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Revisiting the Çüngüş Formation, a controversial tectono-stratigraphic unit in front of the Southeast Anatolian Suture Belt

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Abstract: The turbiditic succession containing exotic blocks of various sizes deposited in the Çüngüş Basin, has been previously identified as the Çüngüş Formation in front of the Southeast Anatolian Suture Belt, Türkiye. These turbiditic sediments, dated as Eocene-Early Miocene, were interpreted as the lowermost allochthonous tectono-stratigraphic unit thrust over the Lice Formation during the Miocene within the Çüngüş-Hakkari nappes. In this study, the stratigraphical, sedimentological, palaeontological, and structural features of the Çüngüş and Lice formations are examined and reinterpreted within a basin model. Both formations consist of sandstones, siltstones, mudstones, and subordinate conglomerates, indicating ramp-fringe palaeochannel, submarine fan, and basin-floor turbidite facies associations. In the northern part of the basin, just in front of the suture belt, volcanic, metamorphic, and ophiolitic rocks and nummulitic limestones are included as blocks and tectonic slices within the turbidite succession. Based on nannoplankton analysis, both Çüngüş and Lice formations are assigned an Early Miocene age.
The sedimentary facies associations filling the Çüngüş Basin are transitional from proximal to distal facies. The thrust in the previous maps separating the Çüngüş and Lice formations cannot be confirmed in the field. Based on our field observations and age data, we interpret that the Lice and the Çüngüş formations deposited continuously within the Çüngüş Basin that was opened as a foreland basin by flexural subsidence of the Arabian Autochthon under the crustal load of the Pütürge-Bitlis Massifs and the Maden Complex during the Early Miocene. The turbidite deposits containing exotic blocks in the north of the basin are interpreted as wedge-top deposits of the foreland basin, while those in the south are considered foredeep deposits.

Key words: Foreland basin, wedge-top depozone, foredeep depozone, ramp-fringe palaeochannels, submarine fan deposits, Çüngüş Basin

1. Introduction

Early Miocene blocky clastic rocks, outcropping on the Arabian autochthon along a narrow belt to the south of the Southeastern Anatolian Suture (Figures 1a and 1b), have been previously designated by various names in different studies, such as Çüngüş Formation (Sungurlu, 1974a), Tertiary Formations of the Baykan Complex (Sungurlu, 1974b), Engene Formation of the Baykan Group (Özkaya, 1978), Pütürge Thrust Belt (Yazgan, 1981, 1983), Eastern Taurus Thrust Front Belt (Yazgan and Chessex, 1991). The Çüngüş Formation is referred to be tectonically overlain by the Pütürge-Bitlis Massifs and the Maden Complex and thrust over the turbidite deposits of the Lice Formation (Sungurlu, 1974b; Özkaya, 1978; Perinçek, 1978, 1979; Yazgan, 1981; Yazgan and Chessex, 1991) (Figure 1b). The Çüngüş Formation, which has been described as a nappe, thrust sheet, slice or allochthonous unit, was accepted as Eocene-Early Miocene (Sungurlu, 1974b; Perinçek, 1978, 1979; Sungurlu et al., 1985); or late Eocene-Oligocene (Yazgan, 1981) in age. Özkaya (1978) and Perinçek (1979) assumed that this formation is the equivalent of the Lice Formation, which was deposited under deeper depositional setting in the north of the basin. Inconsistencies in the previous studies on the age, depositional environment and origin of these rocks have led to a poor understanding of the Eocene-Miocene palaeogeographic and tectonostratigraphic evolution of the basin.

Suture belts and the basins in front of these belts are the areas where compressional tectonic deformations such as thrusts, reverse faults, tear faults and folds most intensely observed (Mattauer, 1986; Coward et al., 1986; Dewey et al., 1986). In front of the Southeastern Anatolian Suture Belt, there is a 5–15-km-wide deformation zone on the Arabian autochthon containing various deformational structures, intensity of which increase towards the suture (Figure 2).

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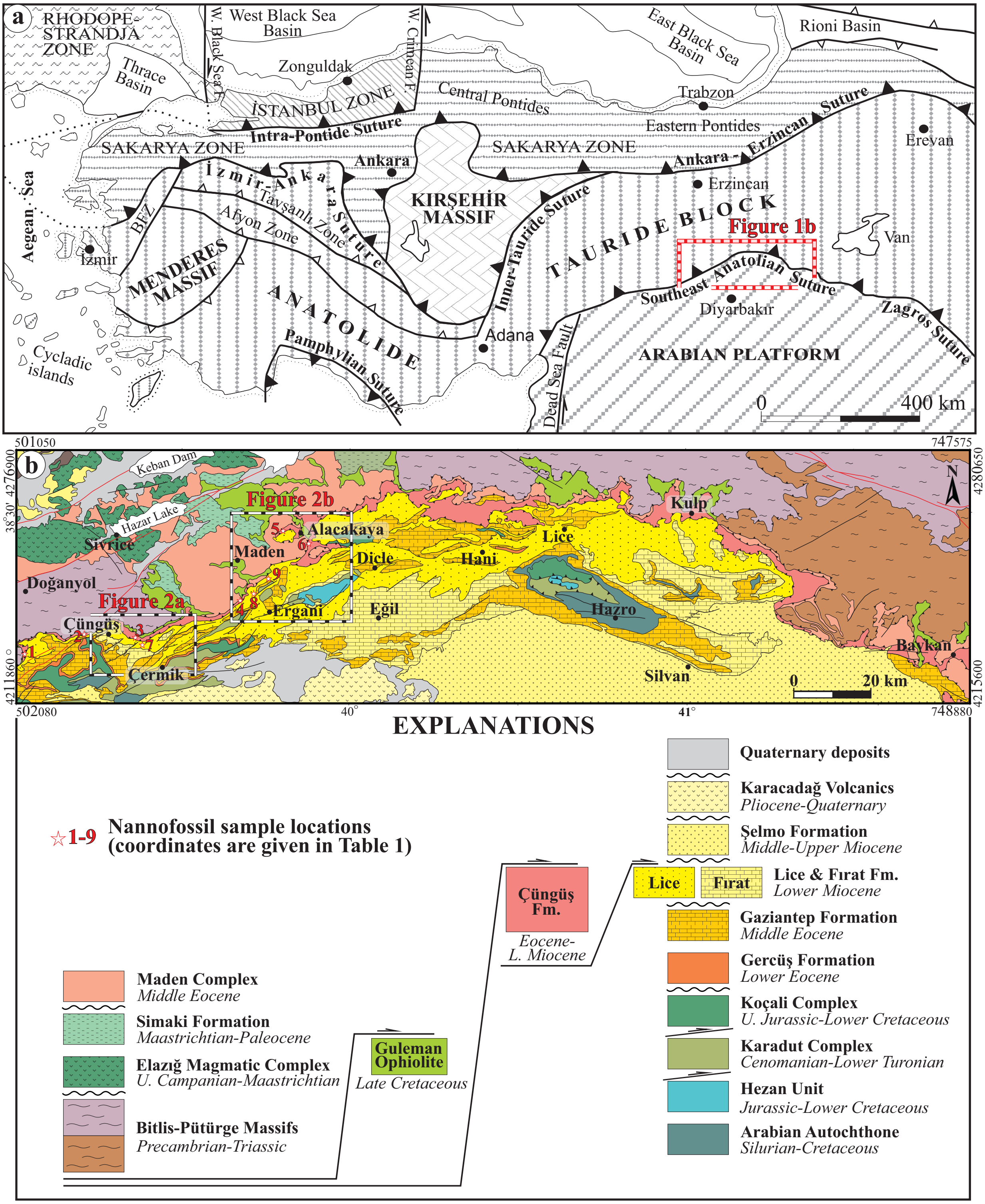

Figure 1. (a) Palaeotectonic map of Anatolia (from Okay and Tüysüz, 1999) showing sutures, tectonic units and the location of the study area. Sutures are indicated by thick lines, and the polarity of former subduction zones is indicated by filled triangles. (b) Geological map of the study area in the Bitlis-Zagros Suture Zone (modified from Tarhan, 2002; Keskin, 2011). The points from 1 to 9 in map B show the sampling sites for biostratigraphic dating of the basin sediments.

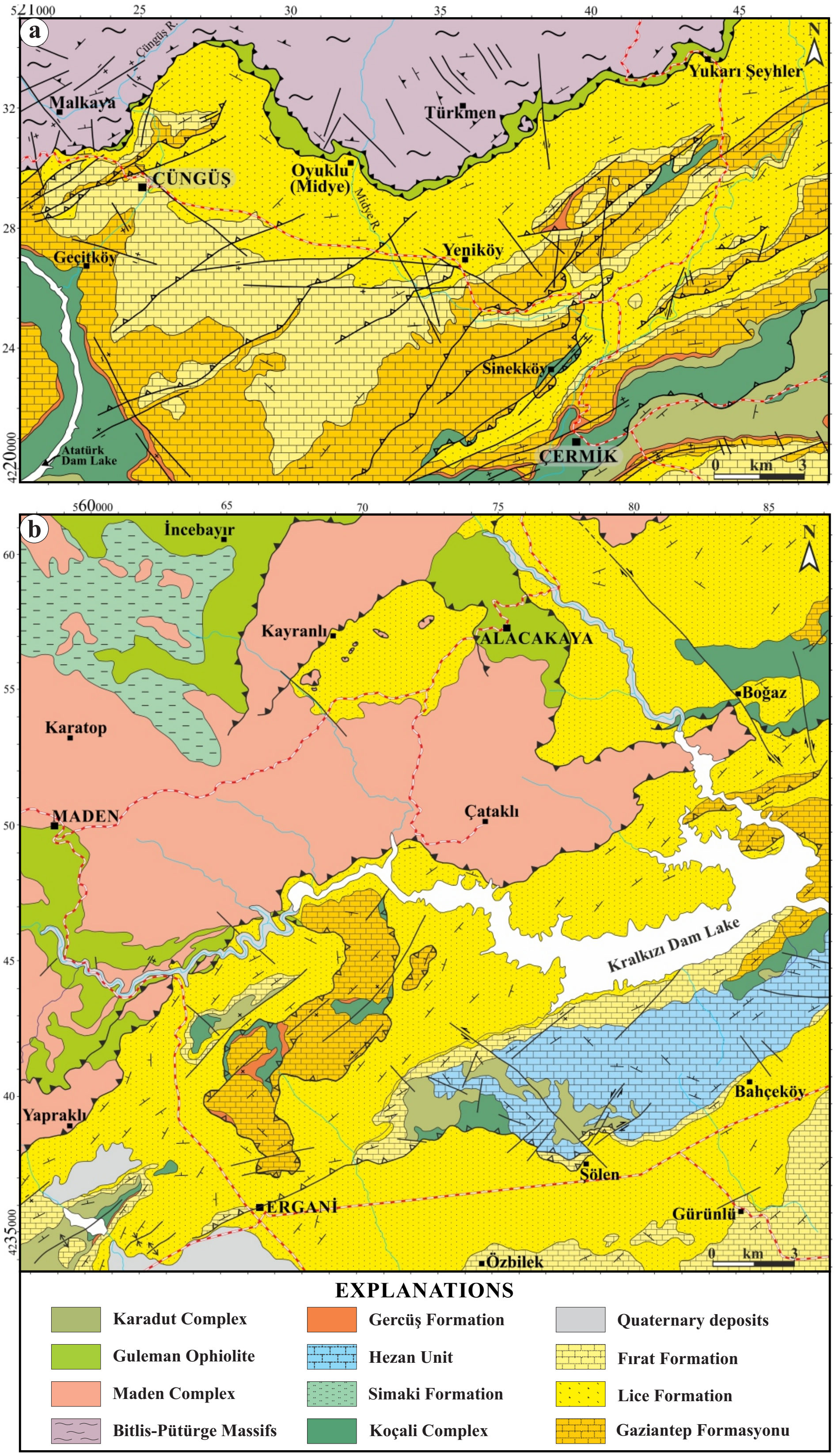

Figure 2. Detailed geological maps of (a) Çüngüş-Çermik and (b) Maden-Ergani regions revised in this study.

Accurate identification and use of structural elements such as thrust faults, reverse faults, and nappes are as important as stratigraphic features in correctly interpreting the regional tectono-stratigraphic evolution of a basin. Displacement of a rock unit due to compression along a low-angle fault plane is defined as "thrust" (Norris, 1958; Dennis et al., 1981). A large, allocthonous, sheet-like tectonic unit that moves along a subhorizontal floor in excess of 5 km is called a nappe (Dennis et al., 1981).

In this study, stratigraphical, sedimentological, palaeontological and structural characteristics of the Çüngüş Formation were investigated in detail, and compared with those of the Lice Formation deposited in the same basin, and the existence of the so-called Çüngüş Formation was questioned. In addition, the depositional environments of both formations were interpreted within a basin model.

Conventional field study methods, including geological mapping, sedimentological logging, kinematic data collection, and paleontological and petrographic sampling, were used. In the descriptive sedimentological terminology Harms et al. (1975, 1982) and Collinson et al. (2006) were followed.

2. Regional geological setting

The compound Anatolian craton located on the Alpine-Himalayan Orogenic Belt, contains many suture belts (Figure 1a) developed due to the closing of the Palaeotethys and Neotethys oceans. One of the most important suture belts is the Bitlis-Zagros Suture Zone (Şengör and Yılmaz, 1981; Yılmaz, 1993; Parlak et al., 2009) located in the southeast of Türkiye (Figure 1a). This suture was formed as a result of final closure of the southern branch of the Neotethys Ocean that existed between the Tauride-Anatolide Block and the Arabian Platform during the Middle Miocene to early Late Miocene (Langian-Serravalian) (Şengör and Yılmaz, 1981; Şengör et al., 1985; Yiğitbaş and Yılmaz, 1996a, b; Robertson et al., 2006, 2016; Huesing and Zachariasse, 2009; Kuşçu et al., 2010). To the north of this suture lie the Pütürge-Bitlis Massifs, the Maden Complex, and the Guleman Ophiolite, while the Southeastern Anatolian Autochthon is situated to the south (Figure 1b).

The Pütürge-Bitlis Massifs consist of rocks that underwent metamorphism in amphibolite facies (Ustaömer et al., 2012) during the Precambrian-early Cambrian period and in greenschist facies in the Late Cretaceous (Oberhänsli et al., 2012).

The Guleman Ophiolite comprises dunite, harzburgite, pyroxenite, serpentinite, gabbro, diabase dykes, and basalts (Özkan and Öztunalı, 1984; Parlak et al., 2009). Amphibolites are also observed as thin slices of metamorphic sole rocks. This ophiolite was formed through the northward subduction of the southern branch of the Neotethys Ocean in the Late Cretaceous and was emplaced on the southern margin of the Pütürge Massif before the late Maastrichtian (Beyarslan and Bingöl 2000; Roberston, 2002; Parlak et al., 2009).

The Maden Complex is represented by middle Eocene volcano-sedimentary rocks deposited on the Pütürge-Bitlis Massifs and the Southeastern Anatolian Ophiolites (Göksun, İspendere, and Guleman ophiolites) (Perinçek and Özkaya, 1981; Yazgan et al., 1983; Yazgan, 1983, 1984; Aktaş and Robertson, 1984; Hempton, 1985, Ertürk et al., 2018).

The Southeastern Anatolian Autochthon comprises Precambrian to Quaternary aged sedimentary and volcanic rocks deposited on the northern edge of the Arabian Platform, largely maintaining their original position (Tuna, 1973; Sungurlu, 1974a; Perinçek, 1979; Yılmaz et al., 1987, 1988; Robertson et al., 2012, 2013). The closure of the Neotethys Ocean in the Late Cretaceous and the continent-continent collision in the Middle Miocene (Şengör and Yılmaz, 1981; Yılmaz, 1993; Parlak et al., 2009; Robertson et al., 2016) led to the development of large-scale folds and thrusts, known as "margin folds", in the Southeast Anatolian Autochthon (Ketin, 1966) (Figure 2). The Çüngüş Basin was formed in the south of the Southeast Anatolian Suture Belt due to the southward emplacement of the Pütürge-Bitlis Massifs and the Maden Complex towards the northern margin of the Arabian Plate in the Early Miocene (Rigo de Righi and Cortesini, 1964; Perinçek, 1979, 1980; Dean et al., 1981; Aktaş and Robertson, 1984; Perinçek et al., 1991; Yılmaz et al., 1993; Robertson et al., 2006).

3. Stratigraphy

The study area is situated to the north of the Çüngüş Basin, forming a narrow belt. Bounded by the Pütürge-Bitlis Massifs and the Maden Complex to the north (Figures 1b and 2), the southern margin of the Çüngüş Basin is underlined by the Koçali and Karadut complexes, tectonically emplaced on the Arabian Autochthon at the end of the Late Cretaceous form the bedrock of the basin. The Cenomanian-lower Turonian Karadut Complex (Sungurlu, 1973, 1974a; Perinçek, 1979) consists of siliceous shale, clayey limestone, cherty limestone, radiolarite and chert alternations and lesser amount of sandstone and conglomerate, while the Upper Jurassic-Lower Cretaceous Koçali Complex (Sungurlu, 1973; Tuna, 1973; Perinçek, 1990) consists of basalt, serpentinite, spilite, radiolarite, chert, cherty limestone, gabbro, and pyroclastic rocks. The lower Eocene Gercüş Formation unconformably overlies the Koçali and Karadut complexes (Figure 3a). The Gercüş Formation consisting of reddish-brown coloured conglomerate, sandstone, siltstone, and mudstone alternations deposited in an alluvial fan environment. Transgressively overlying the Gercüş Formation (Figure 3a), the Middle Eocene Gaziantep Formation features grey-cream coloured, thin- to medium-bedded micritic limestone, cherty limestone, algal limestone, and nummulitic limestone (Figures 3b–3d), representing carbonate platform deposits. The Lower Miocene Lice and Fırat formations unconformably overlie the Gaziantep Formation. The Lice Formation, which consists of grey-khaki coloured sandstone, siltstone, mudstone alternations and subordinate conglomerates, represents deep marine turbidite deposits. The Fırat Formation, which is laterally transitional with the Lice Formation, consists of grey-cream coloured, thin-thick

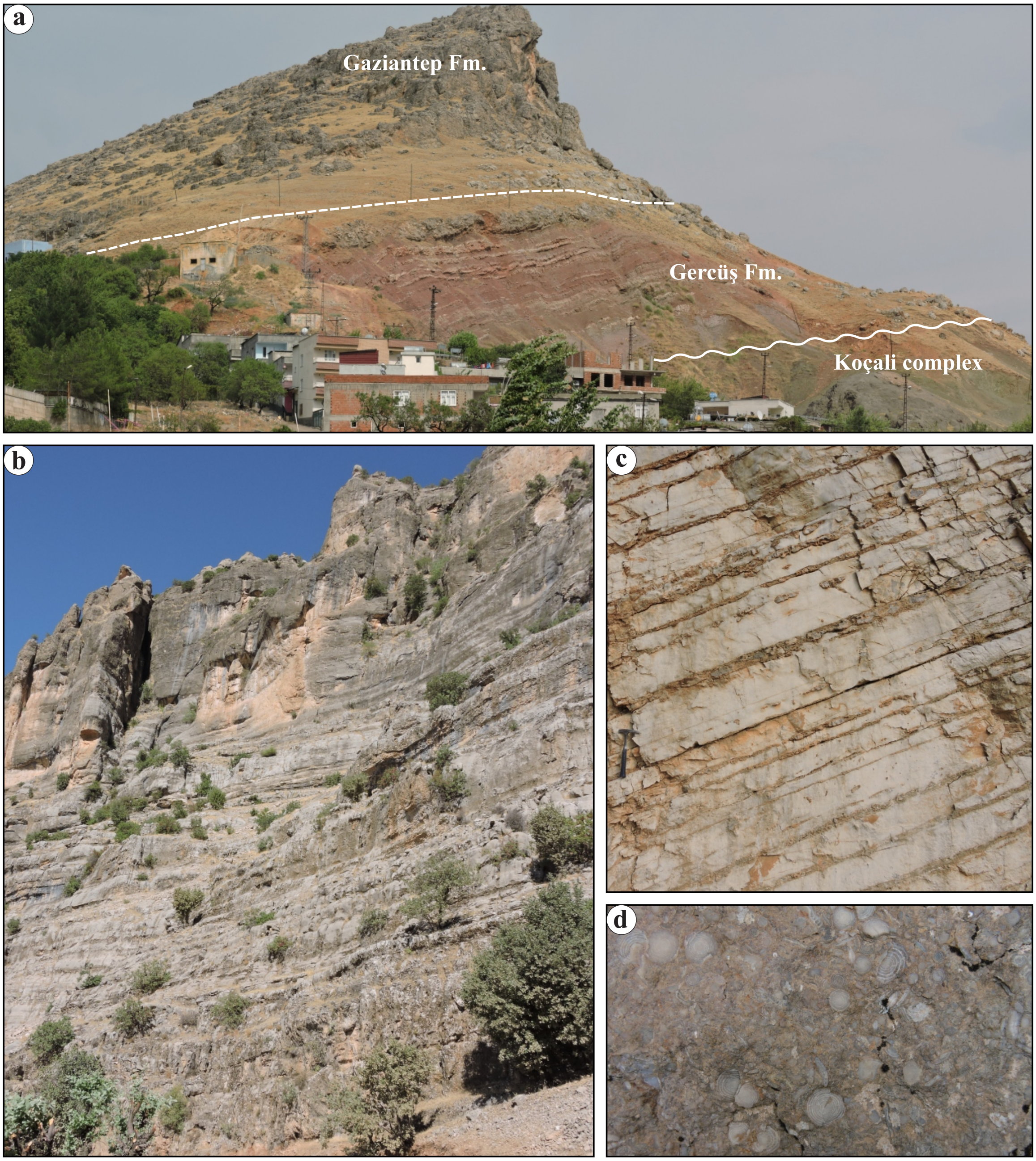

Figure 3. (a) The alluvial fan deposits of the lower Eocene Gerçüş Formation unconformably overlies the Koçali Complex and is transgressively overlain by the middle Eocene Gaziantep Formation. (b) The micritic limestones, (c) cherty limestones and (d) nummulitic limestones belonging to the Gaziantep Formation.

bedded algal limestone, representing the shallow-marine environment.

In the north of the Çüngüş Basin, along a belt approximately parallel to the northern margin, the Lice Formation contains sparsely distributed blocks and tectonic slices of basement rocks ranging in size from tens to hundreds of metres (Figure 4). This blocky turbidite sequence, the focus of this study, has been termed the Çüngüş Formation by Sungurlu (1974a).

The clastic rocks of the Middle-Upper Miocene Şelmo Formation unconformably overlie the Lice and Fırat formations (Yılmaz and Duran, 1997) and are unconformably overlain by the Kuşdoğan basalt of the Pliocene-Quaternary Karacadağ Volcanics (Şaroğlu and Emre, 1987; Ercan et al., 1991).

4. "Çüngüş Formation" in the Literature

Çüngüş Formation, first described in the east of Çüngüş District, consists of dark grey-greyish green coloured shale, marl and sandstone alternations with dispersed exotic blocks (Sungurlu, 1974b; Perinçek, 1978; Yazgan, 1981). Some researchers (Özkaya, 1978; Perinçek, 1978; Yazgan and Chessex, 1991) stated that although the Çüngüş Formation is very similar to the Lice Formation in terms of common lithological features, it differs with its darker colour. In Aktaş and Robertson (1984), the Lice and Çüngüş were interpreted as being intergradational and not separated by thrusts at all points. The thin- to medium-bedded turbiditic sandstones with common current ripples, normal grading, flute and load cast structures were excessively sheared by tectonic movements and the sandstone fragments were embedded in the shale matrix (Perinçek, 1978). Thick-bedded conglomerates with large metamorphic blocks, serpentinite and volcanic rocks were developed in a certain zone within this turbidite sequence (Sungurlu, 1974b) (Figure 4). As it approaches the Pütürge-Bitlis Massifs and Maden Complex towards the north of the basin, volcanic and serpentinite blocks, nummulitic limestones of the Midyat Group appear as tectonic wedges in the turbidite sequence (Sungurlu, 1974b; Özkaya, 1978). In addition, the volcanic and sedimentary rocks of the Maden Complex and their clastic fragments are also found in the turbidite sequence as N-dipping tectonic slices (Yazgan, 1981).

The Çüngüş Formation is considered to be a wild flysch deposited in a deep-marine environment in areas close to the basin margin (Özkaya, 1978; Perinçek, 1978; Yazgan, 1981; Yazgan and Chessex, 1991). The formation was interpreted as "Tertiary Formations in the Baykan nappe" (Sungurlu, 1974b), "the lowermost slice of the end-Miocene thrust sheets" (Perinçek, 1978; Sungurlu et al., 1985), and "tectonic slice" (Yazgan, 1981; Yazgan

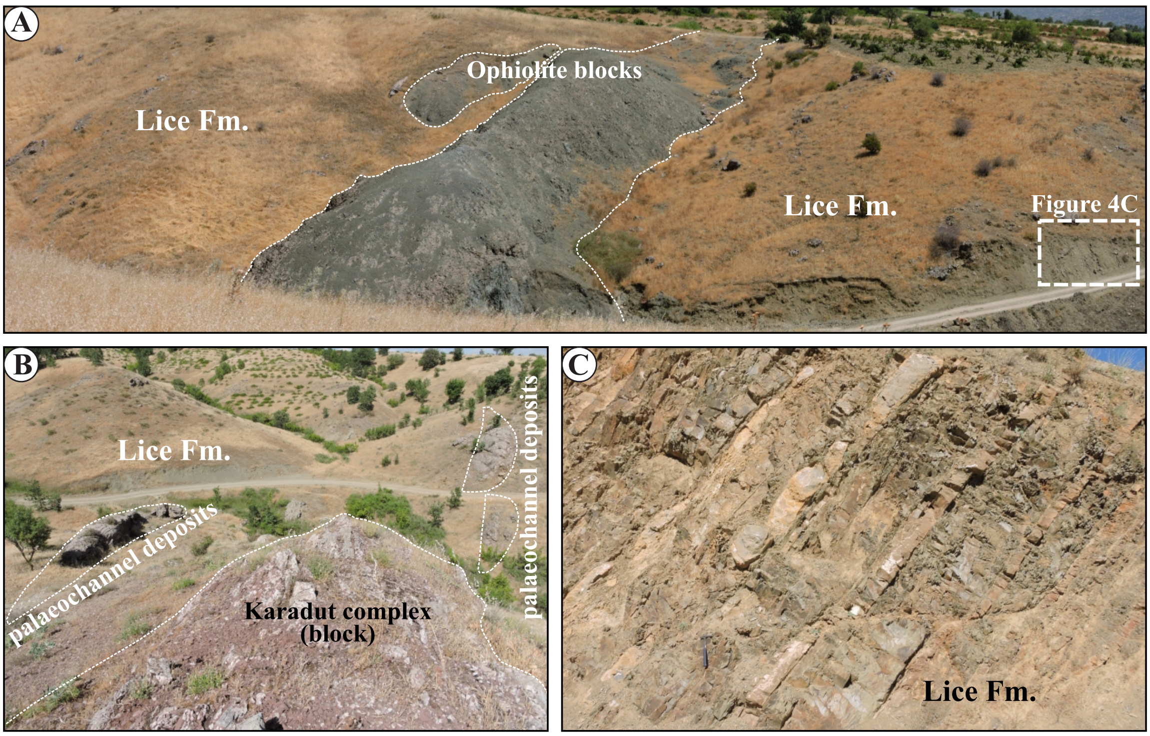

Figure 4. The turbidite sequence of the Lice Formation in the north of the Çüngüş Basin sparsely contains blocks and tectonic slices of basement rocks and palaeochannel deposits.

and Chessex, 1991). Şenel (2004) defined this unit as the lowermost unit of the Çüngüş-Hakkari Nappe. Özkaya (1978), on the other hand, considered that the Çüngüş Formation is a tectonic slice, as well as being the equivalent of the Lice Formation located further north and deposited in a more unstable environment.

5. Results

5.1. Stratigraphical and sedimentological data

The Çüngüş and Lice formations predominantly comprise alternations of mudstone, siltstone, and sandstone, with a minor presence of conglomerate (Figure 4). Additionally, scattered blocks of varying sizes are observed in the northern parts of the basin (Figure 5a). Both formations consist of the same facies associations including foreshore-shoreface deposits (Figures 5b and 5c), basin-floor turbidite deposits (Figure 5d), ramp-fringe palaeochannel deposits (Figure 5e), and submarine fan-channel deposits (Figure 5f).

The stratigraphic succession, unconformably overlying the algal limestones of the Gaziantep Formation, commences with calcirudites and calcarenites constituting the foreshore and shoreface deposits at the base. The calcirudites and calcarenites, mostly derived from nummulitic limestones, exhibit well-rounded, well-sorted, grain-supported texture with planar parallel stratification. The calcarenites forming the shoreface deposits have wave ripples, planar parallel stratification (Figures 5b and 5c) and hummocky-cross stratification. These upper shoreface deposits (Figure 5b) pass upwards into the sandstone-mudstone alternation of the lower shoreface environment (Figure 5c) and further into the mudstone-dominated succession of the offshore deposits. Deep marine turbidite deposits overlie these sediments throughout the basin.

The basin-floor turbidites, forming the most extensive facies of the deep-marine deposits, consist of very thin- to thin-bedded sandstone, siltstone, and mudstone alternations (Figure 5d). Normal graded sandstones with planar parallel- and current ripple cross-stratification are interpreted as deposits of the low-density turbidity currents(sensu Lowe, 1982), while mudstones signify hemipelagic deposition.

The submarine fan deposits comprise sandstones, mudstones, and conglomerates, forming coarsening- and thickening-upward sequences on the basin floor deposits (Figure 5f). The sandstones with lenticular geometry exhibit Ta, Tb, and Tc structures of the Bouma sequence as well as occasional slump structures, convolute laminations, and trace fossils. The channel-fill deposits consist of conglomerates with erosional bases on submarine fan deposits and fining-upward bedsets (Figure 5f).

Ramp-fringe palaeochannel deposits, mainly consist of calcirudites and calcarenites, 1–7-m thick and 15–60-m wide, are embedded within thin-bedded turbidite deposits (Figures 4b and 5e). These lenticular, isolated deposits, featuring concave upward erosional bases, consist of multistorey palaeochannel deposits. Each palaeochannel deposit consists of fining-upward bedsets, which are planar parallel or planar cross-stratified at the uppermost part. The pebble- to block-sized rock fragments in channel-fill sediments, rich in reworked Nummulites probably derived from the Gaziantep Formation or Maden Complex. Palaeochannel deposits are interpreted to be deposits of high- and low-density turbidity currents (Nemec et al., 2018), feeding the submarine fan deposits in the basin.

Apart from these facies assemblages, blocks and slices of serpentinite and volcanic rocks from the basement rocks and nummulitic limestones are observed within the turbidite deposits in the northern parts of the basin (Figures 4a, 4b, and 5a). These sparsely distributed blocks and slices, ranging from 5–40-m-thick and 20–150-m-wide, generally align parallel or semiparallel to the thrust belt.

These facies assemblages exhibit lateral and vertical transitions. In the northern part of the basin, near the thrust contact, ramp-fringe palaeochannel deposits, repeating frequently in the stratigraphic succession, gradually pass into submarine fan and channel deposits to the south. Basin-floor turbidite deposits are widespread throughout the basin, with an increase in the mudstone ratio observed towards the south. Despite extreme tectonic deformation, especially in the north, no structural or stratigraphic breaks are observed between the facies assemblages.All these stratigraphic and sedimentological features suggest that the defined facies associations in the Çüngüş Basin are genetically related to each other and were formed in the same basin under tectono-sedimentary control.

5.2. Paleontological data

To obtain age data from rock assemblages previously identified as the Çüngüş and Lice formations, and to ascertain whether these formations share the same or distinct ages, mudstone samples were collected for nannofossils analysis. Mudstone samples from the Çüngüş Formation were gathered from Oyuklu (Midye) village, the north of Aslankent village, Karakaya road, west and southeast of Alacakaya village, and southwest of Yapraklı village (Figure 1b; Table 1). Mudstone samples from the Lice Formation were collected from the west of Yeniköy, north of Ergani, and northwest of Devletkuşu village (Figure 1b; Table 2). Nannofossil assemblages were examined in smear slides prepared using standard techniques for studying nannofossil abundance and examined under a polarised light microscope at 1200× magnification.

The age data acquired revealed that both formations were deposited coevally during the Aquitanian period. This represents the first age data for the Çüngüş Formation, previously interpreted as Eocene-Miocene without any

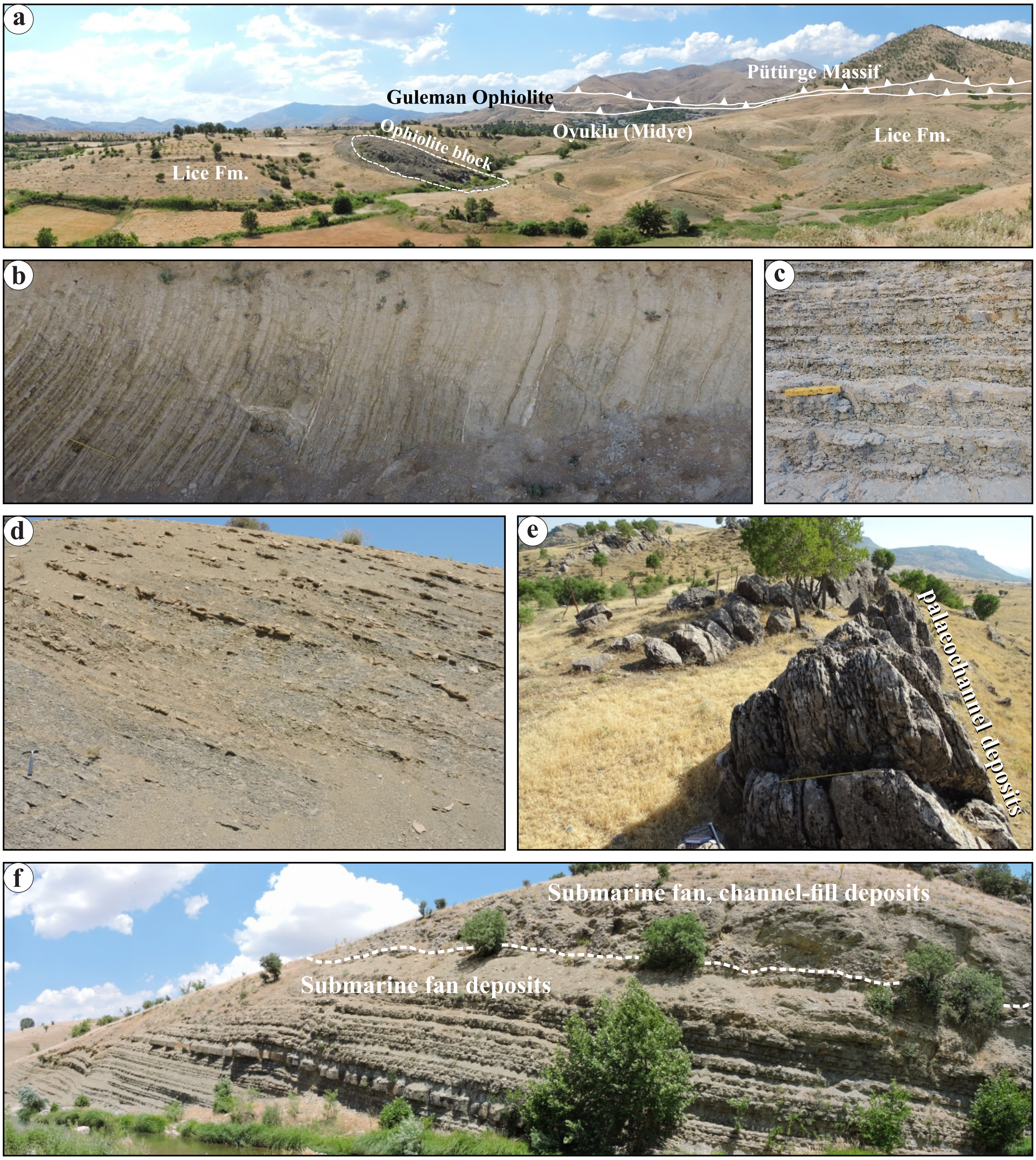

Figure 5. The north of the Çüngüş Basin, where the Çüngüş Formation is defined in the Oyuklu village. In this locality, deep-sea turbidite deposits of the Lice Formation with an ophiolite block are observed. (b) The Lice Formation is composed of different facies associations (b, c) shoreface deposits, (d) basin-floor turbidite deposits, (e) ramp-fringe palaeochannel deposits, and (f) submarine fan-channel deposits.

paleontological age data (Sungurlu, 1974b; Perinçek, 1978, 1979; Yazgan, 1981; Sungurlu et al., 1985).

5.3. Structural data

The Çüngüş Formation was previously defined as an allochthonous tectonic unit by various researchers (e.g., Sungurlu, 1974b; Özkaya, 1978; Perinçek, 1978; Yazgan, 1981; Yazgan and Chessex, 1991), asserting its separation from the overlying and underlying formations by tectonic contacts. These studies claimed the existence of a thrust plane between the Çüngüş and Lice formations.

Table 1. The locations of the mudstone samples from the Çüngüş Formation for the nannofossil examination and the ages obtained in this study.

<table>
<tr><th>Sample section names</th><th>Location numbers in Figure 1b</th><th>UTM WGS 84 coordinates of the location</th><th>Formation names in previous studies</th><th>Obtained ages from this study</th></tr>
<tr><td>North of Aslankent</td><td>1</td><td>503824/4223611</td><td>Çüngüş</td><td>Aquitanian</td></tr>
<tr><td colspan="5">Cyclicargolithus abisectus (Muller), Cyclicargolithus floridanus (Roth and Hay), Discoaster deflandrei Bramlette and Riedel, Discoaster druggii Bramlette and Wilcoxon, Furcatolithus ciperoensis (Bramlette and Wilcoxon), Reticulofenestra lockeri Müller, Reticulofenestra producta (Kamptner), Reticulofenestra stavensis (Levin and Joerger), Sphenolithus calyculus Bukry, Sphenolithus conicus Bukry, Sphenolithus delphix Bukry, Sphenolithus disbelemnos Fornaciari and Rio, Sphenolithus grandis Haq and Berggren, Triquetrorhabdulus carinatus Martini, Triquetrorhabdulus challengeri Perch-Nielsen, Umbilicosphaera rotula (Kamptner), Zygrhablithus bijugatus (Deflandre)</td></tr>
<tr><td>Karakaya road</td><td>2</td><td>517923/4229911</td><td>Çüngüş</td><td>Aquitanian</td></tr>
<tr><td colspan="5">Coronocyclus nitescens (Kamptner), Cyclicargolithus abisectus (Muller), Cyclicargolithus floridanus (Roth and Hay), Discoaster deflandrei Bramlette and Riedel, Discoaster druggii Bramlette and Wilcoxon, Sphenolithus disbelemnos Fornaciari and Rio, Triquetrorhabdulus carinatus Martini, Triquetrorhabdulus challengeri Perch-Nielsen, Umbilicosphaera rotula (Kamptner)</td></tr>
<tr><td>Southeast of Oyuklu (Midye)</td><td>3</td><td>532416/4229217</td><td>Çüngüş</td><td>Aquitanian</td></tr>
<tr><td colspan="5">Calcidiscus tropicus (Kamptner), Clausicoccus fenestratus (Deflandre and Fert), Cyclicargolithus abisectus (Muller), Cyclicargolithus floridanus (Roth and Hay), Discoaster deflandrei Bramlette and Riedel, Discoaster druggii Bramlette and Wilcoxon, Discoaster nodifer (Bramlette and Riedel), Furcatolithus ciperoensis (Bramlette and Wilcoxon), Furcatolithus umbrellus (Bukry), Helicosphaera euphratis Haq, Helicosphaera recta (Haq), Ilselithina fusa Roth, Reticulofenestra producta (Kamptner), Reticulofenestra stavensis (Levin and Joerger), Reticulofenestra umbilicus (Levin), Sphenolithus calyculus Bukry, Sphenolithus conicus Bukry, Sphenolithus disbelemnos Fornaciari and Rio, Sphenolithus grandis Haq and Berggren, Triquetrorhabdulus carinatus Martini, Triquetrorhabdulus challengeri Perch-Nielsen, Triquetrorhabdulus milowii Bukry, Umbilicosphaera rotula (Kamptner), Zygrhablithus bijugatus (Deflandre)</td></tr>
<tr><td>Southwest of Yapraklı</td><td>4</td><td>558990/4238378</td><td>Çüngüş</td><td>Aquitanian</td></tr>
<tr><td colspan="5">Clausicoccus subdistichus (Roth and Hay), Cyclicargolithus floridanus (Roth and Hay), Discoaster druggii Bramlette and Wilcoxon, Furcatolithus ciperoensis (Bramlette and Wilcoxon), Furcatolithus obtusus (Bukry), Helicosphaera carteri (Wallich), Orthorhabdus serratus Bramlette and Wilcoxon, Reticulofenestra bisecta (Hay, Mohler and Wade), Reticulofenestra umbilicus (Levin), Sphenolithus delphix Bukry, Sphenolithus disbelemnos Fornaciari and Rio, Triquetrorhabdulus carinatus Martini, Zygrhablithus bijugatus (Deflandre)</td></tr>
<tr><td>West of Alacakaya</td><td>5</td><td>570059/4257260</td><td>Çüngüş</td><td>Aquitanian</td></tr>
<tr><td colspan="5">Clausicoccus subdistichus (Roth and Hay), Cyclicargolithus abisectus (Muller), Cyclicargolithus floridanus (Roth and Hay), Discoaster druggii Bramlette and Wilcoxon, Furcatolithus akropodus (de Kaenel and Villa), Furcatolithus ciperoensis (Bramlette and Wilcoxon), Furcatolithus distentus (Martini), Furcatolithus obtusus (Bukry), Furcatolithus peartiae (Bown and Dunkley Jones), Furcatolithus predistentus (Bramlette and Wilcoxon), Helicosphaera bramlettei (Müller), Helicosphaera recta (Haq), Nannotetrina cristata (Martini), Pemma papillatum Martini, Reticulofenestra bisecta (Hay, Mohler and Wade), Sphenolithus conicus Bukry, Sphenolithus disbelemnos Fornaciari and Rio, Sphenolithus furcatolithoides Locker, Sphenolithus pseudoradians Bramlette and Wilcoxon, Umbilicosphaera rotula (Kamptner)</td></tr>
<tr><td>Southeast of Alacakaya</td><td>6</td><td>576830/4253105</td><td>Çüngüş</td><td>Aquitanian</td></tr>
<tr><td colspan="5">Cyclicargolithus abisectus (Muller), Cyclicargolithus floridanus (Roth and Hay), Discoaster druggii Bramlette and Wilcoxon, Furcatolithus ciperoensis (Bramlette and Wilcoxon), Helicosphaera euphratis Haq, Helicosphaera recta (Haq), Reticulofenestra bisecta (Hay, Mohler and Wade), Reticulofenestra umbilicus (Levin), Reticulofenestra umbilicus (Levin), Sphenolithus delphix Bukry, Sphenolithus disbelemnos Fornaciari and Rio</td></tr>
</table>

Table 2. The locations of the mudstone samples from the Lice Formation for the nannofossil examination and the ages obtained in this study.

Sample section names	Location numbers in Figure 1b	UTM WGS 84 coordinates of the location	Formation names in previous studies	Obtained ages from this study
West of Yeniköy	**7**	**533694/4227200**	**Lice**	**Aquitanian**
Calcidiscus leptoporus (Murray and Blackman), *Coronocyclus nitescens* (Kamptner), *Cyclicargolithus abisectus* (Muller), *Discoaster druggii* Bramlette and Wilcoxon, *Furcatolithus ciperoensis* (Bramlette ve Wilcoxon*), Helicosphaera carteri* (Wallich), *Helicosphaera truempyi Biolzi and Perch-Nielsen, Reticulofenestra lockeri* Müller, *Reticulofenestra producta* (Kamptner), *Reticulofenestra stavensis* (Levin and Joerger), *Reticulofenestra umbilicus* (Levin), *Sphenolithus disbelemnos* Fornaciari and Rio, *Sphenolithus spinula* Bergen and de Kaenel, *Triquetrorhabdulus carinatus* Martini, *Triquetrorhabdulus longus* Blaj and Young, *Triquetrorhabdulus milowii* Bukry, *Umbilicosphaera rotula* (Kamptner), *Zygrhablithus bijugatus* (Deflandre), *Micrantholithus* sp.				
North of Ergani	**8**	**563108/4240802**	**Lice**	**Aquitanian**
Chiasmolithus altus Bukry and Percival, *Clausicoccus fenestratus* (Deflandre and Fert), *Clausicoccus subdistichus* (Roth and Hay), *Coccolithus biparteoperculatus* (Varol), *Coccolithus eopelagicus* (Bramlette and Riedel), *Cyclicargolithus abisectus* (Muller), *Cyclicargolithus floridanus* (Roth and Hay), *Discoaster deflandrei* Bramlette and Riedel, *Discoaster druggii* Bramlette and Wilcoxon, *Discoaster shumnykii* de Kaenel and Bergen, *Furcatolithus akropodus* (de Kaenel and Villa), *Furcatolithus celsus* (Haq), *Furcatolithus ciperoensis* (Bramlette and Wilcoxon), *Furcatolithus distentus* (Martini), *Furcatolithus predistentus* (Bramlette and Wilcoxon), *Furcatolithus triangularis* Bergen and de Kaenel, *Furcatolithus umbrellus* (Bukry), *Helicosphaera carteri* (Wallich), *Helicosphaera euphratis* Haq, *Helicosphaera granulata* (Bukry and Percival), *Helicosphaera recta* (Haq), *Helicosphaera reticulata* Bramlette and Wilcoxon, *Ilselithina fusa* Roth, *Lanternithus minutus* Stradner, *Micrantholithus* sp., *Orthorhabdus serratus* Bramlette and Wilcoxon, *Pontosphaera enormis* (Locker), *Reticulofenestra bisecta* (Hay, Mohler and Wade), *Reticulofenestra daviesii* (Ha), *Reticulofenestra daviesii* (Haq), *Reticulofenestra filewiczii* (Wise and Wiegand), *Reticulofenestra lockeri* Müller, *Reticulofenestra minuta* Roth, *Reticulofenestra producta* (Kamptner), *Reticulofenestra pseudoumbilicus* (Gartner), *Reticulofenestra stavensis* (Levin and Joerger), *Sphenolithus calyculus* Bukry, *Sphenolithus capricornutus* Bukry and Percival, *Sphenolithus cometa* de Kaenel and Villa, *Sphenolithus compactus* Backman, *Sphenolithus conicus* Bukry, *Sphenolithus delphix* Bukry, *Sphenolithus disbelemnos* Fornaciari and Rio, *Sphenolithus dissimilis* Bukry and Percival, *Sphenolithus grandis* Haq and Berggren, *Sphenolithus moriformis* (Brönnimann and Stradner), *Sphenolithus truaxii* Bergen and de Kaenel, *Toweius gammation* (Bramlette and Sullivan), *Triquetrorhabdulus carinatus* Martini, *Triquetrorhabdulus challengeri* Perch-Nielsen, *Triquetrorhabdulus milowii* Bukry, *Umbilicosphaera rotula* (Kamptner), *Zygrhablithus bijugatus* (Deflandre)				
Northwest of Devletkuşu	**9**	**565354/4246000**	**Lice**	**Aquitanian**
Cyclicargolithus abisectus (Muller), *Cyclicargolithus floridanus* (Roth and Hay), *Discoaster druggii* Bramlette and Wilcoxon, *Furcatolithus ciperoensis* (Bramlette and Wilcoxon*), Furcatolithus peartiae* (Bown and Dunkley Jones), *Furcatolithus predistentus* (Bramlette and Wilcoxon), *Furcatolithus tribulosus* (Roth), *Helicosphaera carteri* (Wallich), *Hughesius tasmaniae* (Edwards and Perch-Nielsen), *Reticulofenestra bisecta* (Hay, Mohler and Wade), *Reticulofenestra umbilicus* (Levin), *Sphenolithus delphix* Bukry, *Sphenolithus disbelemnos* Fornaciari and Rio, *Sphenolithus spinula* Bergen and de Kaenel, *Umbilicosphaera rotula* (Kamptner)				

The deformation zone extending along the belt in Cenozoic rocks in front of the Southeast Anatolian Suture Belt (Figure 1b) contains various types of faults and folds, which are observed quite intensively in the vicinity of the suture (Figures 5a and 6a–6d). In the Çüngüş-Çermik region, limestones of the Gaziantep Formation and the Koçali and Karadut complexes were thrust over the turbidite succession of the Lice Formation (Figure 2a). All these reverse faults clearly show that the units were thrusted from NW to SE direction on planes striking NE-SW, dipping NW as a result of compression in NW-SE direction. Fold axial planes with NE-SW trending are concentrated around Ergani (Figures 6b and 6d). The NW-SE directed strike-slip faults cuts both the reverse faults and the folds in the region (Figure 2b).

The thrust contact between the blocky turbidite succession and the overlying Pütürge-Bitlis Massifs is clearly visible on the Çüngüş-Malkaya village road (Figure 7a) and in sections north of the Midye village and the valley north of Devletkuşu, north of Ergani. Intense cataclastic deformation is observed along a 50-m-wide zone in the locality where the Pütürge metamorphites thrust onto the deep-marine turbidite sequence on the Malkaya road section (Figures 7a and 7b). As a result of this thrust, the

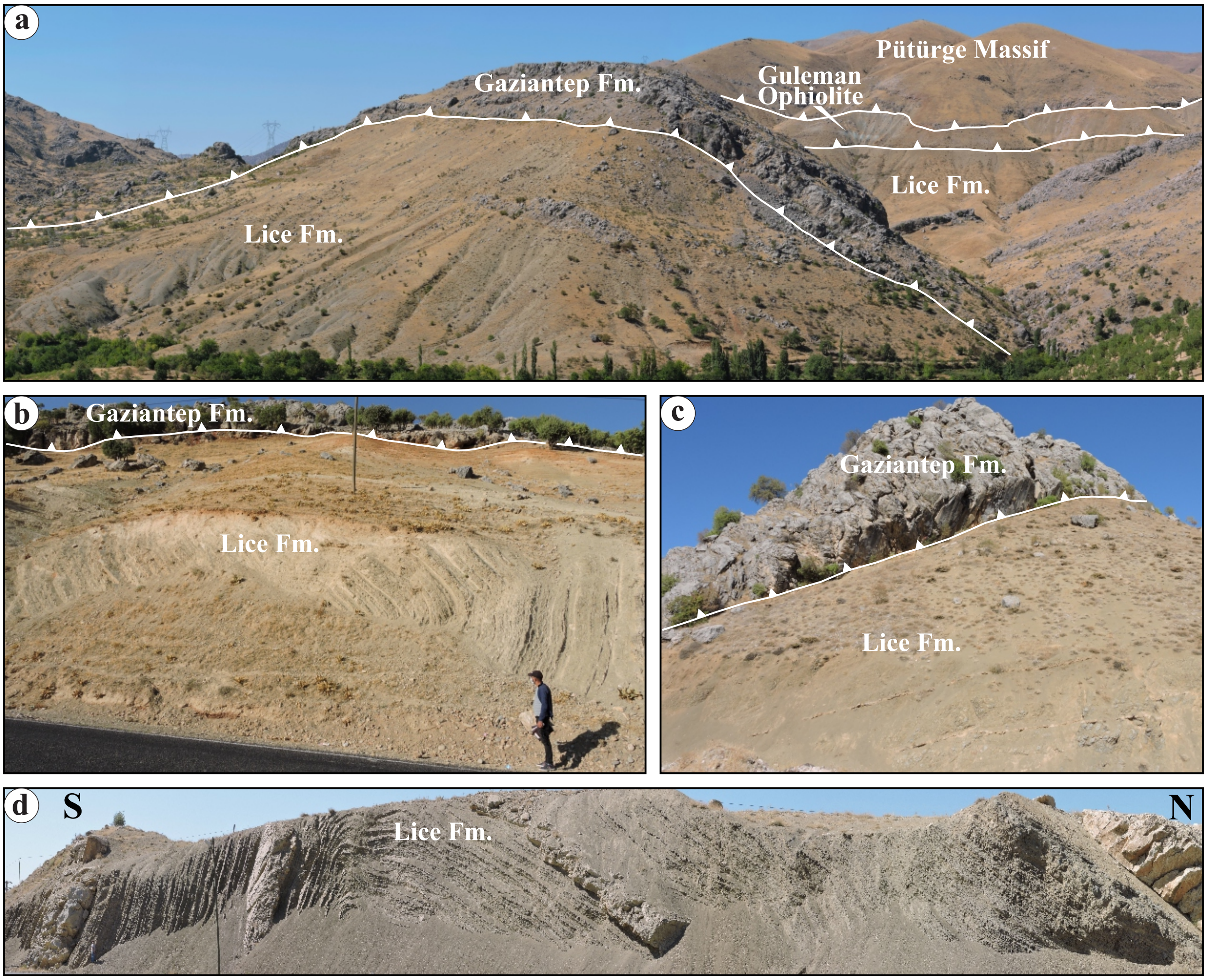

Figure 6. The Çüngüş Basin contains many deformation structures as different types of faults and folds in the areas close to the suture zone. (a) Suture zone and the reverse fault in the NE of Çüngüş district. (b) Revese fault and associated fold in the Çermik-Çüngüş road. (c) Revese fault in the Çüngüş-Malkaya road. (d) Asymmetric anticline observed within the Lice Formation, north of Ergani.

deep-marine turbidite succession was intensely deformed, with cleavages in the sandstones and mudstones and the disappearance of bedding planes. Cracks and fracture systems developed in the Pütürge metamorphics, roughly parallel to the main thrust. In the north of Devletkuşu, the Guleman ophiolites thrust onto the deep marine turbidite deposits (Figure 7c). However, no reverse or thrust fault is observed in the field between the blocky turbidite sequence defined as the Çüngüş Formation and the turbidite sequence of the Lice Formation, as claimed in previous studies. The blocky part of the succession corresponding to the "Çüngüş Formation" passes into the Lice Formation to the south without any sharp contact. A continuous thrust contact, such as the lower contact of the Çüngüş Formation shown on previous maps, is not observed in the field.

If a regional scale Çüngüş Nappe was present over the Lice Formation, an intense deformation zone would be expected to occur south of the thrust line. The presence of such a deformation zone and the movement throughout this zone would have led to extreme cataclastic deformation within the Lice Formation. However, field data show that there is no such deformation zone.

All researchers working in the region agree on the presence of slices of pre-Miocene basement rocks near the thrust contact in the northernmost part of the basin (Sungurlu, 1974b; Özkaya, 1978; Perinçek, 1978; Yazgan, 1981; Yazgan and Chessex, 1991), implying synsedimentary imbrications. Ophiolites, volcanics, and nummulitic limestones are inserted into the Miocene turbidite sequence as tectonic slices of different sizes (10–50 m thick and 30–200 m long). Although reverse faults are

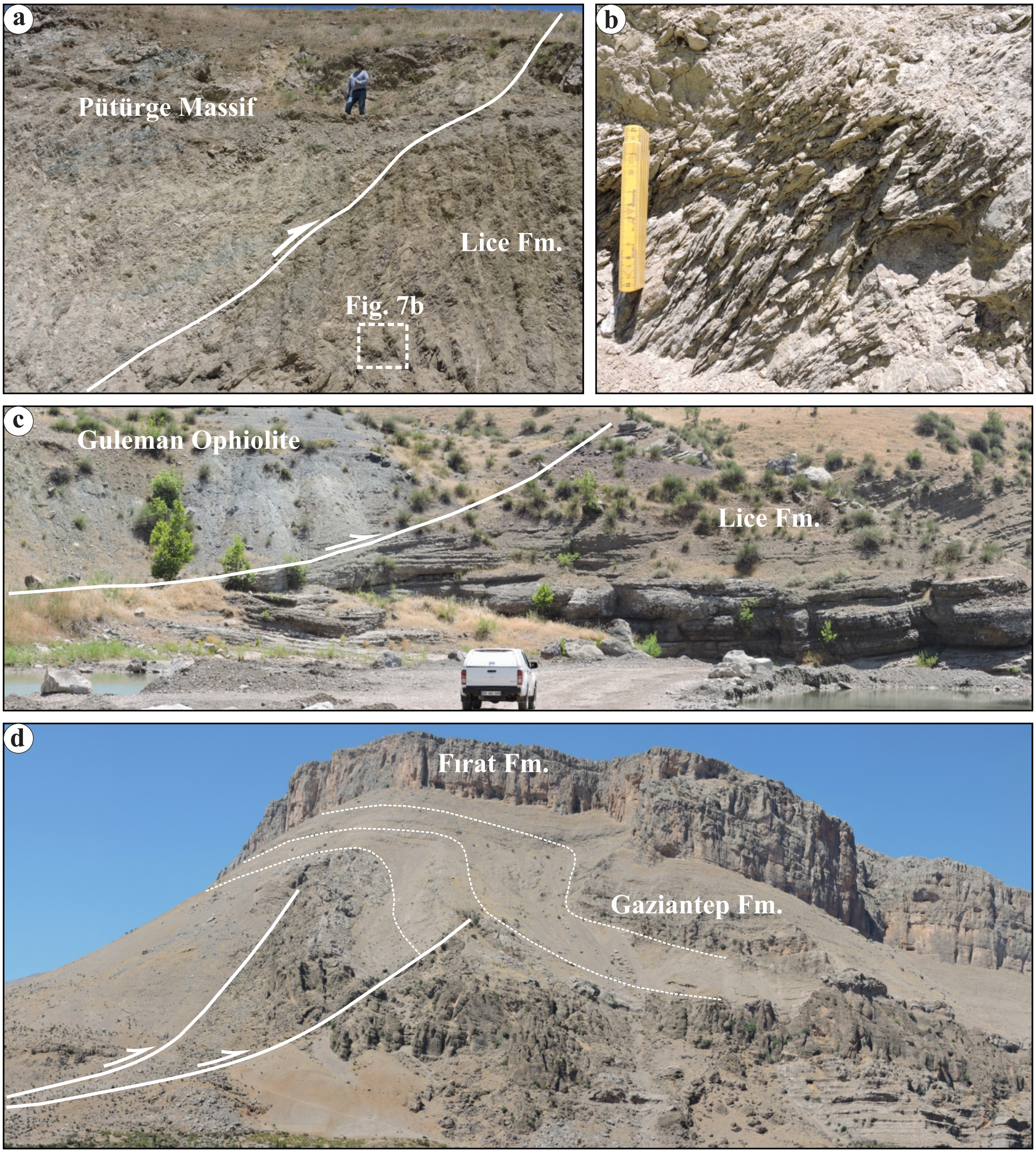

Figure 7. (a) The thrust contact between the Pütürge-Bitlis Massif and the turbidite succession on the Çüngüş-Malkaya road, and (b) close-up view of the deformation. (c) The Guleman ophiolite overthrusts the submarine fan deposits of the Lice Formation to the north of Devletkuşu. (d) Blind thrusts defined in the North of the Çüngüş Basin.

observed between these slices and the turbidite sequence, the discontinuous reverse faults terminate laterally within the turbidite sequence. Blind thrusts defined in the basin have also produced folds at different scales (Figure 7d). However, these postdepositional folds also disappear after a certain distance.

Since all the deformations observed in the region are developed between the basement rocks and basin sediments, and there is no allochthonous tectonic unit that can be defined as a nappe in the stratigraphic succession, there is no reason to generate a separate lithostratigraphic unit in the Çüngüş Basin. The most representative north-south directed section of the deep-marine turbidite sequence is seen in the Ergani-Maden road cut. The deep-marine turbidite deposits of the Lice Formation continue uniformly and uninterruptedly from the Ergani district northwards towards the Maden Complex. There is no allochthonous succession defined as the Çüngüş nappe in this section of the road cut. This section presents the best outcrops disproving that there is no nappe slice in the region.

6. Discussion

The interpretations drawn from the stratigraphical, sedimentological, structural, and palaeontological data in the Çüngüş Basin can be summarised as follows: a) the facies assemblages are transitional and there is no structural or stratigraphic break between them; b) both the Çüngüş and Lice formations are determined to be of the same age, deposited during the Aquitanian period; c) the previously indicated thrust contact between the formations, as depicted in earlier maps, cannot be confirmed in the field.

These conclusions suggest that the turbidite succession, containing olistoliths of the bedrock, cannot be interpreted as an allochthonous tectonostratigraphic unit. Therefore, its facies and depositional environment must be interpreted within a basin model.

The question then arises: "What is the Çüngüş Formation, and what is its position in a basin model?" The Çüngüş Basin has been traditionally conceptualized as a deep trench, and the Çüngüş Formation has been interpreted as a trench-fill type flysch deposited by gravity sliding due to vertical tectonics (e.g., Sungurlu, 1974b; Perinçek, 1978; Yazgan, 1981). However, Erdoğan (1983) emphasized that the main stress axis causing the Miocene tectonics was horizontal from north to south and could not cause gravity sliding. Özkaya (1978), on the other hand, studied the Çüngüş Formation under the name of Engene Formation in the Ergani-Maden region and interpreted it as the equivalent of the Lice Formation, which is located further north and deposited in a more unstable environment.

6.1. A new interpretation of Çüngüş Formation

In this study, the Çüngüş Basin is interpreted as an Early Miocene foreland basin (Figure 8). The flexural subsidence of the Arabian Autochthon, driven by the crustal load of the Pütürge-Bitlis Massifs and the Maden Complex, led to the development of sediment accommodation

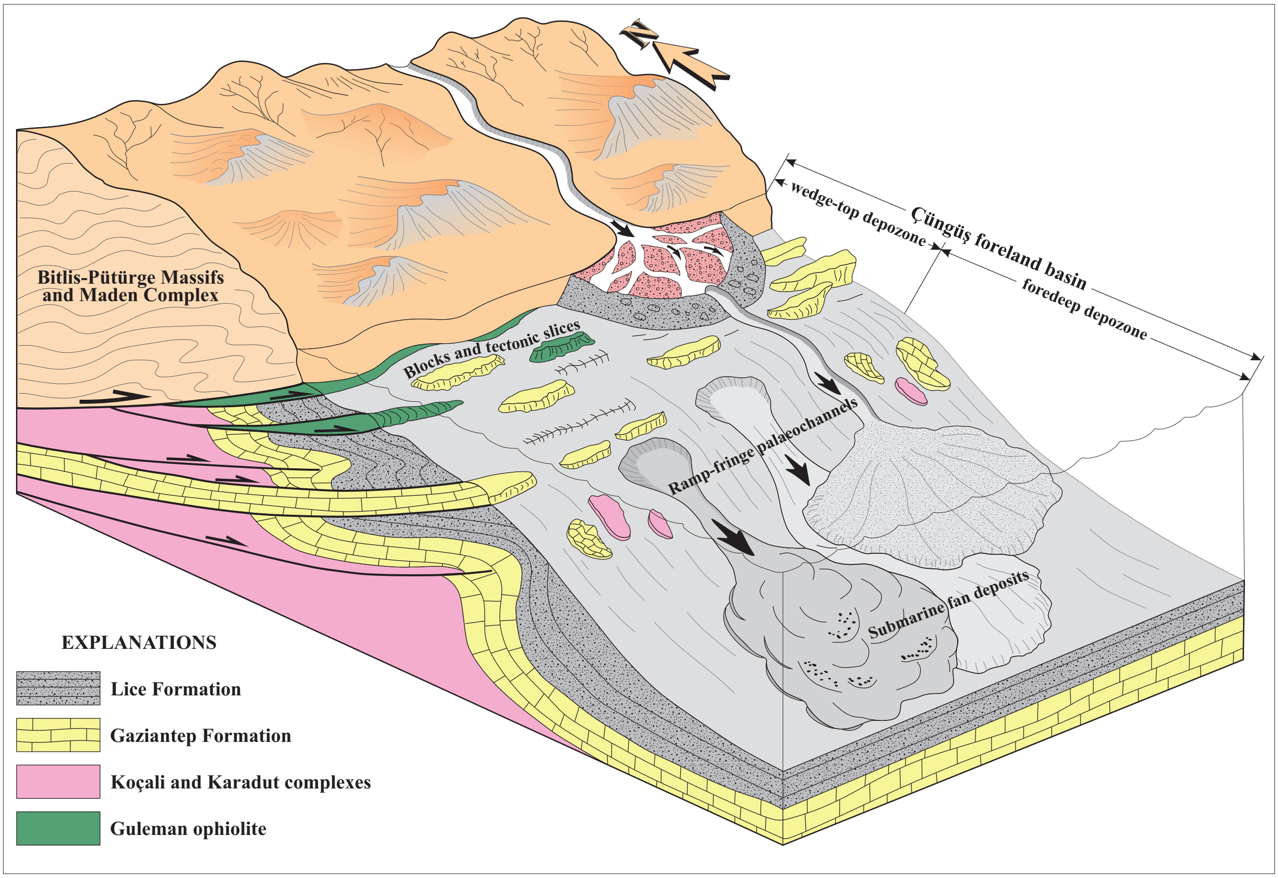

Figure 8. Schematic model showing the development of the Çüngüş foreland basin in front of the Pütürge-Bitlis Massifs and the Maden Complex and the depositional environments of the facies assemblages defined in this basin.

space. Tectonic loading from the north resulted in the development of a deep-marine environment in the north and a shallow-marine environment in the south, creating an asymmetrical geometry in the north-south direction in the Çüngüş foreland basin. Subenvironments such as wedge-top, foredeep, and forebulge developed within this framework, reflecting the diverse environmental conditions of a foreland basin.

Deposition in the Çüngüş Basin occurred on both the active continental margin in the north and the passive continental margin in the south. Clastic sediments derived from the Pütürge-Bitlis Massifs and the Maden Complex in the north, constituting the bedrock of the active continental margin, fed the deep marine turbidite deposits. Turbidity currents allowed for the deposition of ramp-fringe palaeochannel deposits, submarine fan, and channel sediments in the basin (Figure 8). This process was accompanied by the transportation of blocks from the bedrock on the northern margin of the basin. Additionally, syndepositional reverse faults and thrusts were generated in the active margin of the Çüngüş Basin due to continuous southward movement of the massifs (Figure 8), leading to uplift and partial exhumation in these areas. Slices of nummulitic limestone exposed by these tectonic movements and also supplied sediments to the basin. Thus, tectonically controlled sedimentation facilitated the development of a tectono-stratigraphic succession consisting of blocky turbidite deposits on the active continental margin in the north of the basin. The progressive deformation, various types of growth structures, including folds and faults, and the compositional immaturity of the sediments are interpreted as the key distinguishing features of the wedge-top depozone in a foreland basin (Anadon et al., 1986; Lawton and Trexler, 1991; Suppe et al., 1992; DeCelles and Giles, 1996). Consequently, the blocky turbidite sequence of the so-called Çüngüş Formation is interpreted to be representative of the wedge-top deposits of the Çüngüş foreland basin (Figure 8).

These wedge-top deposits gradually pass southward into the basin-floor turbidites and submarine fan deposits of the Lice Formation. The thick deep-marine turbidites represent the deposits of the foredeep subenvironment (Figure 8). The absence of a shallowing-upward sequence in this succession indicates a balance between deposition and subsidence during the basin evolution, maintained by factors such as the advancing mountain belt, hinterland erosion, and the subsidence rate of the basin floor.

7. Concluding remarks

In this study, the stratigraphical, sedimentological, palaeontological, and structural data collected from the Lower Miocene deep-marine turbidite sequence in the Çüngüş Basin were evaluated together with the surrounding elements, and the previous interpretation of the rock assemblage, which was defined as the "Çüngüş Formation" was discussed. ." The key findings and conclusions derived from this analysis are as follows:

- ➢ The sedimentary facies of the Lower Miocene turbidite succession in the Çüngüş Basin is transitional from proximal to distal facies;
- ➢ Nannoplankton examinations demonstrate that both the "Çüngüş Formation" and the Lice Formation are of Early Miocene in age;
- ➢ The continuous thrust contact between the Çüngüş and Lice formations shown in previous maps cannot be confirmed in the field;
- ➢ There is no allochthonous tectonostratigraphic unit that can be defined as a nappe that was tectonically emplaced in the Çüngüş Basin by being transported under the Pütürge-Bitlis Massif and the Maden Complex;
- ➢ The obtained results show that it is unnecessary to define a separate lithostratigraphic unit under the name of "Çüngüş Formation";
- ➢ The Çüngüş Basin developed as a foreland basin by flexural subsidence of the Arabian Autochthon under the load of Pütürge-Bitlis Massifs and the Maden Complex in the Early Miocene;
- ➢ The southward movement of the massifs caused the emplacement of the tectonic slices in the northern part of the basin, giving rise to the formation of wedge-top and foredeep depozones;
- ➢ The Çüngüş and Lice formations reflect the wedge-top subenvironment and the foredeep subenvironment of the Çüngüş foreland basin, respectively.

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