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Stratigraphy and pre-Miocene tectonic evolution of the southwestern part of the Sivas Basin, Central Anatolia, Turkey

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In central Anatolia there are several important basins developed mainly after closure of the northern branch of Neotethys. These are the Haymana, Tuzgölü, Ulukışla, Kızılırmak, Çankırı-Çorum and Sivas basins. The Sivas Basin is located in the eastern part of central Anatolia between the Central Anatolian Crystalline Complex (CACC) in the north and Taurides in the south. The basement to the southeastern part of the basin consists of recrystallized limestone and clastics of the Permian–Lower Cretaceous Bünyan Metamorphics. These units are overlain by an Upper Cretaceous ophiolitic olistostrome that is overthrust by ophiolites and high pressure–low temperature metamorphic rocks. Lower Palaeocene cover units unconformably overlie this sequence. The basement to the northwestern part is constituted by CACC that includes a high temperature–low pressure polymetamorphic succession of Palaeozoic–Mesozoic age, overthrust by ophiolites and intruded by Upper Cretaceous post-collisional granitoids and syenitoids. The uppermost Maastrichtian–Palaeocene continental to shallow marine (lagoonal) unit unconformably overlies this unit. Upper Cretaceous–Palaeocene siltstone, shale, pelagic limestone, volcaniclastic rocks and basic volcanic rock intercalations of a within-continental-plate eruptive setting have also been developed on the basement unit. These sequences represent the products of an extensional episode during Late Cretaceous–Palaeocene times in the region between the Taurides and CACC. The Middle Eocene is represented by a regional transgression which was followed by a compressional episode evidenced by thrust faults at the margins and continued regression in the central part of the basin. This compressional period continued up to the end of the Early Miocene. Units formed during this episode are overlain by Upper Miocene–Quaternary continental units intercalated with volcanic rocks formed in fault-controlled extensional basins. It is suggested that the palaeotectonic events were the result of terminal closure of the northern branch of Neotethys. However, the neotectonic events are the result of the collision of the Arabian Plate and Anatolides which causes a westward escape of the Anatolian Plate.

KEY WORDS Sivas Basin; intracontinental basin; within-continental-plate eruptive setting; transpression; transtension

1. INTRODUCTION

The Sivas Basin is the largest and one of the most important intracontinental basins of central Anatolia and extends from the east of Sivas in the northeast Dündarlı at the southwestern tip of the basin (Figure 1). It developed on two main tectonic units, namely the Taurides to the south and the Central Anatolian Crystalline Complex (CACC) in the west and northwest (Figure 1). Detailed studies concerned with the stratigraphy and tectonics of the Sivas Basin have mainly concentrated on the northern and eastern parts of the basin (Gökçen 1981; Gökten 1983, 1986, 1993; Gökçen and Kelling 1985; Gökten and Floyd 1987; Cater *et al*. 1991; Gürsoy *et al*. 1992, 1997, 1998; Tekeli *et al*. 1991; İnan 1993; Temiz *et al*. 1993; Yılmaz 1994; Guezou *et al*. 1996; Poisson *et al*. 1996; Temiz 1996). In contrast, studies related to the southern and

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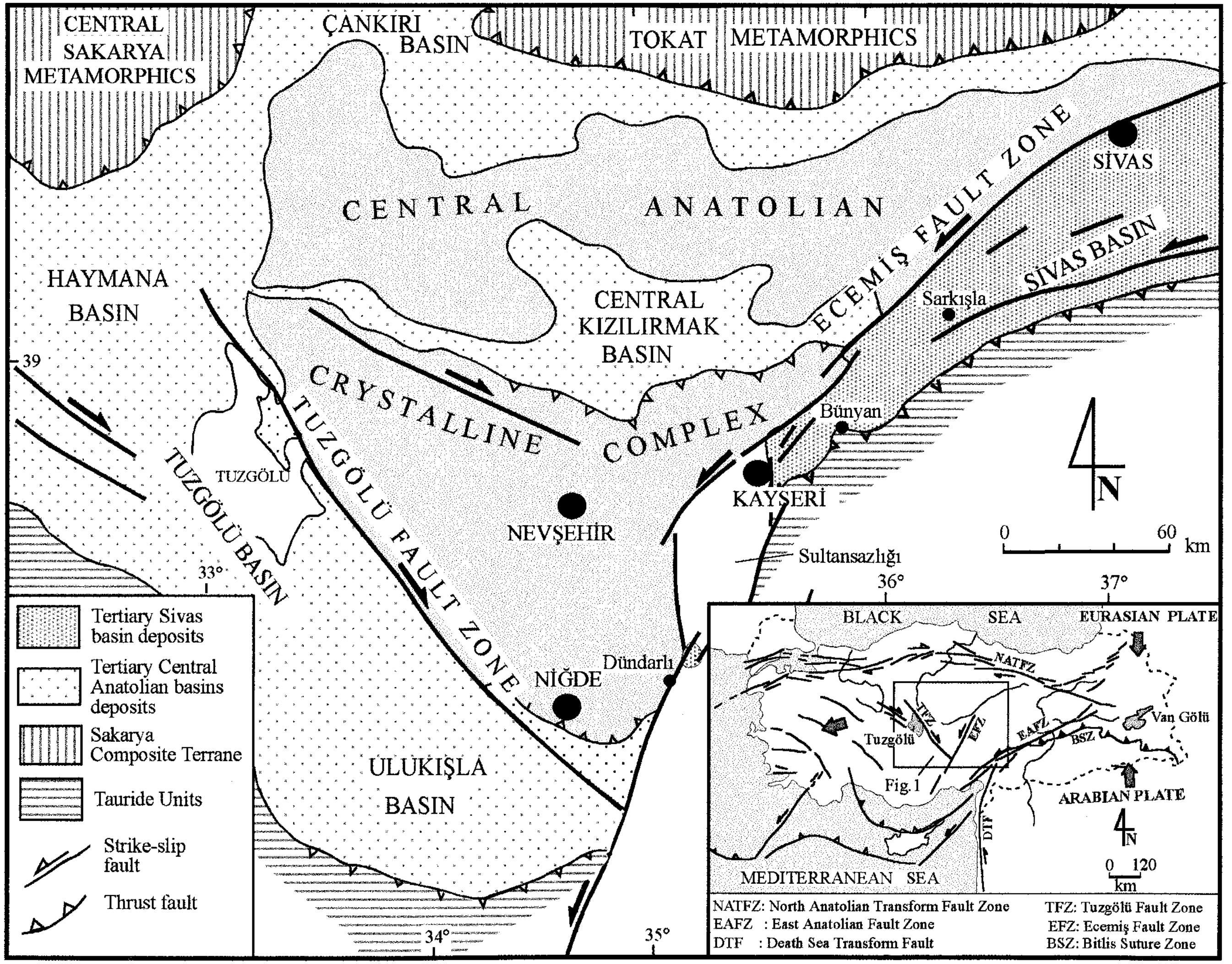

Figure 1. Index map showing major tectonic elements and basins of central Anatolia

southwestern part of the Sivas Basin are limited (Erkan *et al.* 1978; Göncüoğlu *et al.* 1994; Dirik and Göncüoğlu 1996). Two models have been proposed for the evolution of the Sivas Basin. (1) It developed on the accretionary prism of the Suture Zone, formed by closure of the Inner Tauride Ocean. This ocean is one of the northern Neotethyan branches which opened during the Jurassic causing separation of the Kışehir Block from the Tauride–Anatolide Platform, and closed during latest Cretaceous–Palaeocene time due to northward subduction of the oceanic basin (Oktay 1982; Görür *et al.* 1984; Tekeli *et al.* 1992). (2) The basin developed within the Tauride–Anatolide Platform units during Late Maastrichtian–Early Palaeocene times as the result of a tensional–transtensional regime (Göncüoğlu *et al.* 1991, 1993; Yılmaz 1994; Poisson *et al.* 1996).

The southwestern part of the basin, which has not been studied in detail before, was chosen as a key locality. This study considers latest Cretaceous–Miocene evolution of the southwestern Sivas Basin based mainly on our stratigraphic and structural field studies. The neotectonic features of this region have already been evaluated by Dirik and Göncüoğlu (1996), and Koçyiğit and Beyhan (1998). Therefore, these features are only briefly summarized in this paper.

2. STRATIGRAPHY

The basement rocks and their sedimentary cover constitute two groups of rocks exposed in the area.

2a. Basement rocks

The Sivas Basin is underlain unconformably by various rock units of dissimilar degrees of metamorphism and origin. They are collectively named the basement rocks (Figures 2 and 3).

Lithostratigraphy of basement rocks exposed in the northwestern part

The basement rocks exposed at the northwestern part of the study area have been called the Central Anatolian Crystalline Complex (CACC) by Göncüoğlu *et al.* (1991; Figure 3). The CACC consists of the Central Anatolian Metamorphics (CAM), the Central Anatolian Ophiolites (CAO) and felsic to intermediate plutonic rocks of the Central Anatolian Granitoids (CAG) (Göncüoğlu *et al.* 1991, 1994).

The CAM is represented by metamorphosed platform-type successions (Figure 3), and detailed petrologic studies suggest that they were subjected to polyphase medium- to high-grade metamorphism with temperatures locally reaching partial melting conditions (Göncüoğlu *et al.* 1991). K/Ar, biotite and muscovite cooling ages (71–75 Ma) indicate that the main metamorphic event took place prior to early Late Cretaceous time (Göncüoğlu 1986).

The CAO consist of ultramafic rocks, isotropic gabbros, plagiogranites, diabases, pillow lava basalts, and epi-ophiolitic sediments (Yalınız and Göncüoğlu 1998). According to the faunal age of the ophiolite-related sediments, the formation age of this supra-subduction zone-type ophiolite is Turonian to Santonian (Yalınız *et al.* 1996). These rocks were emplaced as thrust sheets over the Tauride–Anatolide Platform during closure of the İzmir–Ankara–Erzincan Ocean.

The CAG consists of granitoids and syenitoids generated during, and after, southward obduction of the above-mentioned ophiolitic rocks onto the Tauride-Anatolide Platform during the Late Cretaceous (Göncüoğlu 1986; Göncüoğlu *et al.* 1991, 1992; Akıman *et al.* 1993). These intrusive rocks cut across the Central Anatolian Metamorphics and Ophiolites, and are overlain by cover units.

Lithostratigraphy of the basement rocks exposed in the central part

The ophiolitic rocks constitute the basement of the central part of the Sivas Basin. They are exposed to the southeast of Tuzla Gölü (Figure 2) and consist of ultramafic rocks, gabbros and diabases. The ophiolitic suite is overlain by the Tuzla Formation with a depositional contact (Figure 3).

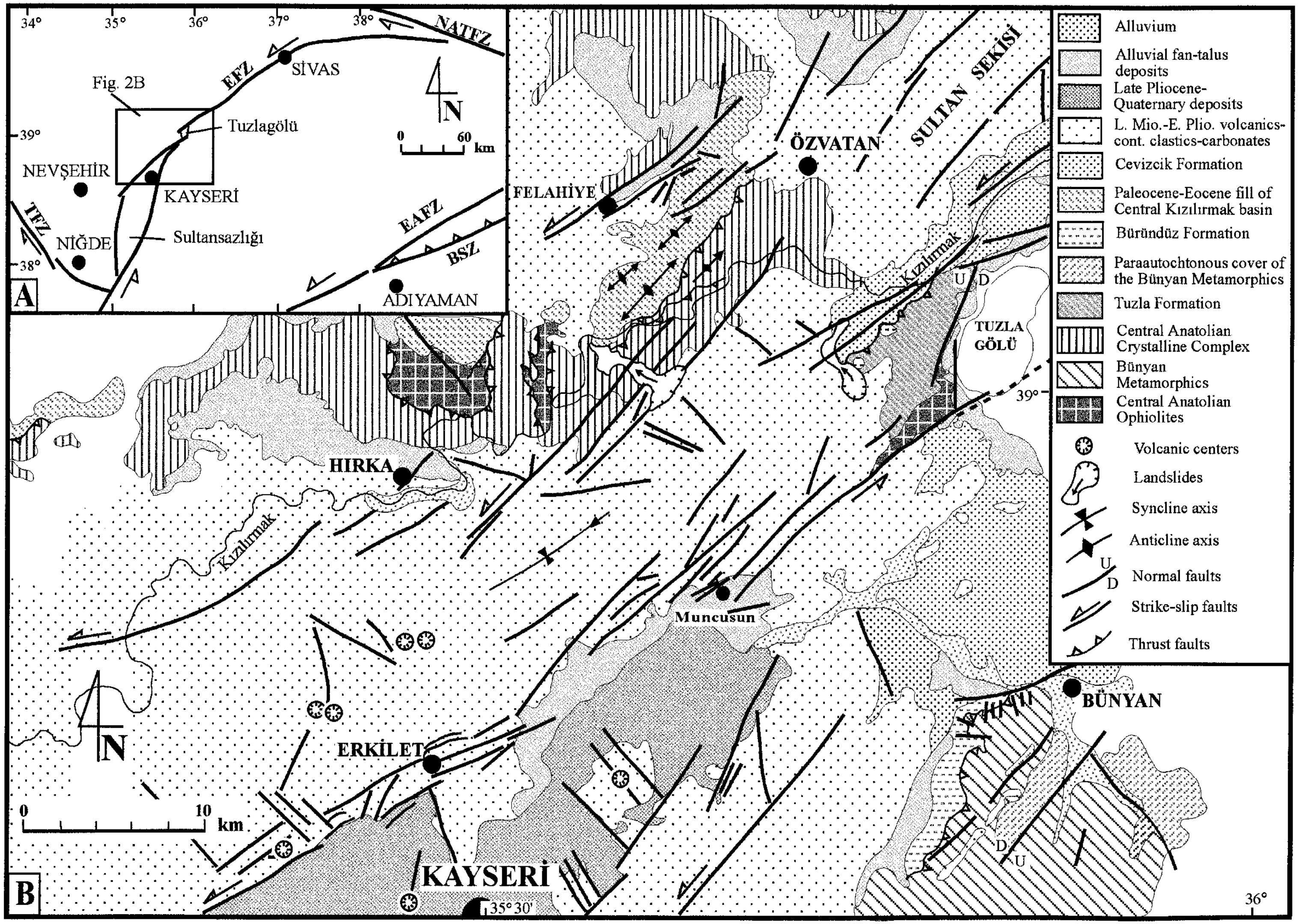

Figure 2. (A) Location map of the study area. (B) Detailed geological map showing major rock units and structural features of the southwestern part of Sivas Basin

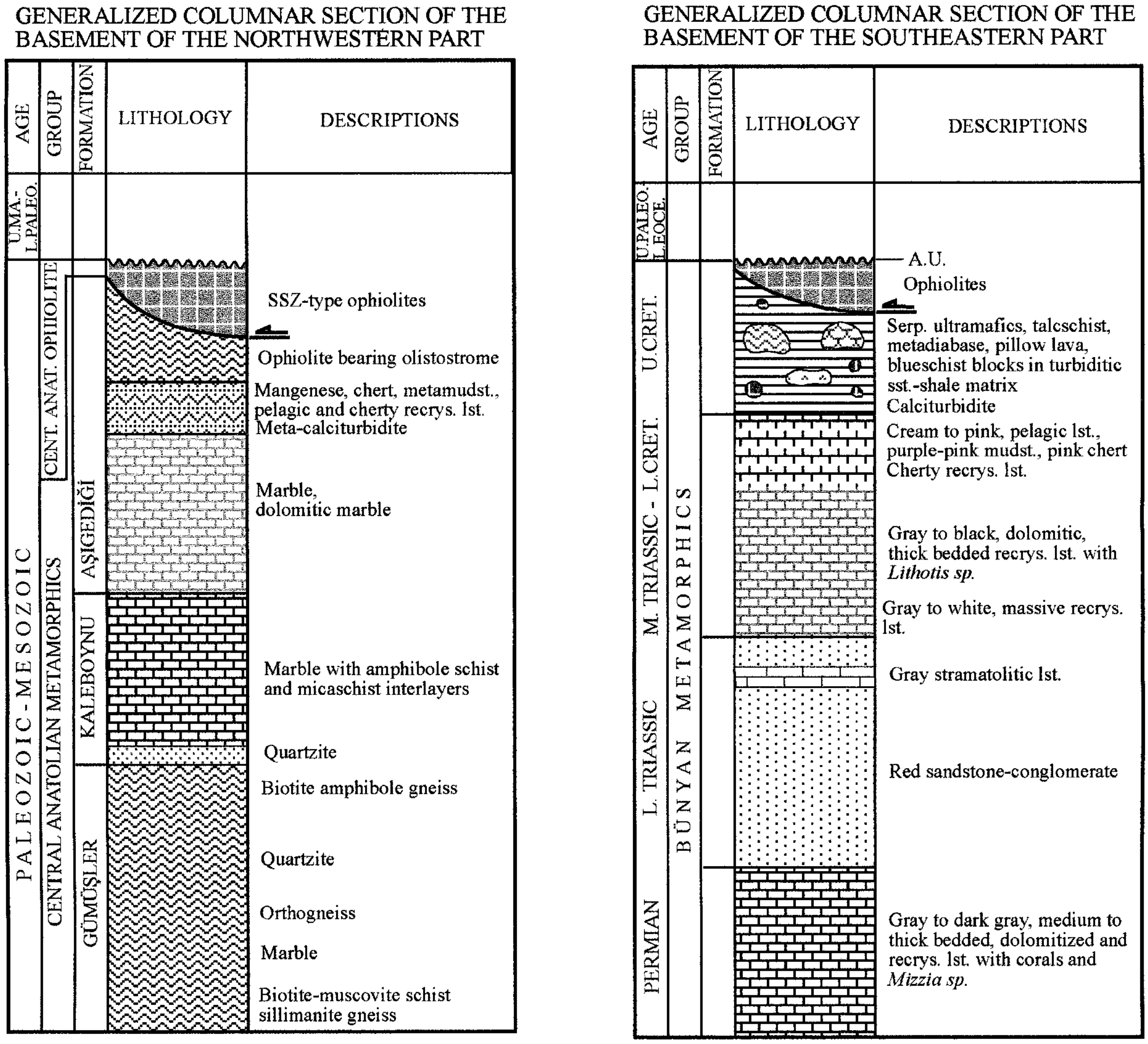

Figure 3. Generalized tectono-stratigraphic columns of the basement rocks exposed along the northwestern and southeastern parts of the study area

Lithostratigraphy of the basement rocks exposed in the south-southeastern part

The metamorphic basement rocks exposed in the southwest margin of the Sivas Basin were named the Bünyan Metamorphics by Erkan *et al.* (1978). They outcrop in the southern part of Bünyan (Figures 2 and 4). The observed sequence starts with dolomitized and recrystallized limestone with deformed corals and crinoids and continues with recrystallized neritic limestone and dolomite intercalations (Figure 3). *Pseudoschwagerina* sp., *Textrataxis* sp., *Globivalvulina* sp., *Girvenella* sp. and *Schwagerina* fragments have been observed in the lower horizons; and *Nankinella* sp. and *Mizzia* sp. are found in the upper levels of this unit. Based on this fossil content, an Early–Middle and Late Permian age is assigned to this unit. A Carboniferous age had formerly been assigned to the lowermost part of this unit by Erkan *et al.* (1978).

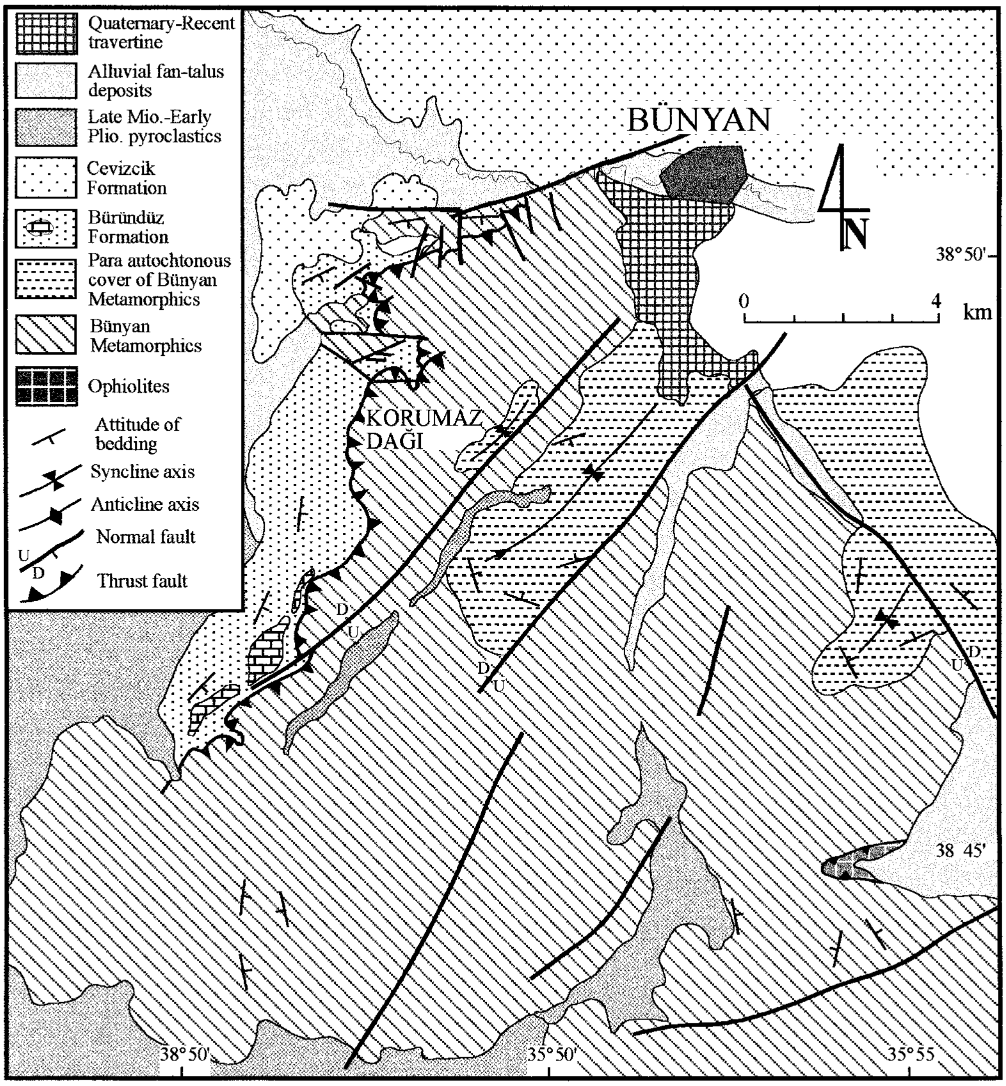

Figure 4. Detailed geological map showing major rock units and structural features of the southern part of Bünyan

The central part of the Bünyan Metamorphics consists of variously coloured clastic rocks, disconformably overlying recrystallized limestone of Permian age. The lower part begins with thin-bedded sandstone including clasts of underlying recrystallized limestone, and continues with fine-grained recrystallized limestone with abundant shell fragments, and slaty cleaved mudstone. Stromatolitic limestone bands are also observed in this unit. Based on facies characteristics, it may be correlated with Lower Triassic units of the Tauride sequence. This sequence is followed by medium–thick to very thick bedded recrystallized limestone and dolomite. To date, no characteristic fossils have been found in this unit, but a Late Triassic–Cretaceous age may be inferred by correlation with Tauride units. The uppermost part of the Bünyan Metamorphics grade into recrystallized calciturbidites and ultramafic, talc schist, serpentinite, metadiabase, pillow lava, blueschist blocks embedded in turbiditic sandstone and shaly matrix. This olistostromal facies is overthrust by southward-emplaced ophiolites (Figures 3 and 4).

2b. Cover sequence

The cover sequence of the CACC exposed in the northwestern part of the study area is the product of another important extensional basin of central Anatolia, referred to as the Kızılırmak Basin (Göncüoğlu *et al.* 1993, 1995). Since this basin is outside the scope of the present paper, only a generalized columnar section of the sequence in this basin is given in Figure 5.

Para-autochthonous cover of the Bünyan Metamorphics

This sequence is well exposed to the south of Korumaz Dağı (Figure 4). At this locality the sequence begins with a 50 m thick conglomerate which is poorly sorted and graded, unbedded and carbonate cemented. The pebbles consist of recrystallized limestone of Bünyan Metamorphics, red pelagic limestone, mudstone and radiolarite. The succession continues with medium bedded sandstone–conglomerate–muddy limestone alterations. Olistostromal horizons with blocks of radiolarite, serpentinite, recrystallized limestone and blueschist are common in this part of the sequence. *Nummulites* sp. was determined in the sandstone–muddy sandstone and limestone horizons of this unit, and therefore a (?) Middle Eocene age has been assigned. The lithologic characteristics suggest the presence of an active marginal environment during deposition.

Cover sequence of the Sivas Basin

This sequence is represented by the Tuzla, Büründüz and Cevizcik formations and Upper Miocene–Quaternary units (Figure 5).

The Tuzla Formation. This is the oldest unit of the cover sequence in the Sivas Basin and was first named by Tekeli *et al.* (1992). It is exposed in the west, to the north of the Tuzla Gölü and north of Dündarlı (Figures 1 and 2), and consists of highly sheared pelagic limestone, shale, and sandstone alternations and volcaniclastic rocks associated with andesitic pillow lavas (Figure 5). The earliest marginal shallow marine facies of the basin, typically representing its extensional character, is observed to the north of Dündarlı (Figure 1). In this section the sequence starts with coarse clastics of alluvial fan deposits and laterally grades to proximal turbidites and volcaniclastics with andesitic to trachyandesitic lava interlayers (Figure 6A). The coarse clastics of the marginal facies grade upwards to uppermost Maastrichtian marl, argillaceous limestone and sandy limestone, followed by reefal limestone (Göncüoğlu *et al.* 1991). Sirel (1996, figure 3; Sirel 1998, figure 15) has shown by detailed biostratigraphic analysis that the Cretaceous–Tertiary boundary is between a sandy limestone and a conformably overlying reefal limestone of Danian age. These reefal limestones pinch out towards the central part of the basin. These data clearly indicate very rapid deepening of the basin margin which is controlled by normal faulting. In the Tuzla Gölü area this unit includes limestone, gabbro, ultramafic and metabasalt olistoliths and megablocks. The matrix of the Tuzla Formation is represented by an alternation of pelagic limestone (calciturbidite)–turbiditic sandstone–shale–siltstone and locally volcaniclastics. It overlies the ophiolites with depositional contact to the west of Tuzla Gölü. The pelagic limestone is laminated and of calcareous mudstone composition. The fossil content (*Globotruncana* sp., *Globotruncana stuarti Lap.*, *Globotruncana* cf. *contusa*, *Siderolites calcitrapoides*, *Orbitoides cf.* media, *Orbitoides* sp., *Lepidorbitoides* sp., *Iranites* sp., *Racemigumbelina* sp., *Heterohelix* spp., *Hedbergella* spp., Rotalidae) suggests that the age of this pelagic limestone is latest Cretaceous–(?)Palaeocene. The same age has been obtained by Gökten (1983; Kaleköy Formation) in the Şarkısla area. Hornblende and plagioclase are the dominant minerals in the volcaniclastic rocks, which are probably crystal tuffs intercalated with epiclastic rocks. The volcaniclastic rocks are mostly associated with andesitic pillow lavas (Gökten and Floyd 1987). Geochemical data support a within-plate eruptive setting developed on continental crust. The Tuzla Formation also includes blocks of massive volcanic rocks, gabbro, serpentines and recrystallized limestone of Triassic age. Volcanic rocks are represented by basalt and diabase. Ophiolite blocks of varying size are represented by serpentinite, pyroxenite, gabbro and diabase, embedded in a slaty matrix (Figure 6C).

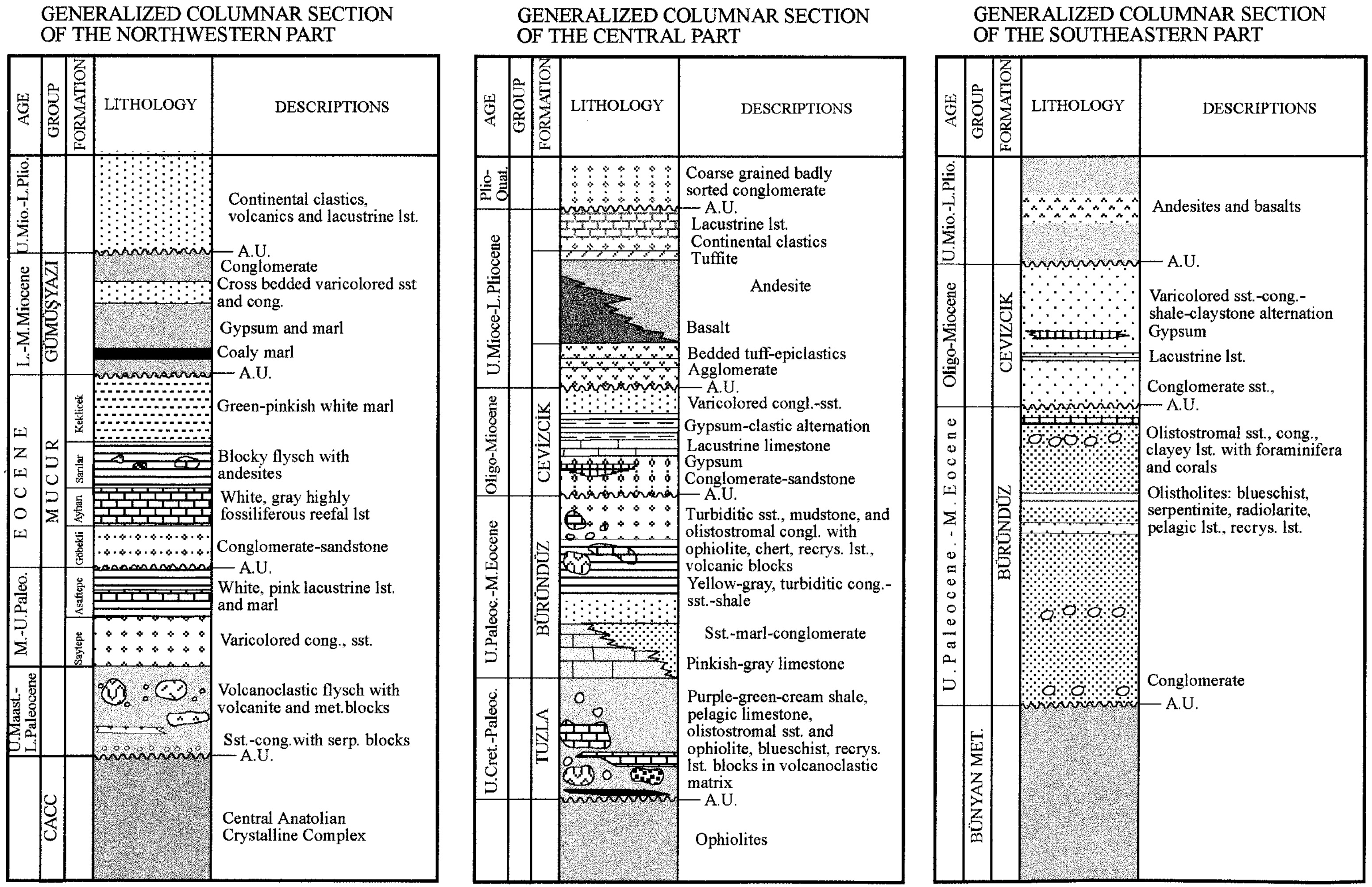

Figure 5. Generalized stratigraphic columns of the cover units. CACC = Central Anatolian Crystalline Complex; AU = angular unconformity

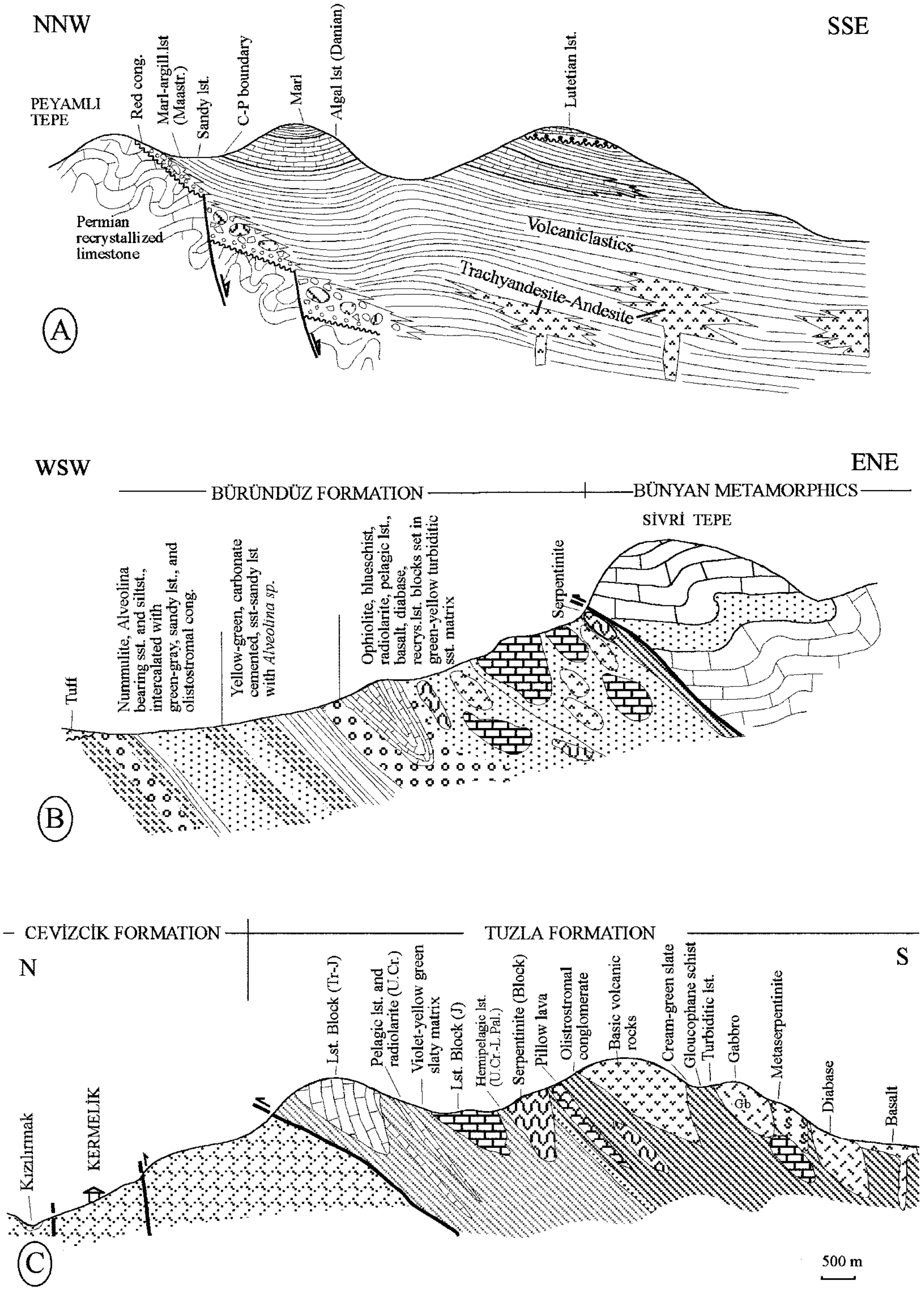

Figure 6. (A) Sketch cross-section illustrating the relationship between basement and lowermost sequence of the Sivas Basin fill (North of Dündarlı. (B) The structural relationships between Bünyan Metamorphics and Sivas Basin units (southwest of Korumaz Dağı). (C) The lithologic characteristics and structural relationships of the Tuzla Formation (west of Tuzla Gölü)

The Büründüz Formation. This unit was first named by Göncüoğlu *et al.* (1995) and is well exposed to the west-southwest of Bünyan. It consists mostly of sandstone–marl–conglomerate–calciturbidite–limestone intercalations and local reefal to pelagic limestones. It grades upwards into olistostromal deposits.

The lower part of the formation has been observed to the west of Tuzla Gölü. At this locality fossiliferous limestone, with black-coloured matrix and abundant opaque clasts, overlies the Tuzla Formation with a slightly deformed depositional contact. This limestone grades into pelagic limestone indicating deeper marine conditions in the central part of the basin. The fossil content (*Discocyclina* spp., *Nummulites* spp., *Assilina* sp., *Miscellanea* sp., *Ronikothalia* sp., red algae fragments in the dark grey–black-coloured limestone horizons; *Globigerina* sp., *Globigerinatheka* sp., *Morozovella* spp., *Acarinina* sp. in the pelagic limestones) suggests that the age of these levels is Late Maastrichtian (?)–Early Eocene.

Although the base of the Büründüz Formation is not exposed in the west and north of Korumaz Dağı, the lower part of the unit is represented by sandstone–marl–conglomerate and calciturbidite alternation at this locality (Figure 6B). The marly horizons include large brachiopods, pelecypods and gastropods, and grade upward into sandy marl–sandstone–calciturbidite alternations with abundant *Nummulites* and *Assilina*. The sandstones are medium bedded, grains are angular to sub-rounded, poorly sorted and of fine to medium grade. Granitic and ophiolitic clasts are common in both sandstone and calciturbiditic horizons. The latter are grain-supported with clast size ranging from sand to gravel. At the top this unit grades into a sequence of olistostromal conglomerates: various Permian, Mesozoic limestones, ophiolitic mélange, pelagic limestone and Lower Eocene limestone blocks embedded in sandstone and mudstone matrix (Figures 6B and 7C).

The following fossil content is observed in the lower part of this formation exposed west-southwest of Bünyan: *Alveolina* sp., *Alveolina* spp., *Flosculina* spp., *Discocyclina* spp., *Gypsina* sp., *Orbitolites* sp., *Nummulites* sp., *Nummulites* spp., *Opertorbitolites* sp., *Asterigerina* sp., *Assilina* sp., *Miscellanea* sp., *Ronikothalia* sp., red algae fragments, *Disticloplax biserialis*. Based on this fossil content, a Late Palaeocene–Early Eocene age is assigned to the lower horizons of the unit. The following fossils were determined in the middle–upper levels of this unit: *Nummulites* spp., *Assilina* sp., *Lockhortia* sp., *Orbitolites*, *Discocyclina*, *Linderina*, *Amohistegina* sp. and *Asterigerina* sp. From this fossil content, a Middle Eocene age is proposed for these beds. Hence we conclude that this unit was deposited between Late Palaeocene and Middle Eocene times.

The Cevizcik Formation. This unit was first named by Gökten (1983) and is generally represented by red to greenish grey fine-grained sandstone, siltstone and claystone alternations, intercalated with both massive and bedded gypsum.

The Cevizcik Formation unconformably overlies all of the above-mentioned units. It begins with a sub-rounded, poorly sorted conglomerate with grain size ranging from pebble to block at the base grading upwards into finer sizes. The clasts are composed of marble, recrystallized limestone, sandstone and gabbro. Vertical gradation to sandstone and medium-bedded cherty limestone and lateral gradation to red sandstone–conglomerate–shale and clay alternation with gypsum lenses is observed. This sequence continues upwards with gypsum lenses intercalated with sandstone–conglomerate–mudstone alternations. To date, no fossils have been found in the Cevizcik Formation. The age of this was considered to be Oligo-Miocene by Kurtman (1973) and Oligocene by Gökten (1983). Sümengen *et al.* (1990) dated the top of the gypsiferous beds as Oligocene using a vertebrate fauna. Cater *et al.* (1991) attributed this unit to a Late Miocene age. Since the Upper Palaeogene continental sediments become younger from east to west, we suggest a Late Oligocene–Early Miocene age. The Cevizcik Formation can be correlated with the Selimiye Formation of Kurtman (1973) and the Hafik Formation of Poisson *et al.* (1996).

Units of Late Miocene–Quaternary Age. These have a widespread distribution in the study area and unconformably overlie all other older units and structures. The rock units of these basins were described by Dirik and Göncüoğlu (1996), Dirik (1998) and Koçyiğit and Erol (1998). In summary, they are characterized by a thick succession of pyroclastic rocks intercalated with calc-alkaline–alkaline volcanic rocks. The volcanic sequence is unconformably overlain by Pliocene lacustrine–fluviatile deposits intercalated with ignimbrites and tuffs. Thick, coarse-grained alluvial/colluvial fan deposits of marginal facies and fine-grained clastics and carbonates of central facies display very characteristic syn-sedimentary structures with volcanic intercalations. This is the main evidence for the development of new transtensional basins associated with the sinistral Ecemiş Fault Zone in Pliocene time (Dirik 1998).

3. STRUCTURAL GEOLOGY

The present area displays two important structures: thrust faults and strike-slip faults (Figures 2 and 4).

3a. *Thrust faults*

There are three important sets of northeast–southwest trending thrust faults in the area (Figure 2). The first is located in the northeast, which brings units of the CACC over the Eocene sedimentary rocks of the Central Kızılırmak Basin. This thrust determines the southern margin of the Central Kızılırmak Basin on the CACC. The second is located within the Sivas Basin, to the west of Tuzla Gölü. Along this thrust the Tuzla Formation has been thrust over the Oligo-Miocene Cevizcik Formation (Figure 6C). The third lies west-southwest of Bünyan and emplaces the Bünyan Metamorphics onto the Büründüz Formation of the Sivas Basin (Figures 4 and 7A–C). These thrust faults are important evidence for Late Eocene compressional tectonics in the region, and the accompanying closure of the Central Kızılırmak and Sivas basins. Traces of the thrust faults have been concealed by Upper Miocene–Pliocene deposits. The Late Eocene compressional tectonics generated a set of NE–SW trending anticlines and synclines. The first set of these folds is observed southeast of Felahiye (Figure 2), where they are overturned and N-verging near the southern thrust-faulted margin of the Central Kızılırmak Basin, and they become tight and doubly plunging away from this margin. Similar types of folds are also observed along the southern thrust-faulted margin of the Sivas Basin southwest of Bünyan (Figure 7C). The third set of folds occurs within the para-autochthonous cover of the Bünyan Metamorphics. These are asymmetric, northeast plunging folds with approximately NE–SW trending fold axes (Figure 4). Very gentle folds with axes trending in a NE–SW direction occur in the Upper Miocene–Lower Pliocene volcanics–continental clastics–carbonates. These folds are evidence of a pre-Late Pliocene compressional palaeotectonic regime. In contrast, the Plio-Quaternary neotectonic regime is dominated by strike-slip faulting.

3b. *Strike-slip faults*

The southwestern part of the Sivas Basin and adjacent area are dominated by well developed sinistral strike-slip faults representing the central part of the Ecemiş Fault Zone (EFZ in Figure 2), recently named the Central Anatolian Fault Zone by Koçyiğit and Beyhan (1998). This zone is one of the major structures of Turkey and runs from Sivas in the northeast to Mersin in the southwest. Around the central part, it is characterized by transtensional depressions, namely the Sultansazlığı and Tuzla Gölü pull-apart basins (Figure 2A), formed by left-stepping and southward bending of the fault zone (Dirik and Göncüoğlu 1996; Dirik 1998). Along the NE–SW trending faults which constitute the EFZ, the uppermost Miocene–Pliocene deposits and Quaternary deposits are juxtaposed. The presence of active landslides, fault scarps, step-faulted lava flows, very thick and tilted alluvial fans are quite distinctive morphotectonic features along these faults.

4. TECTONIC EVOLUTION

Major events of the tectonic evolution of the southwestern part of the Sivas Basin can be summarized as follows.

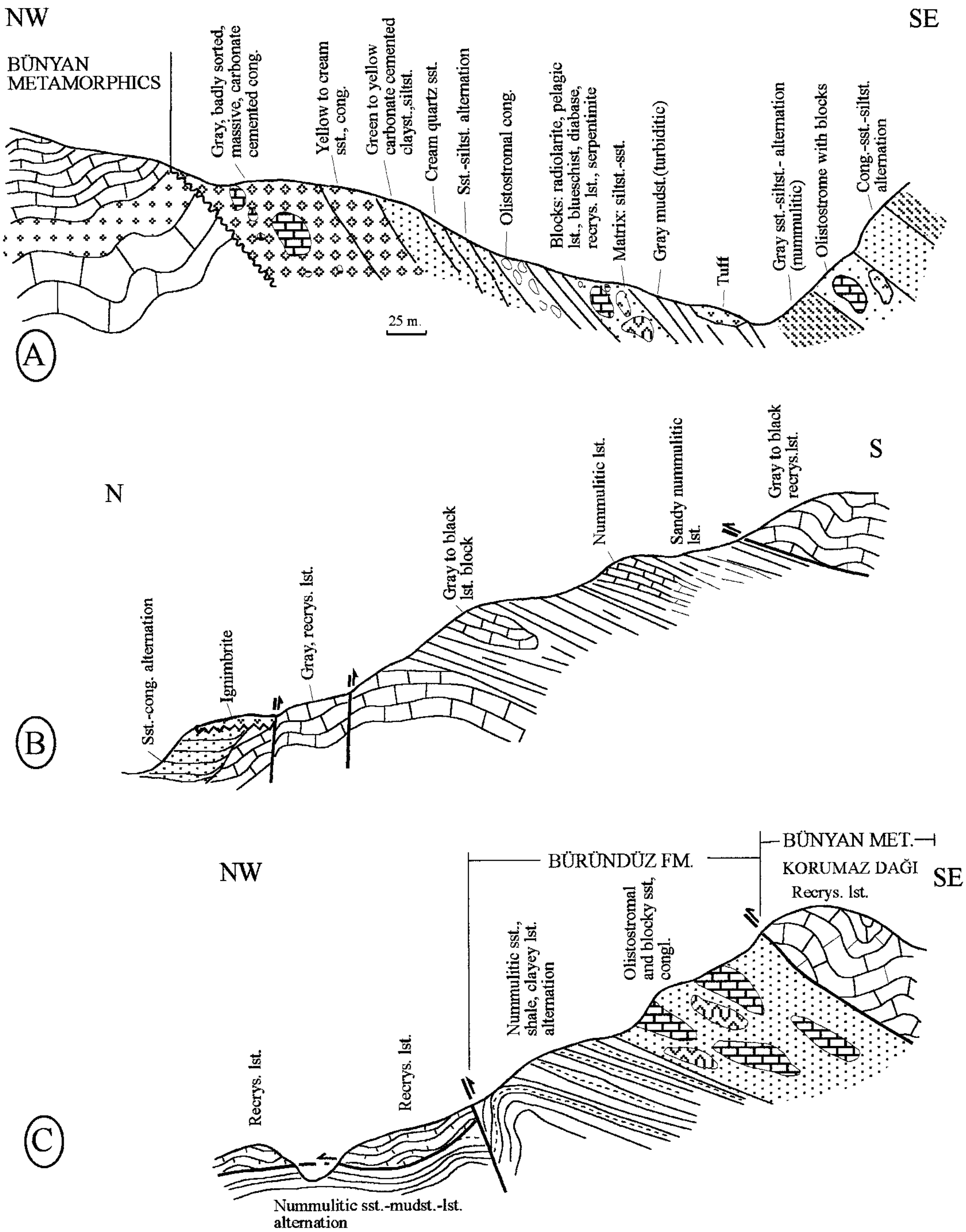

Figure 7. (A) The lithologic characteristics of the para-autochthonous cover of the Bünyan Metamorphics (southeast of Korumaz Dağı). (B) The structural relationships between Büründüz Formation and other units (north of Korumaz Dağı). (C) The lithologic characteristics and structural relationships of the Büründüz Formation (northwest of Korumaz Dağı)

4a. Jurassic–Early to Late Cretaceous

During the Jurassic to Early Cretaceous, the Sakarya Continent and Tauride–Anatolide Platform formed the passive margins of the İzmir–Ankara–Erzincan Ocean (northern branch of Neotethys, Figure 8A). Closure of this ocean and northward subduction of the oceanic crust was initiated in early Late Cretaceous, and continued convergence resulted in obduction of ophiolites and marginal nappes over the Tauride–Anatolide Platform (Görür *et al.* 1984). This obduction thickened the crust and produced the high temperature–low pressure metamorphism of the Central Anatolian Metamorphics in the north (Göncüoğlu 1986) and the Bünyan Metamorphics to the south (Figure 8B; Göncüoğlu *et al.* 1994).

4. Latest Cretaceous–Early Palaeocene

Thermal relaxation during the latest Cretaceous resulted in the formation of the extensional Central Kızılırmak and Sivas basins (Göncüoğlu *et al.* 1993). The Sivas Basin is underlain by the CACC in the north and the Bünyan Metamorphics in the south. The former represents a more deeply buried and more highly metamorphosed part of the Tauride–Anatolide Platform. The Upper Cretaceous–Palaeocene Tuzla Formation consists of siltstone, shale, pelagic limestone (calciturbidite), volcaniclastics and basic volcanic rock intercalations developed on basement units. It includes fragments of ophiolite, recrystallized limestones of the CAM, Bünyan Metamorphics, pelagic limestone and blueschist with sizes ranging from pebble to megablock. This formation represents the marginal to central part of the basin with fault-controlled margins. The lateral extent of this facies is represented by volcaniclastics, turbiditic limestone and pelagic–hemipelagic shales around the Şarkısla area located to the northeast. Interpretation of the geochemistry of these volcanic rocks supports a within-continental-plate eruptive setting (Gökten and Floyd 1987). According to Gökten (1986), a thick Palaeocene carbonate sequence with volcanic–volcaniclastic intercalations occurring in the Şarkısla area has been derived mainly from carbonate turbidites associated with volcanism; vertical–lateral relationships suggest deposition in a submarine fan. Subsidence of this basin may have been controlled by gravity faults located along the margin. The data support the existence of an extensional period during the Late Cretaceous–Palaeocene between the Taurides and CACC (Figure 8C). The presence of a basement of continental crust at the base of the basin fill, the allochthonous nature of the ophiolitic nappes, and the within-continental-plate eruptive setting suggest that the Sivas Basin never became an oceanic basin as proposed by Görür *et al.* (1984, 1998).

4c. Late Palaeocene–Early Eocene

Subsidence of the basin continued and therefore this period is represented by a regional deposition transgression. This is evidenced by the continued deepening and deposition of the lower sequences of the Büründüz Formation (Figure 8D).

4d. Middle Eocene

In the study area, both at the northern and southern margins, Middle Eocene is represented by a renewed transgression characterized by the deposition of coarse clastics (column 1 in Figure 5, and Figure 8E). In the central part of the basin, however, the continuous limestone–sandstone deposits of Late Palaeocene–Early Eocene age abruptly change a new succession represented by turbidites with olistoliths (Figure 5, columns 2 and 3) of Middle Eocene. The development of the asymmetrical basin during this period is ascribed to the formation of a half-graben associated with transtensional movements. This speculation is supported by the initiation of the sinistral strike-slip 'Ecemiş Fault Zone' during pre-Lutetian (Yetiş 1978), that probably propagated northeastward during the Middle Eocene.

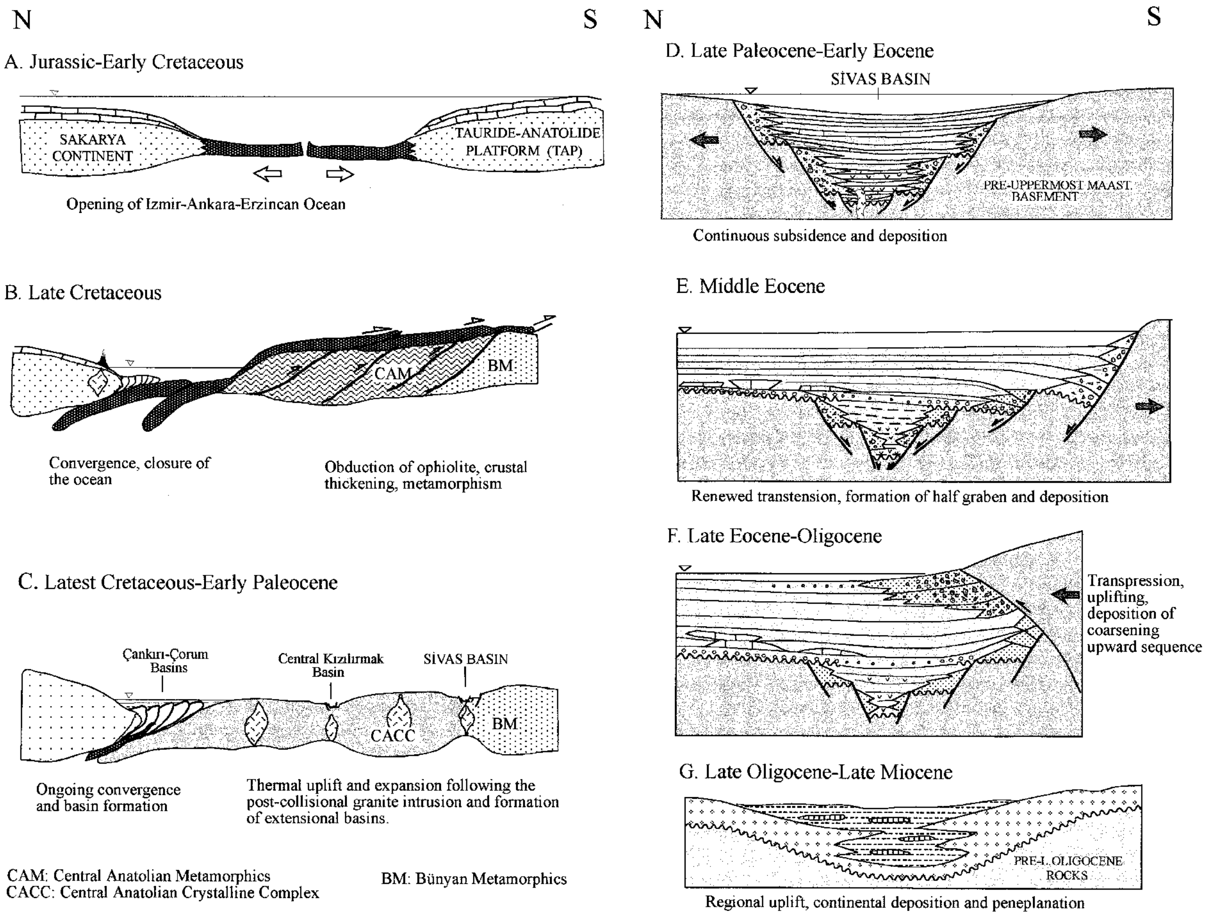

Figure 8. Schematic diagrams showing evolution of the southwestern part of the Sivas Basin

4e. Late Eocene to Oligocene

At the southern margin of the basin, upper levels of the Büründüz Formation grade from turbiditic sandstone–shale–sandy limestone alternation to conglomerate, olistostromal conglomerate deposits interpreted as slope-fan deposits developed in front of uplifting and northward-moving basement rocks. Evidence for a compressional period is the presence of thrust faults at the basin margins and a continued regressive sequence in the central part of the basin. The basin must have been isolated from the sea and emergent during the Oligocene. Evidence for this is the presence of red-coloured continental clastics intercalated with bedded to massive gypsum of the Oligocene Cevizcik Formation overlying the Büründüz Formation. The final collision of the basement of Pontide units with the CACC was probably responsible for this Late Eocene–Oligocene compressional period which continued up to the end of the Early Miocene (Figure 8F).

4f. Late Oligocene–Late Miocene

Prior to this period the basement units were already emplaced on the basin fill along thrust faults. The entire area was emergent and became a site of erosion, but the deposition of lacustrine–fluviatile deposits was also common (Figure 8G). However, local overthrusts on the Miocene deposits in the area (Figure 6C), and folding and overthrusting of the Middle Miocene (Akgün *et al.* 1994) continental clastics in the Central

Kızılırmak basin by basement units further to the north, suggest that the regional compression continued during this period.

4g. Early Pliocene–Quaternary

Reactivation of the sinistral Ecemiş Fault Zone triggered the development of NE–SW trending transtensional basins on the vast plateau formed during Late Miocene (Dirik and Göncüoğlu 1996; Koçyiğit and Beyhan 1998; Dirik 1998).

5. CONCLUSIONS

Sedimentological, stratigraphic and structural evidence summarized in this paper suggests that the Sivas Basin started to form as the product of Late Maastrichtian extensional tectonism in Central Anatolia. This extension might have originated by continental rifting due to post-collisional extension following crustal thickening which resulted in southward emplacement of oceanic and marginal nappes onto the passive margin of the Tauride–Anatolide Platform. The stratigraphic successions of the Bünyan Metamorphics and the CAM are almost identical up to the end of the Mesozoic so there is no evidence for an oceanic basin that separated them during the Mesozoic era. Moreover, ophiolitic rocks are not restricted to the basement of the Sivas Basin but cover vast areas on the CACC, which suggests an origin for these nappes further to the north. The presence of continental crust-type basement rocks at the base of the basin beneath the ophiolites and the fact that the Uppermost Cretaceous–Lower Palaeogene volcanic rocks display a within-continental-type eruptive setting strongly suggest that the Sivas Basin opened on the Tauride–Anatolide Platform as an intracontinental extensional basin and was not a pre-existing suture zone as proposed by various authors (Tekeli *et al.* 1992; Gökten 1993; Görür *et al.* 1998).

This period of extension prevailed until Early Eocene times. The Middle Eocene is characterized by a new extensional period, which is mainly reflected by the presence of gravity flow deposits on the southern margin of the basin and a regional transgression to the north. This asymmetrical development is ascribed to the formation of a half-graben system in relation to strike-slip movements, probably associated with the initiation of the Ecemiş Fault. On the other hand, the north-vergent thrust faulting at the southern margin suggests a compressional regime during Late Eocene–Oligocene, which may have continued up to the end of the Late Miocene.

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