The role of the Ankara Melange in the development of Anatolia (Turkey)

Teoman N. Norman

SUMMARY: The 'Ankara Melange', as defined by Bailey & McCallien (1953), comprises several belts, sub-belts and lenses of melange units, as well as some intercalated ocean floor fragments and continental (magmatic arc?, island arc?) slivers. Two significant observations are the successive younging of melange units from north to south (or northwest to southeast locally) and mega-debris flow features in some of melange units indicating a possible flow direction from east to west (or northeast to southwest). Both observations can be explained by assuming an obliquely northward moving Tethys ocean plate, subducting under a continental mass against which successive accretion and obduction of ocean floor irregularities (such as ocean plateaux, ridges, magmatic island arcs or even continental slivers) from Early Jurassic times to Middle Oligocene, produced the present complex melange system. Flow features can be explained by the development of local high ground where a non-subducting oceanic platform transpressed obliquely against the already-formed melange material, causing it to flow successively to depressed (trench) regions. Such flows were naturally interbedded with, or accompanied by, other types of mass flows and slivers of continental and/or oceanfloor material.

The name 'Ankara Melange' was given to a group of rocks (Bailey & McCallien 1953) around Ankara in Anatolia (Turkey) which showed an unusual degree of fragmentation and mechanical mixing, bringing together material of diverse origin and age. The strict definition of the term, as well as the delineation of its boundaries was presumably considered to be of secondary importance. However, subsequent work over a period of 30 years indicates that these rocks extend over several hundred kilometres in an east to west direction, and attain an average width of about 100 km (Fig. 1). The Ankara Melange itself is made of several sub-parallel belts, sub-belts and lenses (Erol 1956; Boccaletti *et al.*, 1966; Çalgın *et al.* 1973; Norman 1975a; 1975b; Çapan & Buket 1975; Gökçen *et al.* 1978; Çapan 1981; Akyürek 1981; Ünalan 1981; Seymen 1981). Also there are several other sub-parallel melange belts

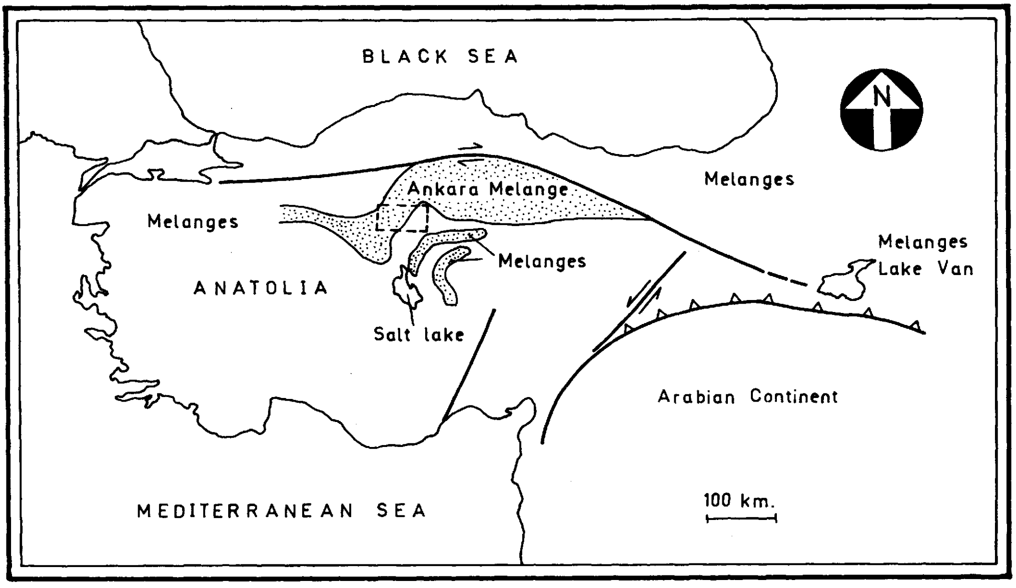


FIG. 1. Location and position of Ankara Melange and other major melange belts in Central Anatolia. Original Study area is shown by rectangle, Fig. 2 forms the southwestern quarter of this area.

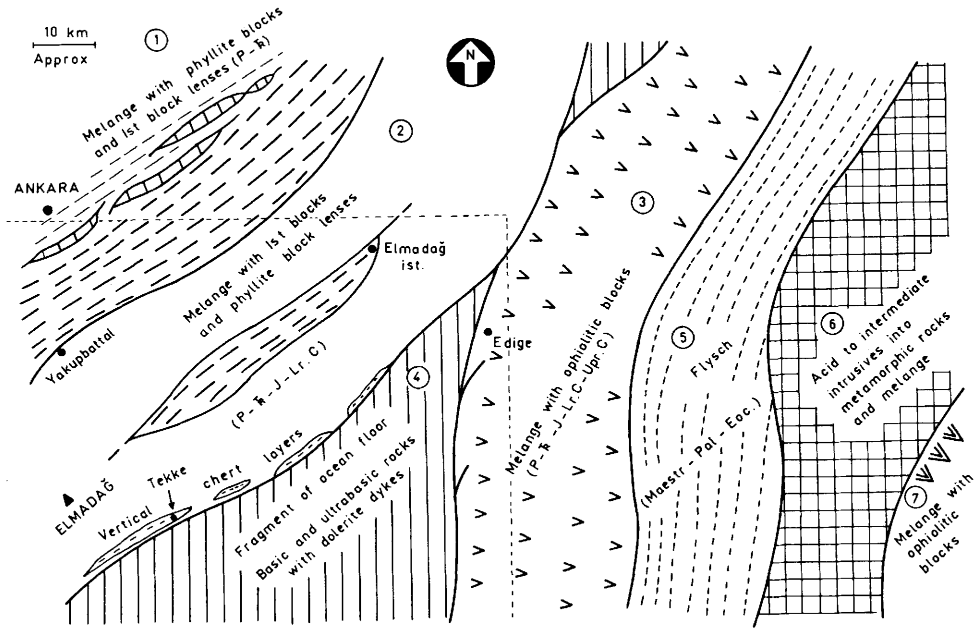


FIG. 2. Sketch map showing the major belts and sub-belts of Ankara Melange within the study area (some locality names are included for cross-reference with Fig. 3).

nearby, and other melange belts of similar character in other parts of Anatolia.

Significant features of melange units

At least 7 major belts (and several sub-belts and lenses) may be distinguished within the 'Ankara Melange' zone. In the area under study these sub-parallel belts will be described from north-west to southeast (Fig. 2), corresponding to a sequence from north to south, before local rotation by subsequent tectonic events.

Melange with phyllite blocks (metamorphic-block-melange)

This forms the outermost belt in the study area, including the foundation of the city of Ankara. The phyllite blocks of andesitic tuff origin are set in a graywacke matrix, consisting of graded turbidites (volcanic arenite), laminated mudstones and occasional channel conglomerates of a submarine fan environment. Occasional interbedded spilitic lava flows appear to have flowed over wet sediment presumably under high pressure, forming wrinkles at their soles but no pillows or vacuoles. Within this belt, there are several sub-parallel sub-belts and lenses consisting of limestone blocks (Permian), spilitic pillow lava blocks with Triassic fauna between pillows, agglomerates, tuffaceous olistostromes and radiolarite chert blocks (few), all set in a tuffaceous graywacke matrix. This part of the Ankara Melange has probably a Late Triassic-Early Jurassic age.

Melange with limestone blocks

This consists of oblong limestone blocks forming linear 'trains' which are generally sub-parallel to the general trend, but they may also curve around to form 'nose' or 'fan' (Fig. 3) shaped structures (Norman 1973, 1975). In addition to limestone blocks there are also blocks of conglomerate, agglomerate, diabase and graded turbiditic chert, set in a matrix of graded volcanic arenites and laminated black shales. The ages of limestone blocks have been palaeontologically determined as ranging from Permian through Early Cretaceous (up to Albian). A lens-shaped large sub-belt of phyllite-block melange divides this belt into two sub-belt units (Fig. 2).

A noticeable feature of this complex is the presence of mega-debris flow features, such as imbrication of blocks, concentration of larger blocks at the 'front' end, abrasion surfaces with sub-horizontal slicken-sides, curving 'noses' developed by flow lines, one-side abraded limestone blocks (Norman 1975b; Johnson 1970, 1981, personal communication). Considering

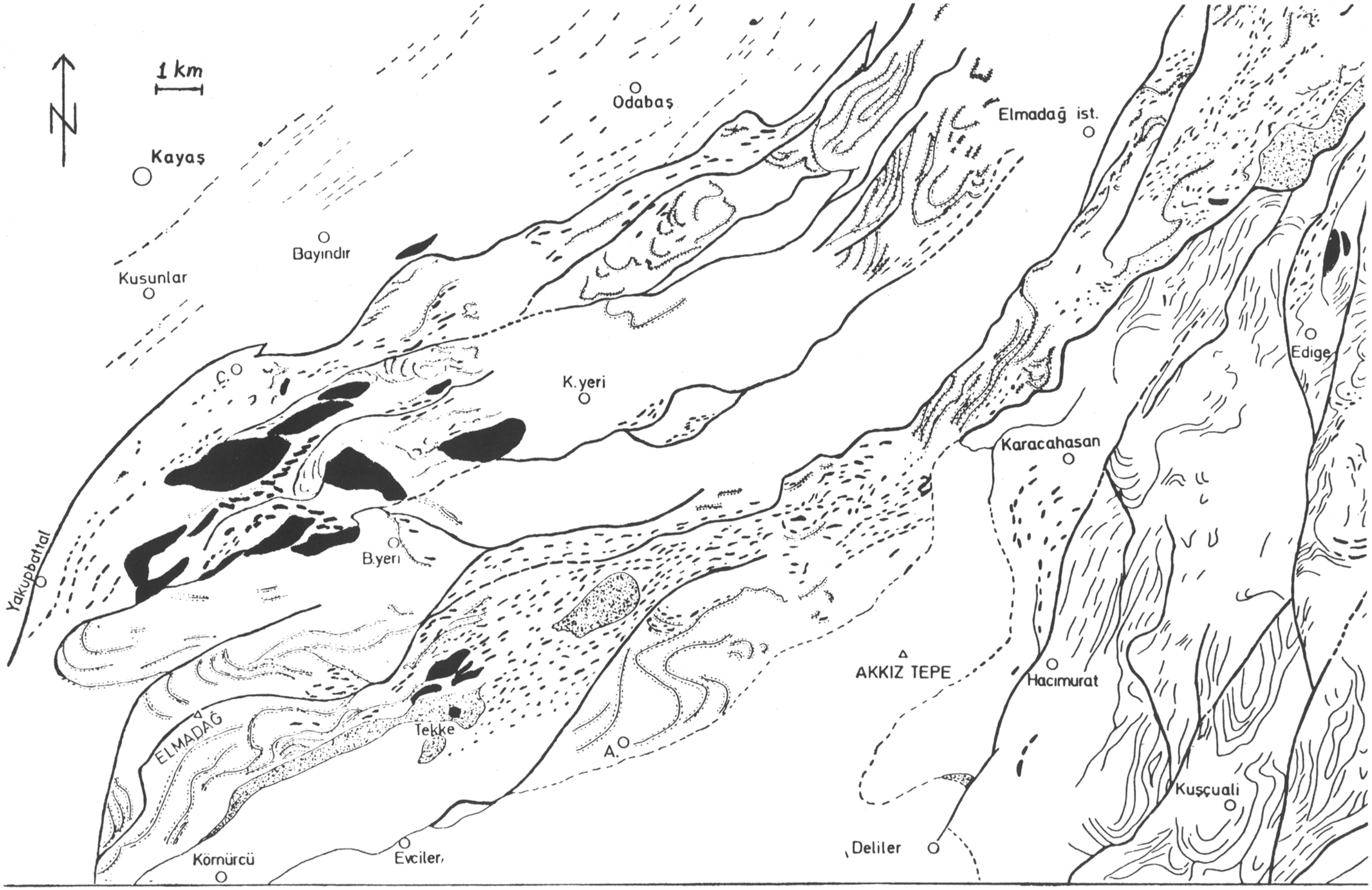


Fig. 3. Part of Ankara Melange, showing imbricated limestone blocks, cross-cutting abrasion surfaces (thick lines), 'trains' of blocks producing fan-shaped or nose-shaped flow lines. Flow movement direction from northeast to southwest (After Norman, 1975b). *Note:* Black patches indicate larger limestone blocks, stippled blocks outline radiolarite cherts (Map based on airphoto mosaic, with local ground control, at an original scale of 1:35 000).

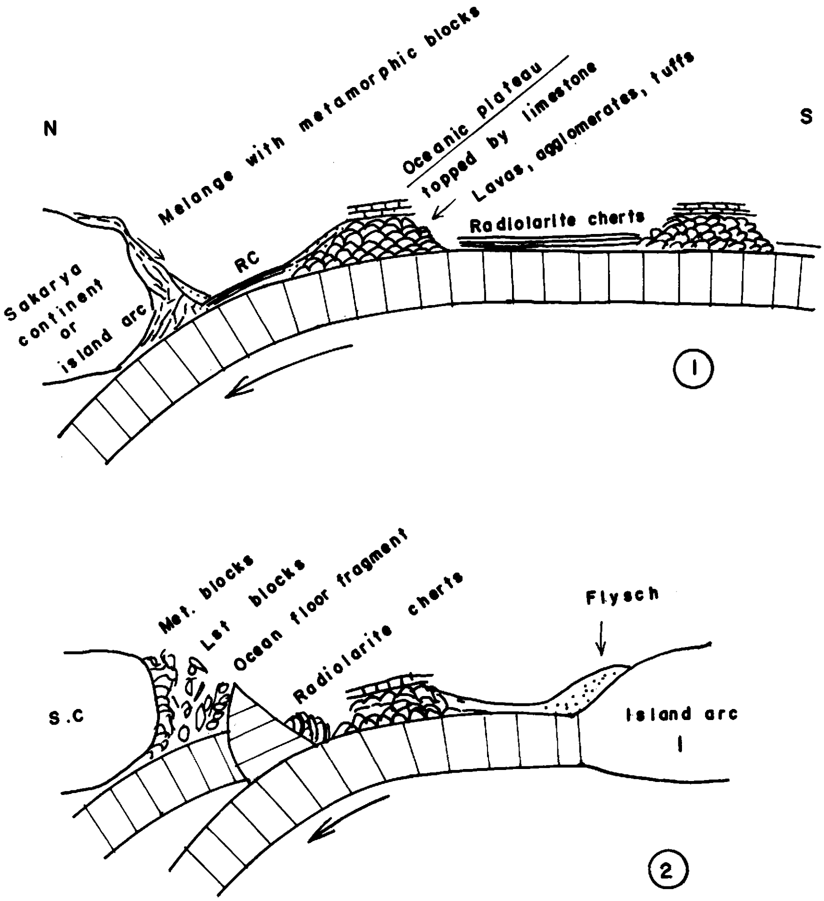


FIG. 4. Development of the various belts of Ankara Melange by accretion above a northward dipping subduction zone.
(1) Late Jurassic to Early Cretaceous: Formation of melange with metamorphic blocks as well as Permian-Triassic-Jurassic and Lower Cretaceous limestone blocks.
(2) Late Cretaceous to Paleocene: Ophiolitic melange, obduction? of ocean floor fragment.

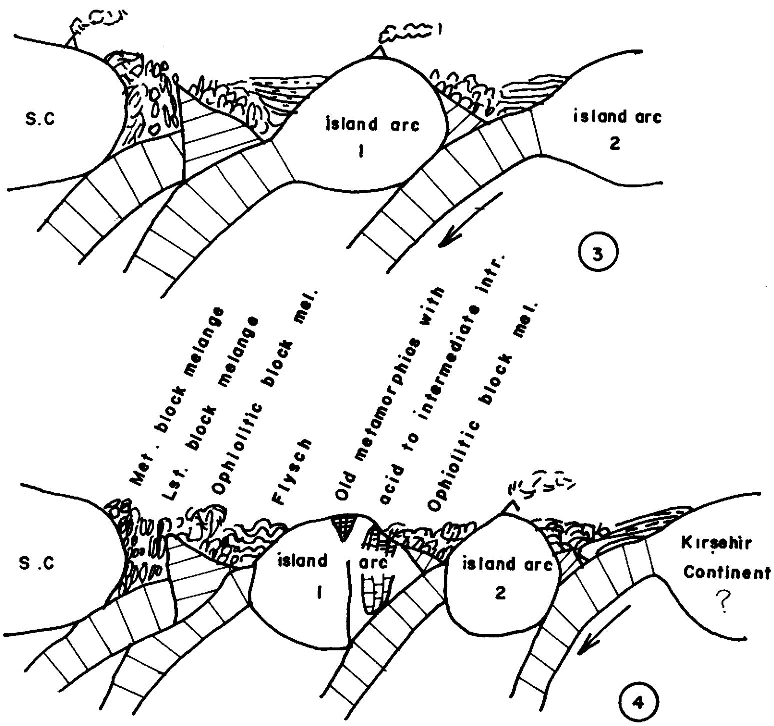
the nearly vertical attitude of the 'layers', such flows can be interpreted as having moved from northeast to southwest or east to west in general.

Melange with ophiolitic blocks

This consists of pillow lava and agglomerate, conglomerate, sandstone and limestone blocks, red coloured radiolarite chert, clay and limestone blocks, as well as elongate lenses of serpentinite, in general all set in a tuffaceous matrix. Also noticable are serpentinite lenses which are clearly interbedded with red shales, limestones and laminar cherts, along 'normal' sedimentary contacts, while internally presenting disturbed broken-up structures of serpentinite blocks floating in essentially serpentinite matrix: a typical feature of monogenetic olistostromes. The ages of limestone blocks have been identified as ranging from Permian to Late Cretaceous (Senonian) by several workers (Gökçen 1977; Batman 1977). Since it is overlain by flysch sediments of Maastrichtian age, the formation age of this melange could be Campanian or older. Once again, typical mega-debris flow characters are observed in this melange belt, indicating a flow direction from northeast to southwest or east to west (Norman 1975b).

Ocean floor fragments

Juxtaposed with limestone-block and ophiolite-block melange belts, there are fragments of oceanic lithosphere, with sizes up to



(3) Eocene: Flysch fill over melange basins.
(4) Oligocene: Further squeezing and partial uplift. No major thrusting required.

several tens of km². They have lithological compositions of basic (gabbro) and ultrabasic (harzburgite, serpentinite) rocks with occasional layered chromite. Near vertical dolerite dykes, siliceous veins and magnesite veins cut these rocks and may even become locally dominant features. These areas probably represent obducted fragments of ocean floor (Fig. 2).

Flysch

This consists of turbiditic sandstones (volcanic arenite) and shales with occasional intercalations of debris flows or olistostromes, as well as andesitic lava flows and tuff layers, and appears to rest conformably on the ophiolitic-block melange belt. Ages range from Maestrichtian to Late Eocene, or even possibly Early Oligocene. The environment of deposition is characteristically coalescing submarine fans. Palaeocurrents, though locally variable, seem to have flowed in general from northeast to southwest or east to west (Norman *et al.* 1980). When 'unfolded', the flysch basin widens to 90–100 km, indicating a great amount of shortening during the major Alpine orogeny. Petrographic studies of the clastic mineralogy indicate a steady increase in the quartz and related 'acid' minerals, going stratigraphically upwards (Norman *et al.* 1980). This suggests, for the first time in the geological history of this area, the proximity of a magmatic arc in Early Eocene time.

Acidic and intermediate magmatic rocks

These are intruded as batholiths into 'Ankara Melange'-type formations and older (Early Palaeozoic) metamorphic schists and gneisses (age of intrusion: Palaeocene). The pre-Mesozoic regional metamorphism is considered to have developed in a magmatic arc (Seymen 1982).

More 'Ankara Melange'-like belts, in juxtaposition with other ocean floor fragments and magmatic arcs, are found further southeast (Seymen 1982). New research indicates the presence of Ankara Melange-like belts, running roughly in northeast to southwest direction, within the so-called Kırşehir Massif (e.g. Belt 7, Fig. 1). They appear to include large (km size) blocks of the composition described above as ocean floor fragments. Further east and south, more and more magmatic arc rocks (acidic metamorphics and intrusions) become dominant.

Discussion

From the description above it seems clear that the present day Ankara Melange is built up of several melange belts, formed at different times and places, then brought together by gradual accretion from northwest to southeast. This process can possibly be explained by a northward moving ocean floor, carrying a variety of pillow lavas, agglomerates, tuffs, oceanic plateaux and island arcs with limestone developments, as well as flysch deposits and radiolarite cherts. This plate (Fig. 4) could have subducted under a continental sliver or island arc (Şengör & Yılmaz 1981; Tekeli 1981).

The mega-debris flow features, particularly noticeable in the limestone-block and ophiolite-block melange belts could also be explained by the same kinematic mechanism, provided an oblique shear movement is created by the northward approaching oceanic plateaux and magmatic arcs (Fig. 5). Thus the proximal end of the ridge feature (e.g. island arc) carried by the subducting oceanic plate would exert a transpressive shear, causing local squeezing up of the melange material, which in turn, could start mass flow towards depressions along the trench, parallel to the trend of the subduction zone. With the continued forward movement of the plate, this elevated area could migrate laterally, causing re-sedimentation of the melange material, particularly causing further flows from east to west, or northeast to southwest. This mechanism could also explain the interbedded or subparallel nature of the tectonic features and sedimentary units within melange belts (Norman 1975b; Norman *et al.* 1980).

Such kinematics can be observed today, through oceanographic studies, in the Eastern Pacific off South America, as well as Western Pacific, off the coast of Japan (Ben-Avraham *et al.* 1981).

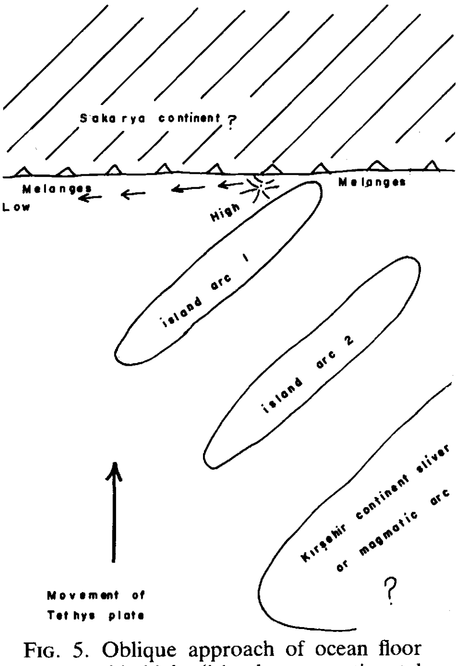


FIG. 5. Oblique approach of ocean floor topographic highs (island arcs, continental slivers, etc.) towards northward subducting zone, causing transpressive shear at a point. This squeezed and elevated site becomes a source for further westward moving melange flows. As the island arc (or any other topographic high) becomes 'jammed' against the (Sakarya?) continent, the next piece of ocean floor is subduced forming a new melange belt.

Conclusions

There appears to be an east to west trending, northward-plunging subduction zone, developed probably during Mid-Jurassic times. Obliquely northward moving Tethys (? Neo Tethys) ocean floor, successively formed the various units of the Ankara Melange. Irregularities on the oceanic plate, such as oceanic plateaux, ridges, magmatic island arcs or even possibly continental slivers, have been accreted along with melange material. Occasional fragments of ocean floor were also involved in the process. Due to oblique transpression, melange material may have flowed successively from 'high' points to depressed areas in the west or southwest.

It may be speculated that the major part of Central Anatolia has been built up by the accretion of melange material intercalated with oceanic and magmatic island arc material, without major continental microplates, *sensu stricto*.

This model suggests a 'gradual' melange formation with 'continuous' deformation and accretion, rather than one or two 'wild' periods of paroxysm and thrusting.

References

AKYÜREK, B. 1981. Fundamental charcteristics of the northern part of Ankara Melange (in Turkish). *Symposium on Central Anatolia, Geol. Soc. Turkey*, 41–52.

BAILEY, E. B. & MCCALLIEN, W. J. 1953. Serpentine lavas, the Ankara Melange and the Anatolian Thrust. *Trans. Royal Soc. Edinburgh*, **62**, 403–442.

BATMAN, B. 1977. *Geological evolution of North Haymana Region and study of the neighbouring melange.* (Unpublished dissertation, in Turkish). Hacettepe Üniv. Ankara. 172 pp.

BEN-AVRAHAM, Z., NUR, A., JONES, D. & COX, A. 1981. Continental accretion: from oceanic plateaus to allochthonous terranes. *Science*, **213,** 47–54.

BOCCALETTI, M., BARTOLETTI, V. & SAGRI, M. 1966. Ricerche sulle ofioliti delle Catene Alpine: I-Osservazioni sul'Ankara Mélange nella zona di Ankara. *Boll. Soc. geol. It.* **85,** 485–508.

ÇALGIN, R., PEHLİVANOĞLU, H., ERCAN, T. & ŞENGÜN, M. 1973. *Geology of Ankara region* (Unpublished report, in Turkish). M.T.A. Rep. No. 6487. 55 pp.

ÇAPAN, U. Z. & BUKET, E. 1975. Geology of Aktepe Gökdere region and ophiolitic melange. *Bull. Geol. Soc. Turkey*, **18,** 11–16.

—— 1981. Views on Ankara Melange and some observations on the characters of melange at Göktepe-Ankara region (in Turkish). *Symposium on Central Anatolia, Geol. Soc. Turkey*, 27–31.

EROL, O. 1956. *Research on the Geology and Geomorphology of Elmadağ region, SE of Ankara.* M.T.A. Publications, series D, No. 9, Ankara 238 pp.

GÖKÇEN, N. 1977. An investigation of the biostratigraphy of the Upper Cretaceous-Paleogenic sequences in the Irmak-Hacıbalı-Mahmutlar area (Ankara-Yahşıhan). *Yerbilimleri*, **3,** 129–144.

GÖKÇEN, S. L., NORMAN, T. N. & ŞENALP, M. 1978. Mesozoic and Cenozoic sediments in the Central Anatolian Basin. *Xth Inter. Sedim. Congress, Jerusalem, Israel, Excursion guide part III: Turkey and Cyprus*, 1–19.

JOHNSON, A. 1970. *Physical Processes in Geology.* Freeman and Co. San Francisco. 326 pp.

NORMAN, T. N. 1975a. On the structure of Ankara Melange. *Int. Geodynamics Project, Report of Turkey*, 78–92.

—— 1975b. Flow features of Ankara Melange *Proc. IXth Inter. Sedim. Congress, Nice, France*, **4,** 246–248.

——, GÖKÇEN, S. L. & ŞENALP, M. 1980. Sedimentation pattern in Central Anatolia at the Cretaceous-Tertiary boundary. *Cretaceous Research*, **1,** 61–84.

SEYMEN, I., 1981. Stratigraphy and metamorphism of the Kırşehir massif around Kaman (Kırşehir-Turkey). *Bull. Geol. Soc. Turkey*, **24,** 101–108.

—— 1982. *Geology of Kırşehir Massif in the neighbourhood of Kaman* (Unpublished dissertation, in Turkish). Technical University of İstanbul, Mining Faculty, 164 pp.

ŞENGÖR, A. M. C. & YILMAZ, Y. 1981. Tethyan evolution of Turkey: a plate tectonics approach. *Tectonophysics*, **75,** 181–241.

TEKELİ, O., 1981. Subduction complex of pre-Jurassic age, Northern Anatolia, Turkey. *Geology*, **9,** 68–72.

ÜNALAN, G. 1981. Stratigraphy of the Ankara Melange, SW of Ankara. *Symposium on Central Anatolia, Geol. Soc. Turkey*, 46–52.

TEOMAN N. NORMAN, Middle East Technical University, Institute of Marine Sciences, Erdemli-İçel, Turkey.