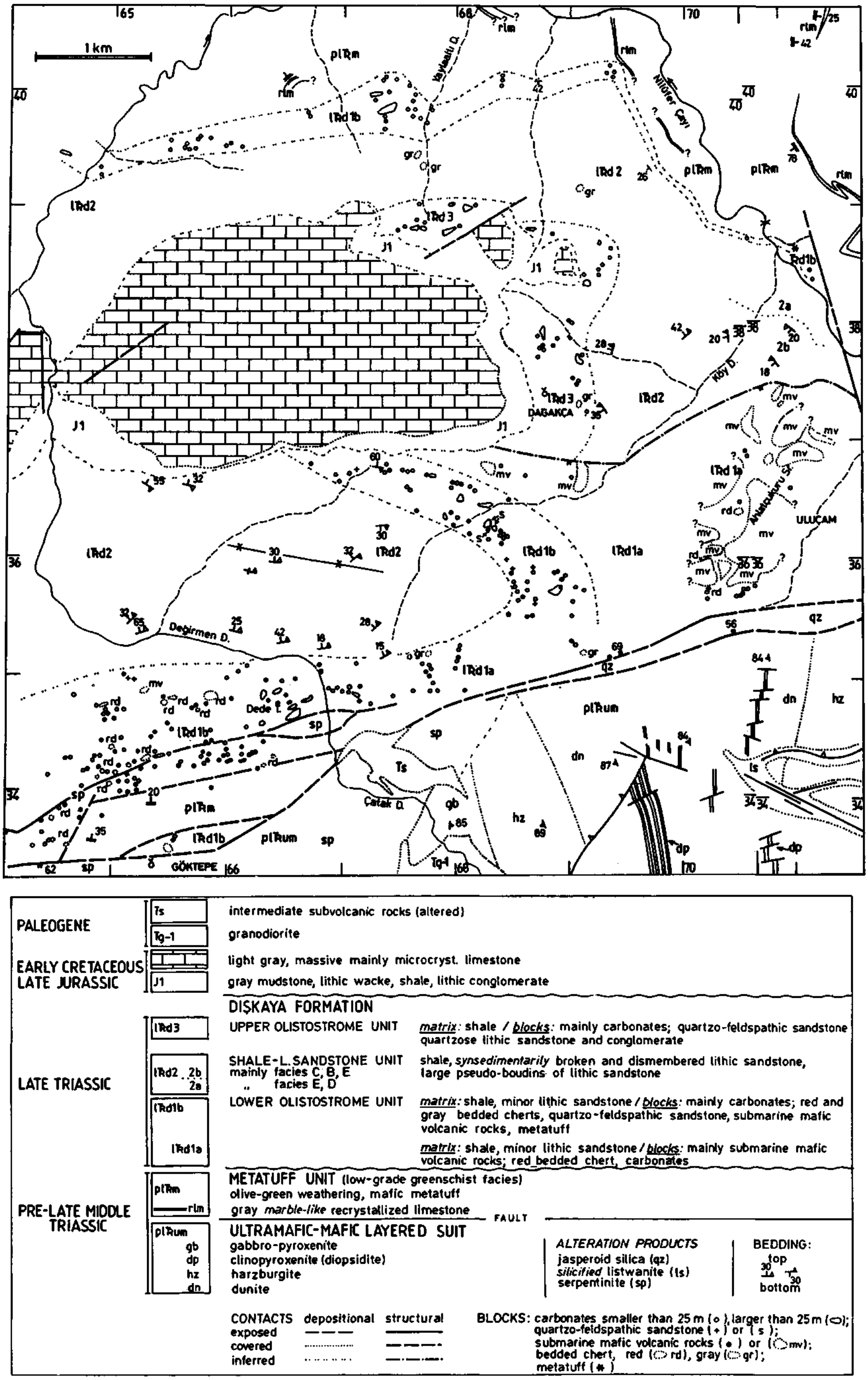

Fig. 3 – Geological map of the study area.

(Fig. 3). The matrix consists of synsedimentarily deformed lithic-sandstone sequences primarily of facies D and C, shale, and minor amounts of pebbly shale. The latter contains small blocks of volcanic rocks with clear outlines (Appendix 1,2).

Shale-lithic sandstone unit: This unit consists primarily of shale, and turoiditic lithic sandstone-shale sequences characteristically containing sandstone pseudo-boudins up to 10 m in size. The unit is divisible into a lower shale (Appendix 1,3) and an upper sandstone dominating part (Appendix 1,4). The shale is facies E. The lithic sandstone-shale sequences originally represent facies D,C and B. They are synsedimentarily deformed to the extent of sandstone-shale melange which is distinguished by its large pseudo-boudins of sandstone representing parts of facies B and A (Fig. 4). The unit locally contains gray bedded chert blocks incorporated in an olistostromal interlayer. Lithic conglomerate, a probable cut-and-fill deposit, occurs locally. It is matrix-supported and characterized by perfectly round clasts of lithic sandstones, and minor metaquartzite and altered granitoid (or gneissoid) rocks.

Upper olistostrome unit: This unit consists primarily of isolated small blocks of gray limestone, quartzo—feldspathic sandstone, quartzose lithic sandstone and, conglomerate, gray bedded chert, and minor submarine mafic volcanic rocks, enclosed in a primarily shale matrix (Appendix 1, 5).

Deformation— Abundant broken and dismembered strata, to the extent of sandstone melange, give the Dışkaya formation its complex structural appearance. The deformation features of the sandstones include pull-apart and pinch-and swell structures in particular pseudo-boudins. The latter range in size from a few centimetres to several metres. The smaller ones are lens to lozange-shaped bodies with polygonal outline and sometimes smooth polished surfaces. Larger ones exhibit slab-like to subround blocky shapes and consist of either massive sandstone or interbedded sandstone and shale which have been cut along the bedding at the top and bottom and bounded by curved fault planes at the sides. The long axis orientation of the pseudpboudins, together with the scaly cleavage of the shale matrix, presents a planar fabric. The criteria indicating a soft- sediment origin for the pseudo-boudins in the sandstone-shale melanges include the following (Lash, 1985, Cowan, 1985, Barber et al., 1986).

— The pseudo-boudins exhibit surface irregularities looking like load casts and deformed scour-and-fill structures (Fig.4A). Flame structures and shale penetrations across the bedding are common occurrences (Fig. 4A,B).

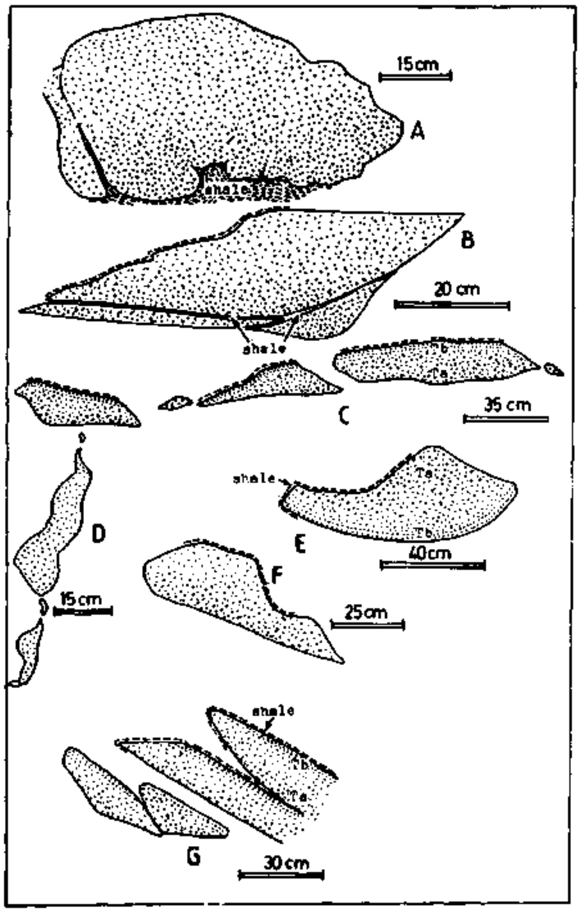

Fig. 4- Representative soft-sediment deformation features in the Dışkaya formation. A- Bulbous protrusions of sand associated with flames of shale, and planar penetration of shale (left side); B- discordant planar shale penetrations; C,D- trains of pseudo-boudins related to synsedimentary stratal disruption; E, F- representative pseudo-boudins; G- synsedimentarily imbricated pseudoboudins as a part of slide mass. On the exposed surfaces pseudo-boudins exhibit encrustations of thin veneer of shale. A and C are drawn from photographs. Localities for the structures are in turn (Appendix 1,5-12).

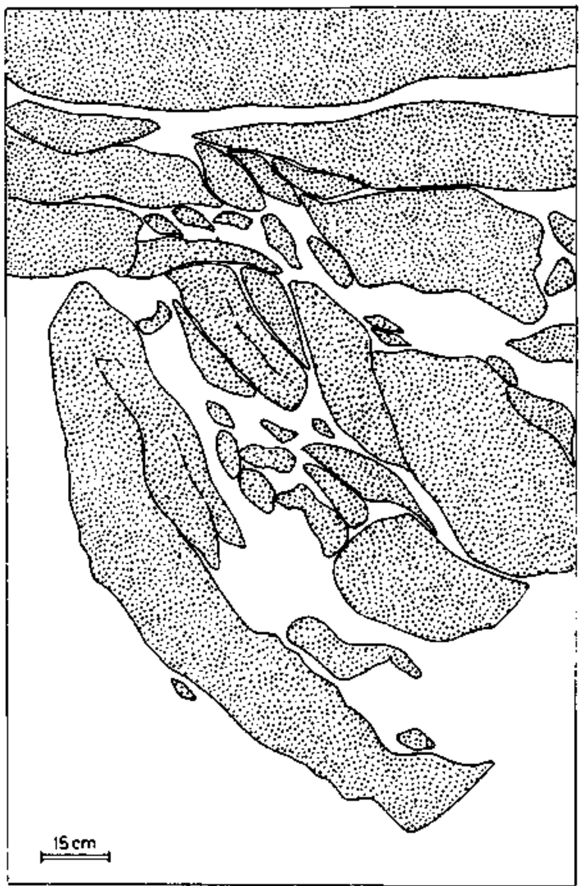

Fig. 5— Slump deposit with accompanying pseudo-boudins of different sizes and orientations. Drawn from photograph (Locality, Appendix 1, 13).

— Trains of pseudo-boudins with the same Bouma divisions and thickness mark the traces of disrupted sandstone strata (Fig. 4C,D).

— Shearing and grain deformation in the peripheral as well as the inner parts of the pseudo-boudins are absent. Sandstone pseudo-boudins are delicately encrusted by shale (Fig. 4A-G).

— Pseudo-boudins, also including the typically phacoid-shaped ones, are the constituents of the slide (Fig. 4G) and slump (Fig.5) masses.

Lower contact.— The lower olistostrome unit (1A) of the Dışkaya formation rests directly on the low-grade greenschist facies metatuff unit, however, the contact is slightly deformed (Appendix 1,14, southern road-cut). In the same place (northern road-cut)the shale matrix encloses blocks of metatuff (Fig.6), up to 8. m across, exactly identical, in their lithic, mineralogic and structural aspects, to the immediately underlying metatuff unit or to that most continuously exposed 250 m westward (Appendix 1,15). The original depositional contact between blocks and matrix rocks is Intact.

The presence of metatuff blocks in the very base of the Dışkaya formation is the first piece of conclusive evidence for the unconformity bounding the so-called Permo-Carboniferous graywacke series.

The polymictic conglomerates recorded by Özkoçak (1969) as the basal elastics of the Permo-Carboniferous graywacke series do not in fact show a traceable outcrop connection with the Dışkaya formation. They are of a lower diagenetic grade when compared with those in the Dışkaya formation, and lithologically resemble the Tertiary deposits outside the map area.

Age.— The matrix of the Dışkaya formation is everywhere barren of fossils. The presence of Late Scythian to Early Norian blocks (Dışkaya Dağları) and the clear-cut unconformity with the early Middle Triassic low-grade greenschist facies metamorphic rocks (Bergama) indicates a Late Triassic age for the Dışkaya formation. In the study area, Early Carboniferous *Densosporites* sp. and *Lophotrilites* sp. recorded by Özkoçak (1969) in fact come from the coaly shale interbeds of gray bedded chert blocks (Appendix 1,16). Restudy of the so-called Globotruncana fragment recorded by Özkoçak (1969) in the Late Cretaceous megabreccia (herein, olistostrome 1A), has shown that the fragment is not informative.

Jurassic—Cretaceous rocks

The Jurassic to Cretaceous rocks include two distinct units, a basal clastic unit, and an overlying limestone unit.

The basal clastic unit consists, in a broadly ascending order, of gray lithic conglomerate, lithic sandstone, mudstone and shale. The conglomerate is grain to matrix-supported, thickly bedded to massive, and contains round pebbles moderately sorted in size. The pebbles include lithic sandstone and shale derived from

Fig. 6— Block of metatuff in the lowermost part the Dışkaya formation. It is exactly identical in all respects to the nearby continuously exposed low-grade Metatuff unit. Drawn from photograph. Locality (Appendix 1, 14).

the immediately underlying Dışkaya formation; and gneiss, metaquartzite, mica schist,metatuff,marble, granite and vein quartz. The sandstone, primarily lithic wacke, contains accessory minerals such as detrital micas, chromite, zircon, tourmaline, apatite,hematite, and spinel. The mudstone and shale consist of siliciclastic material including minor detrital white mica, biotite and ohlorite.

The basal clastic unit shows rapid change in thickness, suggesting that it leveled off the pre-Late Jurassic topography before the deposition of the limestone unit.

The limestone is gray, thickly bedded to massive, and primarily microcrystalline. Algal and foraminiferal detritus and ooids as large as 2.5 cm in size seem to be major constituents. Detrital quartz is locally present. The limestone is locally pervasively recrystallized,and dolomitized and silicified.

The clastic and limestone units can be considered, to be of Late Jurassic and Late Jurassic to Early Cretaceous age, respectively, as several early workers have already recorded. The basal clastic unit has only sparse fossils. Molluscan *Pleuromya alduini* and *P.* aff. *tellina* indicate Bathonian-Oxfordian and Callovian-Portlandian ages, respectively. Foraminifera sampled from the different parts of the limestone unit include Marinella *lugeoni, Trocholina* cf. *alpina, Pseudocyclammina* sp., *Cayeuxia* sp., *Valvulinella* sp., *Valvulina* sp., and Verneulinidae, as a whole indicating a Late Jurassic-Early Cretaceous age.

Tertiary rocks

The Paleocene granodioritic complex exposed as several separate plutons, intrudes the ultramafic-mafic layered suit. Dikes are abundant, both in the surrounding ultramafic-mafic rocks and plutons themselves.

The Neogene dacite, rhyolite and andesite intrude the ultramafic-mafic layered suit and the Dışkaya formation, as dikes and small plugs. In places, they are totally altered to quartz and sericite.

GENERAL CONSIDERATIONS

In all recent tectonic syntheses, the pre-Jurassic blocky sedimentary rocks, together with the coeval low-grade metamorphic rocks, have been viewed as being a subduction-related melange. The suggested tectonostratigraphic units include the Karakaya formation or group (Bingöl, 1974,1978,1983); the Paleo-Tethyan ophiolitic melanges or Karakaya orogen(Şengör et al., 1980,1982; Şengör and Yılmaz, 1981; Şengör et al., 1985), the North Anatolian Melange (Tekeli, 1981), the middle Sakarya melange group (Şentürk and Karaköse, 1981), the Carboniferous and Permo-Carboniferous accretionary prisms (Üşümezsoy, 1987), etc. In addition, Şengör and Yılmaz (1981) and Şengör et al. (1982) established the "root zones" of the Karakaya and ?Bursa sutures comprising the Paleo-Tethyan and Hercynian ophiolites, ophiolitic melange and deep-sea sediments which were superimposed in the surroundings of Bursa, apparently including the study area. Okay (1985) considered the Karakaya as a medium to high pressure greenschist facies complex. Bergougnan and Fourquin (1980) suggested an allochthonous assemblage of diabases, spilites, radiolarites, Halobia-limestones, Triassic clastic rocks and some serpentinites on a Hercynian basement, representing the Triassic opening of the Tethys.

Major field data which does not give a direct support to the recent tectonic interpretations are the following:

1— The Dışkaya formation consists of laterally continuous stratigraphic units. The rock categories include primarily shale (facies E) and lithic sandstone-shale (facies B to D) sequences, their synsedimentarily deformed versions (sandstone-shale melange), and olistostromes are atypical of Flores (in. Hsü, 1974) original definition in not having a matrix of debris-flow origin. Submarine volcanic rocks occur as isolated or intimately admixed blocks which are incorporated in olistostromal interlayers. They are supported by epiclastic matrix and reworked volcanic matrix and are associated with blocks of different rock types. Pelagic rocks are present only as blocks.

The lithologic and sedimentary characteristics of the Dışkaya formation are indicative of a slope apron.

2— Throughout the Dışkaya formation top directins are available and are consistent with an open fold system (Fig.3). Where exposed, blocks show sedimentary contacts with the matrix rocks. The apparently complex internal structure (the sandstone-shale melanges) of the Dışkaya formation is the product of synsedimentary deformation. In other words, the sandstone-shaje melange interlayers are related to submarine sliding of thick piles of semi-lithified sediments. There are no critical accretionary deformation features, such as thrusts and folded packets, which should occur in significant numbers, and refolding structures, penetrative cleavage and elongation lineation. Those existing locally can be best explained as a product of post-Triassic tectonics, primarily because of the absence of transition from ductile to brittle deformation, and conformity with the post Triassic structures, etc.

A great variety of tectonic settings, including passive margins, give rise to soft- sediment deformation to the degree of sandstone-shale melange (Jacobi,1984).

3— The low-grade (glaucophanitic) greenschist facies metamorphic sequence (the metatuff unit) is structurally and stratigraphically coherent. The erosional unconformity between the metatuff unit and overlying Dışkaya formation indicates the latter, at least originally, to be structurally autochthonous.

CONCLUSIONS

— Lithologic, sedimentary and structural characteristics of the Dışkaya formation indicate that it was deposited on a slope floored primarily by low-grade metamorphic rocks. The metamorphic sequence also constituted a nearby provenance.

— There is no direct evidence that the Dışkaya formation itself is of an oceanic origin and it is a tectonic melange representing a part of an accretionary prism.

— Before a Triassic plate tectonics reconstruction is attempted a thorough understanding of the geology of the low-grade metamorphic rocks and ultramafic rocks, within the framework of classical field surveying, seems to be necessary.

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APPENDIX-1

(map coordinates)

1. 70.93:38.64 - 70.96:38.60 (H22d4)
2. 70.87:37.20 (H22d4)
3. 70.80.:38.33 - 71.10:37.90 (H22d4)
4. 70.54:38.10 - 69.20:37.34 (H22d4)
5. 67.58:36.81 - 67.31:36.66 (H22c3)
6. 69.21:37.33 (H22c3)
7. 67.90:36.29 (H22c3)
8. 69.37:37.31 (H22c3)
9. 70.87:37.20 (H22d4)
10. 65.29:36.62 (H22c3)
11. 68.06:36.45 (H22c3)
12. 67.22:35.66 (H22c3)
13. 69.81:37.71 (H22c3)
14. 70.93:38.64 (H22d4)
15. 70.60:38.75 (H22d4)
16. 67.64:39.34 (H21c3)