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Palaeoenvironmental analysis of a Miocene basin in the high Taurus Mountains (southern Turkey) and its palaeogeographical and structural significance

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Abstract – Determination of the relationships between the southern, marine-dominated Miocene basins of south central Turkey and their continental hinterland in southern Turkey has traditionally been frustrated by the apparent absence of basin remnants within the Taurus Mountains. The Dikme basin, which seems to be an enclave of basin remnants within the Aladağ Mountains (Eastern Taurides), consists mainly of coarse-grained continental sediments of various facies. These mostly early–middle Miocene sediments were studied to determine the depositional environments and the factors controlling the basin formation and basin fill architecture, to attempt to close the information gap between the Adana Basin to the south and central Anatolian Miocene further to the north. A generally southwest-flowing axial fluvial system and interfingering coarse-grained marginal alluvial clastics derived from northwest and southeast were identified. The marginal facies to the northwest is bounded by a N 55° E-running structural lineament, that starts from the Ecemiş Fault Zone and in digital elevation models extends toward the north of the study area. Along this lineament, Miocene sediments onlap steep fault-line escarpments. Certain Miocene levels are tectonically disrupted, and an intraformational unconformity and boulder conglomerates are also well-developed in the Miocene sequence. The southeast boundary is similarly defined by a NE-trending fault that periodically elevated the adjacent Tufanbeyli autochthon, producing coarse clastics from this area. This boundary fault also induced fining-upwards vertical patterns and synsedimentary deformation in the marginal facies. Additionally, the central part of the basin exhibits a distinct fault-defined morphology characterized by small-scale (tens of metres to 150 m high) valley-and-sill topography. A thin marine interval was also encountered in the southernmost part of the basin, indicating that the clastic system originating around this area debouched into a Miocene sea situated further to the south. The proposed palaeogeography and basin fill model suggests that the Dikme basin and similar Miocene remnants, all controlled mainly by a northeast-running extensional or transtensional fault system, may have been parts of the terrestrial hinterland that supplied sediment to rapidly subsiding marine areas further south, such as the Adana Basin.

Keywords: Adana Turkey; Miocene; extension tectonics; depositional fault; palaeogeography.

1. Introduction

The Neogene history of south-central Turkey is marked by the development and subsequent deformation of several large sedimentary basins (Adana, Mut, Misis-Andırın, Maraş, etc.) with predominantly marine fill-sequences. Of these, the Adana Basin is one of the most thoroughly studied, due both to its hydrocarbon potential and its geologically important position near the triple junction formed by the East Anatolian Fault, Dead Sea Transform Fault and Bitlis Suture (Şengör & Yılmaz, 1981). The stratigraphy of this basin was initially documented by Ternek (1957) and Schmidt (1961), and later revised by many workers (e.g. S. İlker, unpub. data, 1975; Gürbüz, Gökçen & Gökçen, 1985; Yetiş, 1988). Detailed facies analyses appeared after the mid-1970s (Görür, 1979, 1985; Yalçın & Görür, 1983; Gürbüz & Kelling, 1993; Yetiş & Taner, 1987; Naz, Çuhadar & Yeniay, 1991) and focused mostly on the lower part of the basin fill, ranging from continental clastics to deep sea fans. A later wave of research was principally concerned with palaeogeography and basin evolution at both local and regional scales, with special emphasis on the geodynamic mechanisms responsible for initiation and evolution of the basin (Kelling *et al.* 1987; Akay & Uysal, 1988; Gökçen *et al.* 1988; Karig & Kozlu, 1990; Görür, 1992; Ünlügenç, Williams & Kelling, 1992; Williams *et al.* 1995; ITU, 1998; Dhont, Chorowicz & Yürür, 1999). Although extensional tectonic processes are generally implicated, the precise driving mechanism is still poorly understood. Hypotheses suggested range from a peripheral foreland basin setting to triple junction-determined depression, but more field-based studies are needed to validate the most appropriate model.

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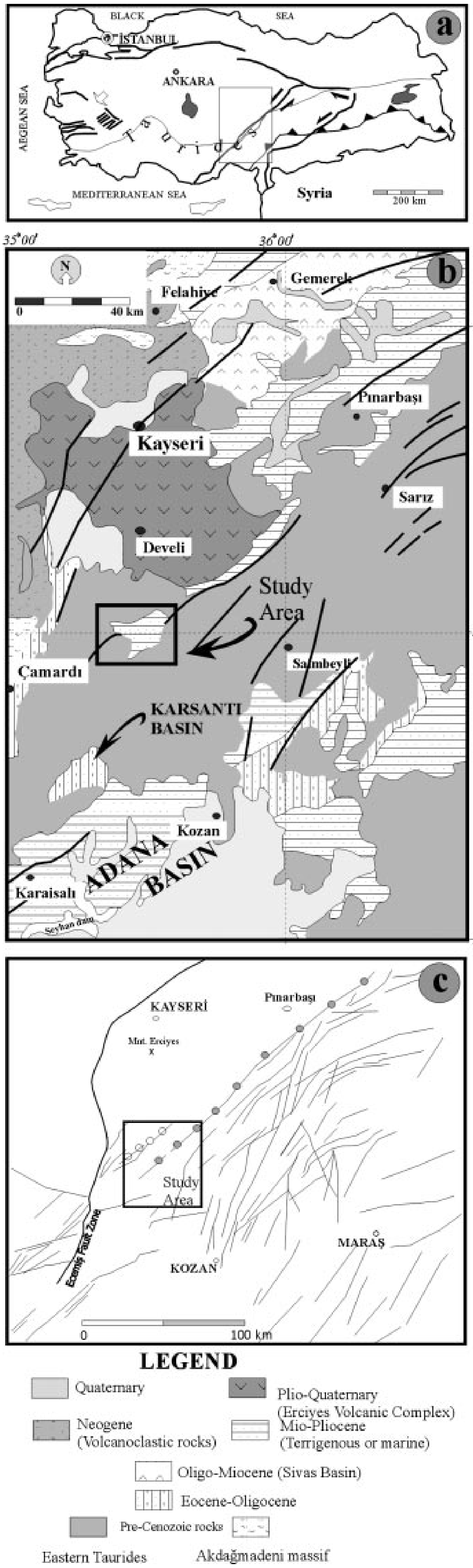

Despite the extensive previous research on the Adana Basin, the nature and geodynamics of its hinterland are almost unknown except for some mineralogical compositional data from Miocene basinal successions (Naz, Çuhadar & Yeniay, 1991; Gürbüz & Kelling, 1993). Because in Miocene times, this hinterland separated two distinct geological entities, the rapidly subsiding Adana Basin to the south and the Central Anatolian volcanic realm further north, any Miocene deposits preserved on this hinterland provide important evidence for integrating the palaeogeography and geodynamics of the eastern Mediterranean.

The investigated Miocene exposures (Figs 1, 2) are located in the high Taurus Mountains, about 40 km north of the nearest Adana Basin outcrops. These sediments were first mapped by Geological Survey of Turkey (MTA), as part of the base-survey for the first Geological Map of Turkey at 1:500000 scale. Since neither the explanatory notes for the Adana sheet, which partly covers the study area, nor any other report of this early study was ever published, it is not known now why the Miocene of the area was designated as ‘md’ (Miocene marine) on that map. Further mapping activities were undertaken by MTA geologists during the 1970s and 1980s. These studies briefly described the Miocene sediments as deposited in continental environments ranging from alluvial fans to lakes with some volcanic intercalations from the nearby Erciyes Volcanic Complex (S. Metin, unpub. data, 1986). A more detailed evaluation was documented just previously by Ulakoğlu (1983/84) who concluded that pollen assemblages from a coalified interval in the sequence indicated a Miocene age for these deposits. He also noted that the sequence included a marine fossil, *Ostrea crassissimata* and moulds of some gastropod species. This marine evidence was recently utilized by ITU (1998) to place the Miocene coastline as far north as the study area in the Palaeogeographic Atlas of Turkey.

This study investigates these marine-influenced deposits (described in this paper as the ‘Dikme basin’) in the summit range of the Taurus Mountains (north-east of Aladağ) at altitudes as high as 1900 m, from a sedimentological viewpoint. The area presents great potential for palaeoenvironmental and palaeogeographical studies thanks to its deeply incised topography and almost undeformed Miocene outcrops. Moreover, its geographic position (Fig. 1) between the Central Anatolian Volcanic Province and the Sivas basin to the north, and the marine Miocene to the south identifies the area as a candidate location to establish some common geodynamic linkages between

Figure 1. (a) Location of the Taurides; (b) Geological map of south-central Anatolia (simplified after the 1:2000000 scale Geological Map of Turkey (M.T.A., 1989)); (c) Lineament map interpreted from digital elevation model of the same region.

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these two geologically contrasting elements within the Alpine orogenic belt in Turkey.

2. Tectonic setting

The study area is situated on the dividing zone between the high altitude eastern Taurides to the south and the relatively flat-lying (with the exception of some huge stratovolcanoes such as Mt Erciyes) Central Anatolian plateau to the north (Fig. 1a, b). The mountainous zone consists of a nappe pile with both oceanic and platform affinities that was telescoped during closure of northerly situated Neotethyan strands in the Late Cretaceous and subsequent collision events (Özgül, 1984). The northern area, that is, the Central Anatolian Volcanic Province (Göncüoğlu & Toprak, 1992), on the other hand, largely consists of the Mio-Pliocene (and some Quaternary) edifice of Capodoccia volcanics and interfingering continental clastics. This zone extends close to the northeast corner of the study area via a narrow faulted corridor (Fig. 1b). To the south of the Taurides range, the Karsantı and Adana basins constitute the neighbouring depocentres where the distinct Oligocene and Mio-Pliocene sedimentary events are recorded respectively (Fig. 1b).

Some of the most prominent tectonic and physiographic features of nearby regions are shown on the lineament map interpreted from the digital elevation data (Fig. 1c). The NNE-striking linear feature, that curves toward the north around the Erciyes stratovolcano, corresponds to the Ecemiş Fault Zone (EFZ), an intracontinental megashear zone (Fig. 1b, c). Towards the east, a wide and parallel-running diffuse fault zone occurs to the north of Kozan, namely the Göksu-Yazyurdu Fault Zone. Both structures are thought to be currently active (Koçyiğit & Beyhan, 1999).

In the vicinity of the study area, there are also some other less prominent NE-running lineaments. One such lineament occurs to the northwest of the study area and disappears under the younger sedimentary cover of Central Anatolia to the north. Towards the southwest, this feature (indicated by open circles on Fig. 1c) is cut by the Ecemiş Fault Zone. Another lineament traverses the study area in a northeasterly direction, and extends to the northeast of Pınarbaşı for more than 180 km (indicated by filled circles on Fig. 1c). The latter constitutes a major lineament between the Taurus Mountains and Central Anatolia. As explained in the following sections, these structures seem to have exerted considerable influence on the sedimentary record of the Dikme Miocene basin.

3. Basin configuration

The Dikme basin is a NE-trending semi-trapezoidal palaeodepression, bordered on three sides by faults of various ages and natures (Fig. 2a, b). Apart from this overall geometry, the basement topography beneath the Miocene fill exhibits the details of the basin configuration (Fig. 3). This palaeotopographic diagram has been produced by plotting altitudes of the stratigraphic contacts between the basement and the fill, revealed in deeply incised valleys through the Dikme basin. Since the general dip of the basin fill is mostly horizontal away from the faulted margins, it is believed that this basement topography map accurately expresses the relief of the basin during deposition. In Figure 3, a N–S-trending major depression gently slopes southwards. To the east and west, some linear uplifts occur. In contrast, the lowest parts of the Neogene fill are abruptly terminated against basement rocks to the north and northwest. Some broadly E–W-trending irregularities to the west of Delialiuşağı are also seen (Fig. 3).

The fault zone in the southeastern margin of the basin consists of two sub-parallel segments that overlap each other for about 8 km. The northern and southern segments are called the Ağılıngedik and Delialiuşağı faults respectively (Fig. 2a). The Delialiuşağı fault has an apparent strike-slip offset. Thus, a sheetflow-dominated Miocene alluvial body to the southwest of Ağılıngedik hill has been dislocated dextrally by more than 2 km against basement ophiolites. Also, slickenlines on the sub-vertical fault surface to the northeast of Faraşa indicate a right lateral slip with a minor reverse component (Fig. 2a). Similarly, the N–S-trending contact between the Tufanbeyli autochthon and the overthrust ophiolite nappe has been dextrally displaced by the Ağılıngedik Fault by more than 10 km (Fig. 2a). This is more pronounced toward the northeast and caused a slight inclination in the Miocene sediments. In the Taslık area, just to the south of Ağılıngedik hill, onlap of the Miocene alluvial sediments against a NE-trending palaeohigh is observed. Furthermore, a coarse-grained Miocene sediment belt, with palaeocurrent pathways mostly perpendicular to the post-depositional Ağılıngedik Fault, is evident (Fig. 2a). As discussed in Sections 4.b and 4.c, these data strongly suggest that the Ağılıngedik Fault was a boundary fault during Miocene times, and was re-activated later.

The northern margin of the Dikme basin is defined by a concave-to-south vertical fault (the Karaköy Fault) with the south block downthrown (Fig. 2a). The slickenlines on the fault surface to the west of Karaköy village indicate a dominant dip-slip and a slight left lateral offset. The Karaköy fault has probably caused some tilting of the Miocene volcanoclastic sediments of about 25° toward the west–southwest, which is in harmony with left lateral oblique-slip. Through the trace of the Karaköy Fault, Miocene sediments are relatively fine-grained, and the relation of the fault with the basin fill is not clear due to thick soil cover.

The northwestern margin of the basin is characterized by both depositional and fault-defined boundaries. Onlap of Miocene proximal alluvial deposits against the basement rocks is clearly visible around

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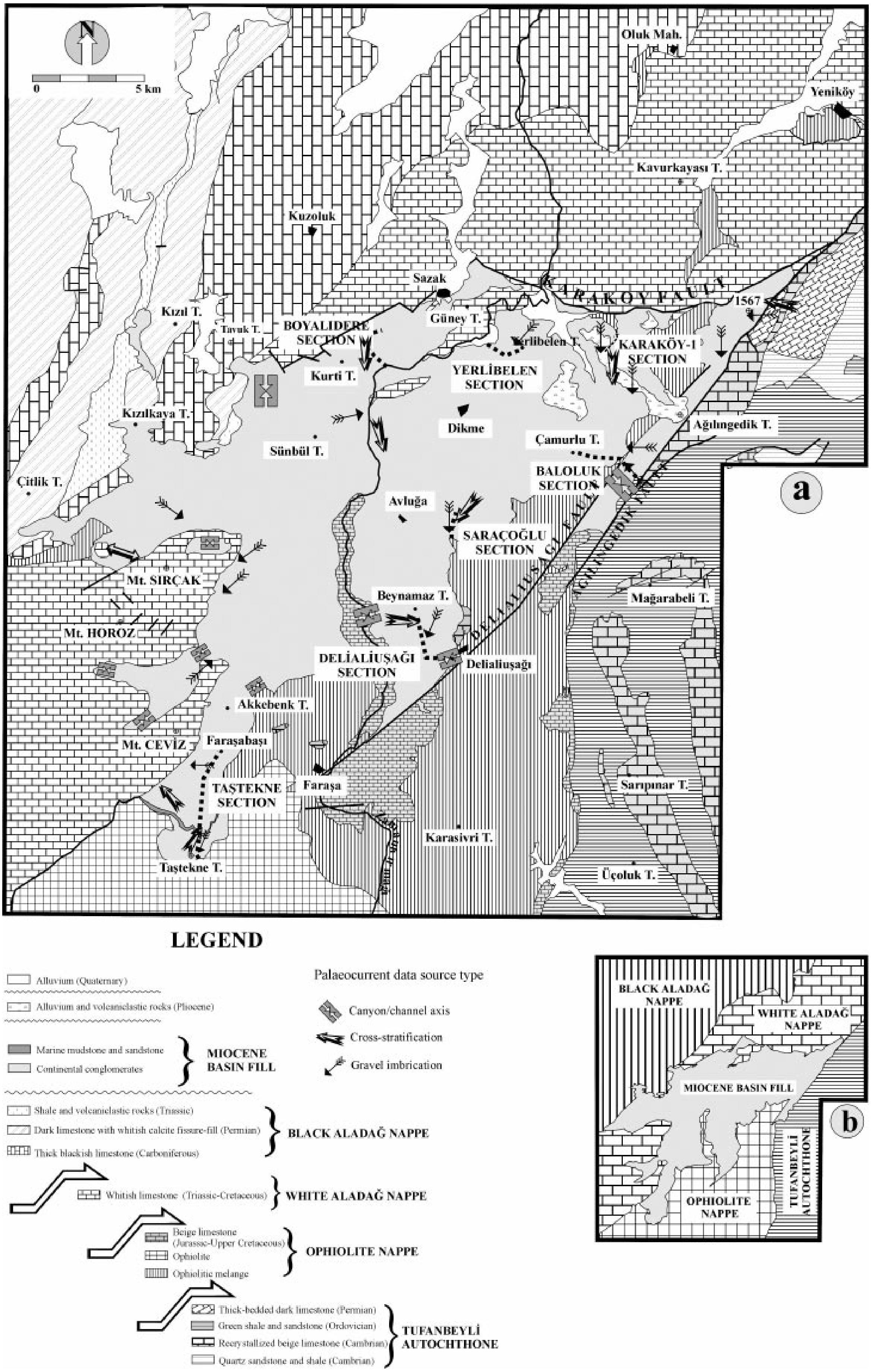

Figure 2. For legend see facing page.

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Kızılkaya Hill (Fig. 2a). Moreover, a 1 km wide N–S-trending valley-like feature filled with boulder conglomerates extends from Kızılkaya Hill and feeds the main basin fill. To the northeast of Kurti Hill, on the other hand, the contact between the basement rocks and the Miocene basin fill is tectonic in character, resulting in disturbed sedimentary packages and large-scale tilting. In a well-exposed section to the south of Kurti Hill, one can also observe tilting of the lower stratigraphic levels of the fill, below the sub-horizontal higher levels (outsized block-bearing alluvial deposits), which is an indication of episodic tectonic activity and subsequent periods of redeposition during filling of the basin (Fig. 4). Toward the western corner of the basin, 2.5 km to the southwest of Karakuyu Hill, the horizontal Miocene coarse sediments unconformably rest upon a N 55° E-running fault scarp. The fault described herein corresponds to only a limited part of a larger-scale structure with N 55° E strike, as clearly seen in Figure 1c (the lineament with open circles). It seems that this feature traverses the entire study area, and is cut by the Ecemiş Fault Zone to the southwest.

The southwestern boundaries, in contrast to the previously defined margins, yield no evidence for post-sedimentary faulting. In the southernmost area (to the south of Taştekne Hill), a N 40° E-trending tectonic contact between the Ophiolite and White Aladağ (Triassic-to-Cretaceous carbonates) nappes is unconformably overlain by Miocene sediments (Fig. 2a). Although the unconformity with the ophiolites is clearly visible, the contact with the White Aladağ Nappe is always obscured due to intense karstification across the contact. Nevertheless, scattered patches of Miocene sediments, perched in the irregular decimetre-scale karstic holes within basement limestone, were observed. Just to the west of Faraşabaşı, the contact turns sharply in an anticlockwise direction to N 30° E, and remains linear for 3 km (Fig. 2a). Northward, this lineament jumps about 2 km to the west and continues up to the north of Çalkırı Hill. In this transfer zone, the Miocene sediments onlap about 5 km southwestward against basement limestone, and fill a bifurcating palaeovalley system. To the north of Mt Sırçak, another large-scale fault trending N 50° E appears to define the palaeotopography on which deposition of Miocene coarse clastics occurred (Fig. 2a).

The basin configuration is further complicated by some secondary small-scale basinal structures, that is, palaeohighs and palaeodepressions. One of the most prominent palaeohighs is situated in the northeast, near Sazak village, and is called the Yıldız Hill uplift. This structure has a northeast trend, and extends for more than 5 km (Fig. 2a). The vertical distance between the apparent base and top of the palaeohigh measures more than 300 m, forming a sharp palaeoscarp. The Miocene sediments onlap against the palaeohigh from the west and the south, without any obvious tectonic deformation. Only some small folding at the contact occurs, probably due to differential compaction. A series of spectacular palaeohighs and palaeodepressions are also encountered through the deep canyon of the Zamantı River which crosses the study area from north to south (Fig. 2a). There, the trend of the palaeodepressions varies from east–west to northeast–southwest, and the depth attains 100–150 m. It is evident that these depressions were filled up with coarse clastics onlapping against the cliff-like margins and these have later undergone slight tectonic deformation.

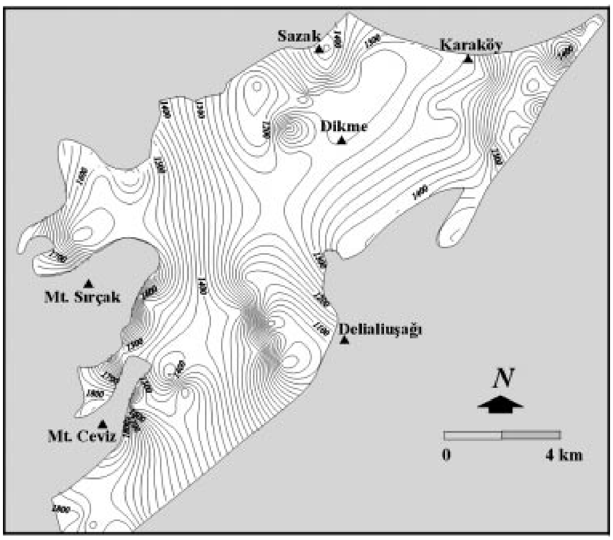

Figure 3. Sub-sedimentary fill topography of the Dikme basin (see text for explanation).

4. Nature of the basin fill

The Dikme basin is characterized by a thick pile of coarse clastics attaining an apparent maximum thickness of 815 m. Even though mudstones and sandstones are generally interbedded with conglomerates, they are only widespread in a limited area in the southwest corner (around Taştekne Hill) where they include marine fossils and are mapped as a separate member (Fig. 2a). Additionally, three members of limited extent were also recognized in the vicinity of Karaköy village. Among them, only the Karaköy volcaniclastics, more widespread than the others, are shown in Figure 2a. Seven detailed sedimentological sections and additional local sedimentological observations were carried out, in order to reconstruct palaeoenvironments and basin fill architecture (Fig. 5).

A series of major depositional features were recognized by correlation of the sedimentological logs in

Figure 2. (a) Geological map of the investigated area. Map is compiled from the archives of Mineral Research and Exploration General Directorate (MTA), and revised by the author. T. – Tepe (Hill); (b) Assignment of lithostratigraphic units to respective structural nappes.

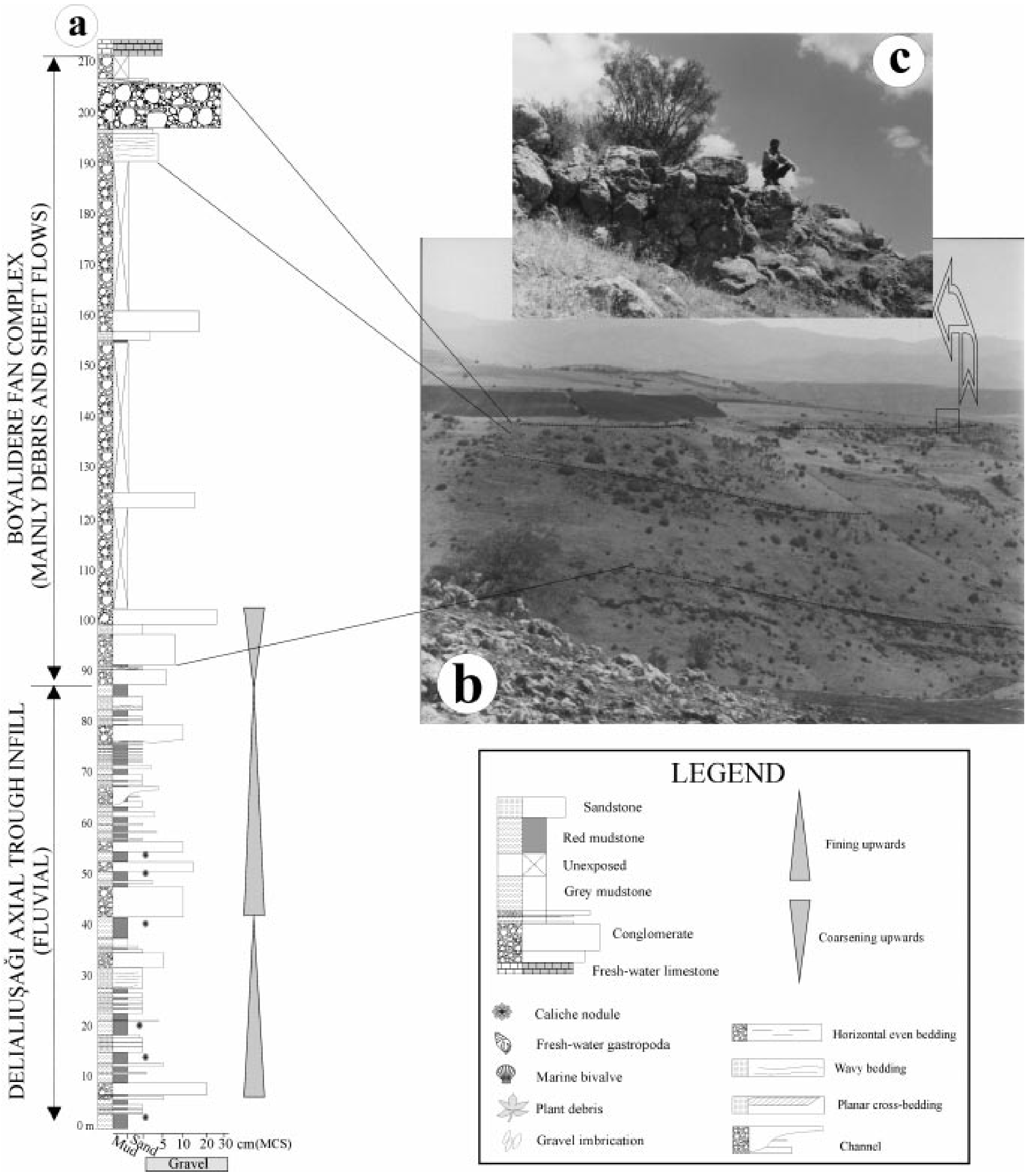

Figure 4. (a) Detail of the Boyalıdere section; (b) Intraformational unconformity within the marginal facies; (c) Boulder conglomerates above the unconformity.

combination with relict morphology, which is still in evidence. In an anticlockwise direction, these features are: (1) Delialiuşağı axial fluvial deposits, (2) Baloluk alluvial fan, (3) Ağılıngedik fan complex, (4) Boyalıdere fan complex, (5) Mt Ceviz valley-fill deposits, and (6) Taştekne marine/coastal plain sediments. In the following account, each of these features is described in detail, with special emphasis on the depositional environments, palaeocurrent data and inferred relationships with the basin margin structures.

4.a. Delialiuşağı axial fluvial deposits

The sub-sedimentary fill topography of the Dikme basin depicts a N–S-trending depression extending first toward the north, and then bifurcating to the north of Dikme village (Fig. 3). The deepest portion of this trough is located around Delialiuşağı, at about 1100 m present altitude. The oldest sediments fill a series of approximately E–W-trending secondary depressions with depths ranging from several tens of metres to 150 m. One such example is encountered at the scarp of the deeply incised Zamantı River, 5 km northwest of Delialiuşağı (Fig. 6). The depression extends to the north–northeast and is bordered by another lying further south. The southern margin of this trough is a palaeoscarp, against which the conglomerate infill passively aggrades. The pinch-outs of the conglomeratic beds show slight bending at the contact perhaps due to later tectonic activity. At the top of this depression, a

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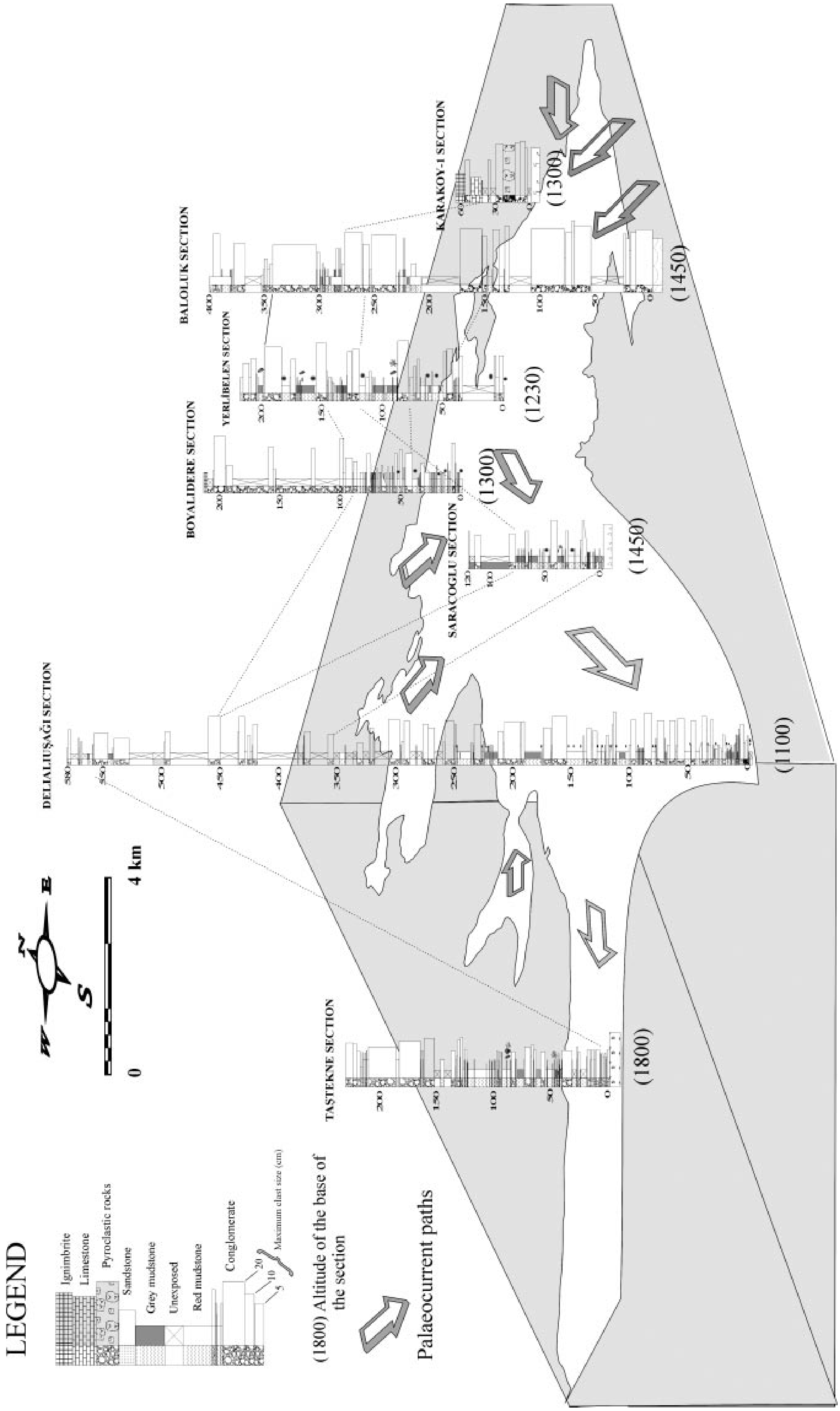

Figure 5. Correlation of the sedimentary sequences in the Dikme basin, with inferred palaeoflow paths.

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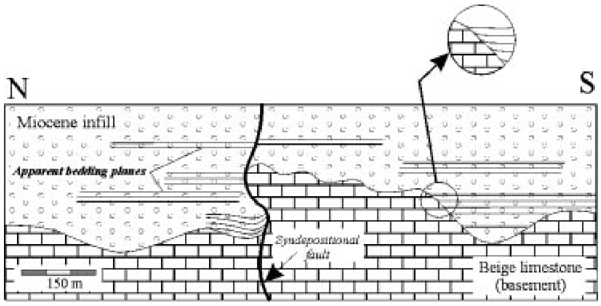

Figure 6. Field sketch of a synsedimentary depression and its fill (west of Beynamaz Hill, the eastern slope of the Zamantı valley). Note the apparent bending of conglomeratic levels adjacent to the fault and decrease of offset toward the top.

small normal offset occurs too. On the northern flank of the other depression, minor bending is evident at the tip of onlapping beds, perhaps resulting from differential compaction (Fig. 6).

The Delialiuşağı section log was recorded in another spectacular depression that is cut by the post-depositional Delialiuşağı fault from the southeast (Fig. 7a). In this section, the lowermost parts consist of thin muddy and coaly levels (which locally reach economic thicknesses), including fresh-water gastropods, and overlying matrix-supported conglomerates (Fig. 7b). Upwards, dominantly grey-coloured, fresh-water gastropod-bearing siltstone alternates with thin (50–70 cm) clast-supported conglomerate. The clasts are sourced totally from basement radiolarite and serpentinite. Between 30 and 150 m up-section, the stratigraphic record involves rhythmic alternations of conglomerate, sandstone and mudstone (Fig. 7b). Conglomerate intervals, having 15–20 cm sized, moderately rounded, polygenic clasts, are erosional at the base. These grey conglomerates are always clast-supported, and pass upward to sandstone. The latter is generally massive to crudely stratified and red in colour. The overlying mudstone (in places mudstone–siltstone–sandstone alternations) is typically red and includes thin lenses or layers of dirty whitish caliche intervals. It is evident from the panoramic view at Delialiuşağı village that this 150 m thick succession gradually onlaps against the slopes of the palaeovalley incised in the basement limestone (Fig. 7a).

The remaining part of the Delialiuşağı section continues in similar lithologies up to 170 m (Fig. 7b). At that level, a sudden change in the gravel composition occurs. While the conglomeratic unit below (between 156–168 m) consists of mostly boulder-sized, polygenic gravels, the overlying 3 m thick conglomerate is composed of well-rounded, relatively small-sized (less than 5 cm in diameter) and almost monogenic gravels (dark limestone) sourced from the Black Aladağ Nappe (Fig. 2a). Since this stratigraphic level corresponds to the top of the depression, it is suggested that the independent fluvial sub-systems in the early period of basin development came to be merged, and flowed toward the south.

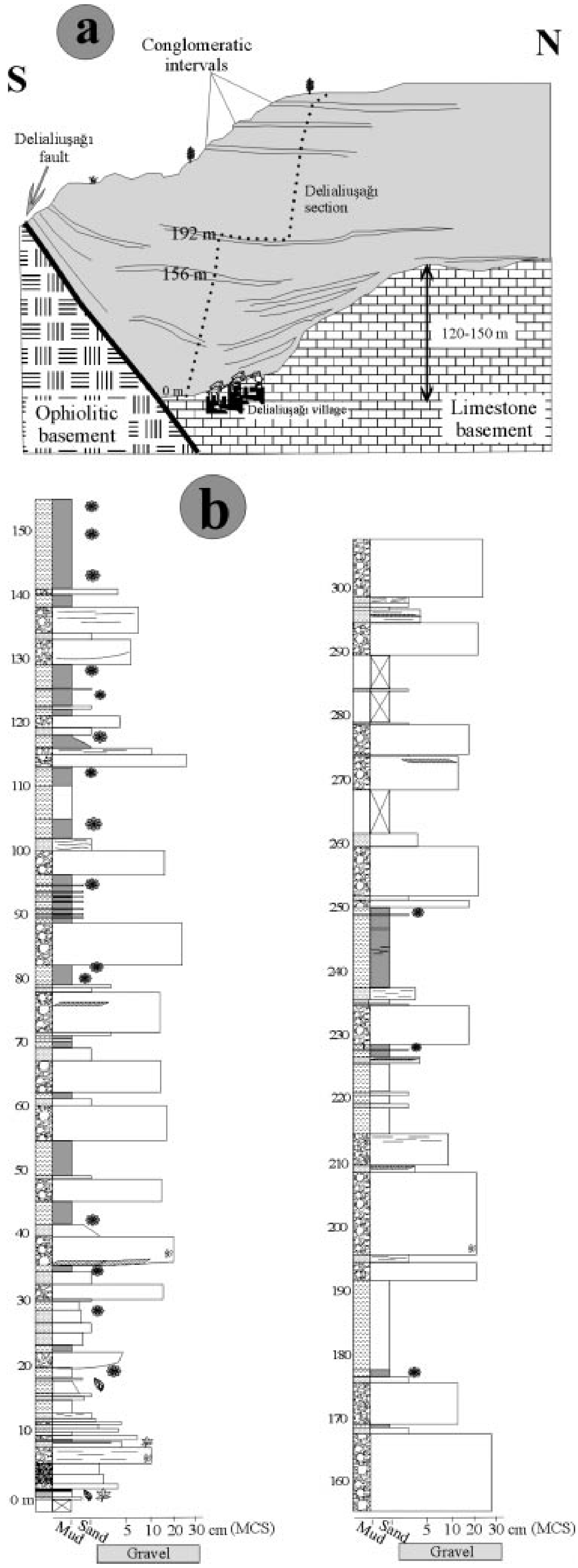

Figure 7. (a) Sketch of the Delialiuşağı palaeodepression; (b) Detail of the fill sequence (for legend see Fig. 4).

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The Yerlibelen and the lower interval of the Boyalıdere sections also constitute parts of the fluvial fill of the Delialiuşağı axial trough to the north (Fig. 5). Both are mostly composed of relatively fine-grained sediments with abundant caliche nodules and bands (Figs 4, 8). The basal intervals in the Boyalıdere section include shallow channelled conglomerate and interlayered mudstone (Fig. 4a). Most of the clasts in the gravel grade are smaller than 10–15 cm. Within the fluvial segment, there are two overall fining-upward cycles, probably reflecting tectonic activity in the feeding fans. In the Yerlibelen section, four separate conglomeratic wedges (10–15 m thick), probably the distal correlatives of the Baloluk alluvial fan system (see next section), interfinger with caliche-bearing red mudstones and fossiliferous grey/black clays (Fig. 8).

The gradual clast size decrease downstream that is expected in an ordinary fluvial system is not observed in the Delialiuşağı fluvial system. This probably requires some coarse-grained point sources contributing to the main system. In the Delialiuşağı case, this should have been achieved mostly by the Boyalıdere alluvial fan system (see Section 4.d).

4.b. Baloluk alluvial fan

The Baloluk alluvial fan is a 4–5 km wide depositional feature, which onlaps against the Tufanbeyli autochthon to the east and fans out toward the Delialiuşağı axial trough to the northwest. The lowermost sediments consist of poorly consolidated cobble-to-boulder conglomerate with thin sandstone intervals. Cobbles are platy in form and mostly angular to moderately rounded. They generally lie parallel to bedding surface (Fig. 8). Sandy interbeds in one basal level show complicated bending and ruptures probably related to synsedimentary faults (Fig. 9). A reverse-slip, probably in conjunction with NE-trending strike-slip is also observed. At 130 m up the section, laterally extensive mudstone–sandstone alternations begin to interfinger with thick (15–40 m) gravelly packages (Fig. 8). The latter are clast-supported, and range from internally massive to crudely bedded, with laterally lenticular sandy splays. The base of each package is mostly erosional on red mudstones. In rare cases, a gradual coarsening-upwards trend is also observed. The upper limit is always fining upward, which strongly suggests gradual shifting of the active clastic system. The interfingered fine-grained interval is mostly composed of massive red mudstone. Sandstone and siltstone with sharp basal contacts, and grey/green-coloured, fresh-water gastropod-bearing mudstone may also alternate with the former. In one level of gastropod-bearing mudstone (Fig. 8, 292 m), teeth belonging to an adolescent crocodile were obtained. It is suggested that such crocodile teeth characterize the Early Miocene, and mark fresh-water conditions at that level (G. Saraç, unpub. data, 2000).

On the base of the sedimentary properties, the interval between 0–135 m is interpreted as colluvial deposits (gravity driven deposits, mainly rockfall and probably related non-cohesive debris flows). The succeeding section represents the repeated accumulation of water-laid alluvial fans (dominantly conglomeratic packages) and overlying overbank fines (mudstone dominated interval) (Fig. 8).

4.c. Ağılıngedik alluvial fan complex

A grey-coloured conglomeratic body crops out on the southern slope of Ağılıngedik Hill and extends toward the unnamed hill of 1567 m altitude to the northeast (Fig. 2a). The apparent thickness of the body is more than 250 m. There is one interval of red mudstone (with thin plant debris bearing sandstone lenses) 12 m thick, which separates the conglomeratic body into two packages. It is laterally widespread for about 4 km toward the northeast. The clasts of conglomerates generally consist of subrounded to rounded polygenic cobbles and boulders that were sourced from ophiolitic and metasedimentary rocks. The imbrication of clasts is common. The crude bedding with a clast-supported texture is the most frequent stratification type, although a massive appearance is not uncommon, especially where the boulders dominate. The matrix is composed of grey-coloured coarse sand to pebbles. The individual pebbly sand beds within the conglomerates laterally pinch out over several metres and show parallel or low-angle cross-bedding. The dominant palaeocurrent pattern is from east to west, though a secondary path from north to south is also indicated (Fig. 2a).

4.d. Boyalıdere alluvial fan complex

In the Boyalıdere section, which is measured by gradually shifting toward the north (the basin margin), the dual nature of the stratigraphic record is clear. A lower sand- and mud-dominated part up to 76 m, probably belonging to the Delialiuşağı axial fluvial system, is succeeded by an upper, poorly exposed, conglomeratic package (Fig. 4a). The latter is widespread toward the southwest and constitutes another coarse-grained basin margin feature, named here the Boyalıdere alluvial fan complex.

Sedimentary facies observed in the lower part clearly belong to a fluvial system whose channels are moderately deep and the overbank facies are relatively well developed. Some of the shallow channels in this part indicate supply to the south. Up the section, maximum clast size increases while the abundance of individual muddy intervals decreases (Fig. 4a). At 100 m, the sediments become mostly clast-supported, massive to crudely bedded cobble to boulder conglomerate. Rare directional data (clast imbrication, epsilon bedding and channel trend) show a palaeocurrent path

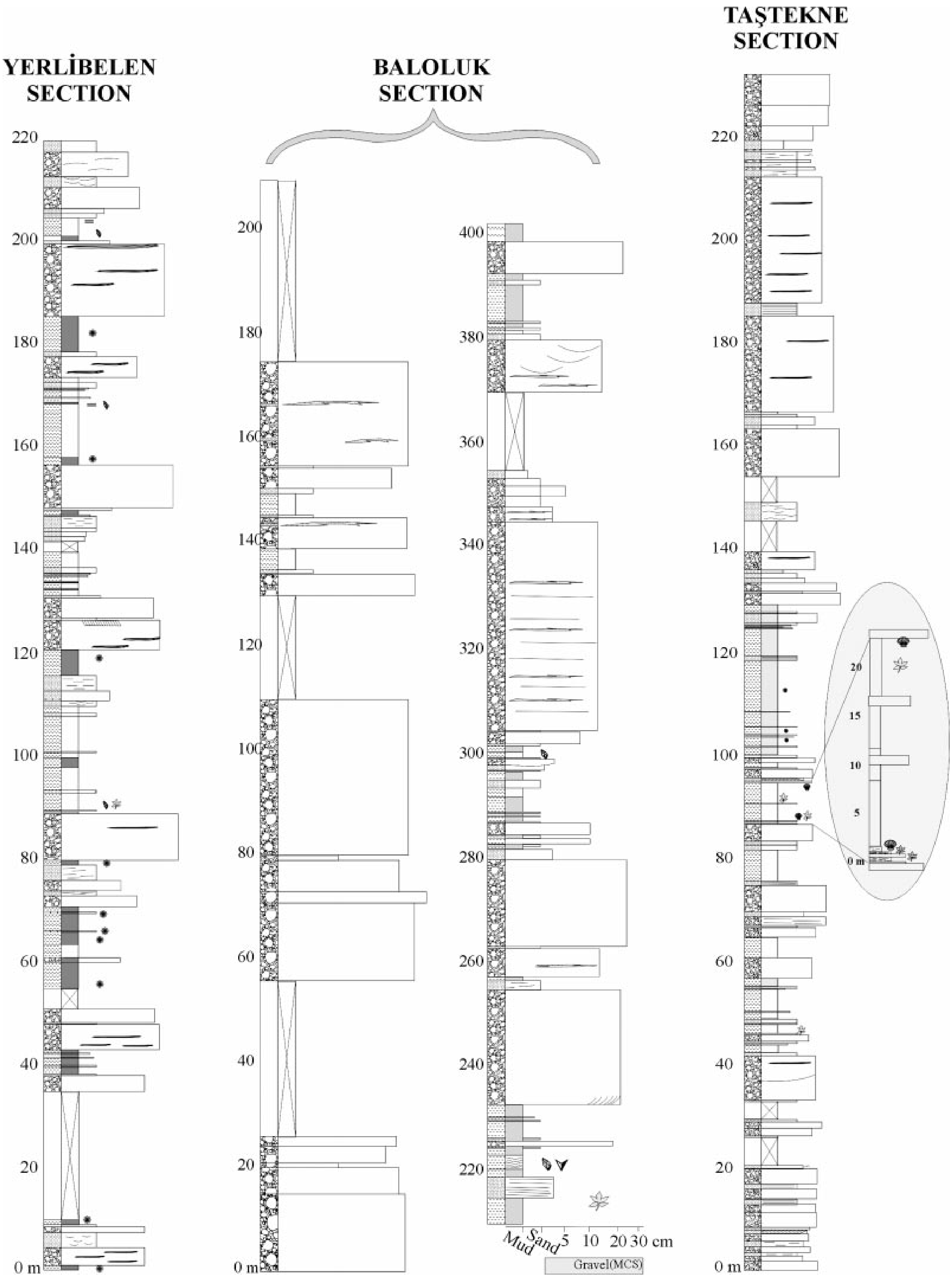

Figure 8. Selected Miocene sedimentological logs from the Dikme basin (for legend see Fig. 4).

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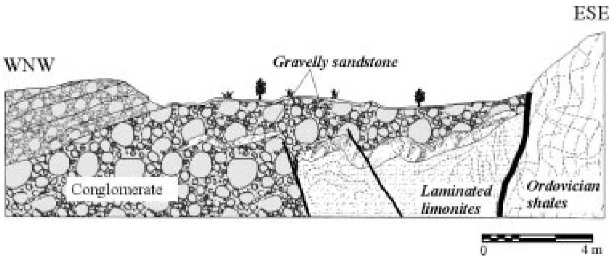

Figure 9. Field sketch illustrating synsedimentary tectonic disturbance in the basal marginal facies (base of the Baloluk section).

toward the south and southeast (Fig. 2a). A 10 m thick chaotic body of boulder conglomerates, whose components are mostly sourced from the White Aladağ Nappe to the north, overlies the uppermost part of the section (Fig. 4b). Some of the boulders in this well-cemented, clast-supported conglomerate attain 2.5 m. An angular unconformity between the sub-horizontal boulder conglomerates and the underlying tilted levels is also observed (Fig. 4c).

To the south of Kızılkaya Hill, the conglomerates of the Boyalıdere fan complex are bordered by the Mt Sırçak palaeo-uplift to the south, while the northern and western boundaries are unconformable over the Black Aladağ Nappe (Fig. 2a). In this area, the system is mostly composed of cobble to boulder-sized clasts (in places several metres in diameter), most of which are derived from the dark limestone of Permo-Triassic age. Crude bedding dominates throughout. Some levels show the characteristics of typical sieve deposits, that is, clast-supported fabric with an openwork texture. The palaeocurrent direction (mostly from the gravel imbrication) is toward the southwest (Fig. 2a).

4.e. Mt Ceviz fluvial valley-fill deposits

These are relatively fine-grained deposits that filled up a bifurcated depression carved in the Triassic–Cretaceous carbonates to the southwest, between Mt Horoz and Mt Sırçak (Fig. 2a). This depression, in fact a palaeovalley system, is divided into two branches to the southwest of the narrow basinal gorge. By using available preserved morphological data, the gradient of the valley floor is measured at about 6°. The width of each bifurcated branch probably was less than 500 m during the deposition of the Miocene sediments in the palaeovalley. Upstream, two distinct valleys within the White Aladağ Nappe can still be traced, extending from the N 60° E-trending northwest basin boundary fault.

The sedimentary fill of the palaeovalley system is dominantly composed of moderately to well-rounded gravels (mostly 3–5 cm in diameter), organized as 5–7 m thick intervals. In between, thin yellow-grey-coloured mudstone and organic-rich brownish intervals occur. In some levels thick, amalgamated, parallel, sometimes cross-bedded sandstone, with thin, laterally pinching out red mudstone is also observed. The components are rarely derived from the neighbouring beige limestone (White Aladağ Nappe), but instead were sourced mainly from dark limestone (Black Aladağ Nappe), situated to the northwest (Fig. 2a).

The nature of the Mt Ceviz palaeovalley fill system suggests that it was sourced dominantly from the tectonically uplifted distant NE-trending fault zone to the west and northwest. Since the distance between the fault zone and the site of deposition (about 10 km) is greater compared to the Boyalıdere fan system, the grain size of the former is relatively smaller and it is partly associated with mud-grade material.

4.f. Taştekne marine/coastal plain intervals

The Miocene stratigraphic record in the south of the study area is characterized by a thin marine and coastal plain interval (the Taştekne member, Fig. 2a) interfingered within terrestrial conglomerates. Up to 40 m thick in the Taştekne section (Fig. 8), massive to crudely stratified clast-supported conglomerates are dominant. In pebbly sand intervals, tabular cross-stratification is also observed. The clasts are generally well rounded and mostly smaller than 5–7 cm in diameter. Ophiolite, radiolarite, black and beige limestone comprise the main sources of the conglomerates. 3–5 m thick thinning/fining-upward sequences are common (Fig. 8). Above a 10 m thick yellowish–reddish mudstone at 47 m, the first marine interval occurs at 87 m. The fossiliferous interval begins above conglomerate with well-sorted and thoroughly burrowed sandstone. Within 50 cm, fine sands and silts with occasional carbonized wood lenses abound. One metre further above, the first marine gastropods appear within carbonaceous mudstones. After another 15 m of non-fossiliferous light grey muds with occasional carbonized wood fragments, the marine fauna (both Ostrea and Turritella forms) reappears. The fauna collected from the both fossiliferous intervals (*Crassostrea gryphoides crasississima* (Lamarck), *Terebralia bidentata* (Defrance), *Terebralia lignitarium* (Eichwald), *Terebralia lignitarium lignitarium* (Eichwald) and *Turritella* (Eichwaldiella)) is typical of the Middle Miocene (probably Langhian) throughout the Taurus belt from Antalya to the Mut basin, and indicates shallow marine conditions (Y. İslamoğlu, unpub. data, 2000).

Overlying the marine interval, a 2 m thick fining-upwards conglomerate and 25 m thick red mudstone (with light grey intervals) occur. Within the mudstones, caliche horizons and laterally widespread thin sandstones are common. The section terminates with a thick package of fining-upwards conglomerate (Fig. 8).

From the limited areal extent and small thickness of the marine and associated terrestrial facies, the Taştekne section probably corresponds to a short-lived marine incursion over a coastal braid plain. Since the marine interval cannot be traced northwards, and is overlain by fluvial sediments, it is suggested that the Middle Miocene sea approached from the south, and was not capable of moving further northwards due to the heavy coarse clastic influx.

5. Toward a model of the Dikme basin

The integration of the structural data and the sedimentological observations with the sub-sedimentary fill topography furnishes the basis for a basin model in the Dikme area.

Although the present configuration of the area resembles a pull-apart basin, the field data, and especially the timing of the Karaköy fault to the north, do not support this idea. Moreover, the sedimentary characteristics of the fill in the Karaköy area do not display any direct fault control. Instead, the whole area seems to have experienced block faulting during Miocene times. Relatively reliable structural data from the N 55° E-striking lineament to the northwest suggest that it formed a basin-bounding feature during Miocene sedimentation (Fig. 2a). The boulder conglomerates (the Boyalıdere fan complex) accompanying the lineament as it is traced to the south, the NE-trending palaeoscarps overlain by conglomerates, and especially the intraformational unconformity within the basin fill all strongly suggest a synsedimentary tectonic control at this margin. Within the basin, the NE-trending palaeo-uplift between Güney Hill and Mt Sırçak constitutes another expression of block faulting (Fig. 2a). The steep slopes to the south of this uplift effectively result from greater subsidence toward the centre of the basin. The east margin of the Dikme basin seems to have been controlled by another fault. Some clues obtained from the base of the Baloluk section also show a significant strike-slip component. The distribution of the coarse-grained wedges (the Baloluk fan and the Ağılıngedik fan complex), their onlap against the steep cliff of basement rocks, the palaeocurrent data, and an overall fining toward the basin centre, are all consistent with a basin margin tectonic feature to the east (Figs 2a, 8). In addition to these main basin margin controls, the smaller scale depressions and uplifts with easterly and northeasterly trends within the basin are partly related to synsedimentary tectonics (Figs 6, 7a).

To the south of the area, the contact between the White Aladağ Nappe and the Dikme basin fill has a northeasterly trend, concordant with the previous structures (Fig. 2a). The Mt Ceviz palaeo-valley also runs parallel to the nearby marginal structures and merges into the basin at the intersection of two secondary faults.

Moreover, the distribution of the depositional features and the tectonic controls are intimately related (Fig. 10). The interpreted alluvial fan complexes accompany the west and east margin structures, and show an overall fining toward the basin centre. In the central part of the basin, the Delialiuşağı axial fluvial system, including temporary stagnant fresh-water bodies, transported sediments toward the south. The Mt Ceviz palaeo-valley system added relatively finer, far-travelled sediments to the main fluvial system, and these then flowed together toward the south. The Taştekne marine intercalation represents a short-lived transgression from the south, and is buried under the continued heavy influx of the Delialiuşağı axial fluvial sediments (Fig. 10).

6. Discussion

The depositional history of the Dikme basin delineated above provides a rare opportunity to improve the current understanding of the hinterland of the Miocene Adana Basin and adjacent troughs. Regional synthesis currently suggests that the Adana Basin was a depression initiated in the Early Miocene and filled throughout the Middle Miocene (up to Tortonian) in a broadly transgressive pattern (Yetiş & Taner, 1987; Görür, 1992; Williams *et al.* 1995; Gürbüz, 1999). It is widely agreed that during deposition of the lowermost continental clastics (Early Miocene) and the Mid-Miocene deep sea fans of the Adana succession, the principal source area was situated to the north (Gökçen *et al.* 1988; Görür, 1992; Gürbüz, 1999). In accordance with these observations, Kelling *et al.* (1987) demonstrated that deeper depositional environments were widespread to the southeast, in the Misis Complex. However, there has been a tendency to fix the northern margin of the Miocene Adana Basin on a line corresponding more or less to the southern flanks of the Taurides range (Yalçın & Görür, 1992; Gürbüz, 1999). Some remote provenances were implied from studies of detrital mineralogical composition (Görür, 1992; Gürbüz & Kelling, 1993), but the Miocene palaeogeography of the Adana basin hinterland has remained almost unknown, although Uçar, Kerey & Yetiş (2001) have described Oligo-Miocene terrestrial clastics (sediments of braid and meandering rivers and lakes) to the west, along the Ecemiş Fault Zone. The present study of the Dikme basin demonstrates that a south-flowing drainage system was carved into the hinterland as much as 40 km north of the apparent margin of the Adana Basin. As one branch of a south-flowing drainage system, the Dikme area was not simply a source area, but also a fault-controlled basin through which substantial amounts of terrestrial material were transported southwards, although some remained trapped. In this respect, if there is a provenance link, logical similarities in mineralogical composition and in mean grain size should exist between the Dikme and Adana basins. Within the axial fluvial

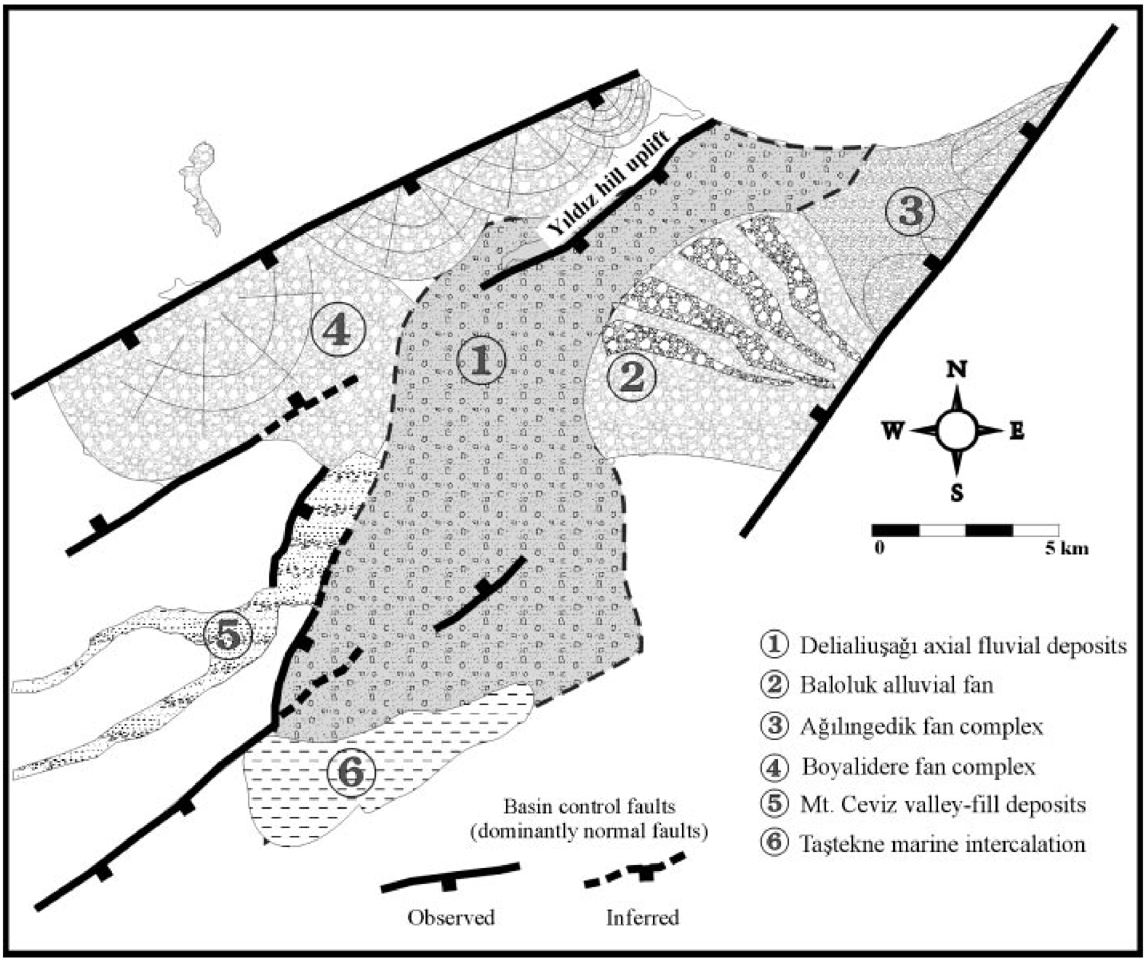

Figure 10. Model of reconstructed depositional and palaeotectonic features of the Miocene Dikme basin.

system of the Dikme basin, components are mostly sub-rounded to rounded, generally 10–15 cm in diameter, and composed dominantly of dark and white limestone, with lesser amounts of radiolarite and ophiolite. In the Adana Basin, the Early Miocene terrestrial to fan-delta clastics consist mostly of pebble-sized sub-rounded to rounded white and dark carbonate fragments (Görür, 1992). Moreover, the inner fan valley-fill facies of one of the Langhian deep sea fans, situated almost directly south of the Dikme basin, is dominated by very well-rounded gravel to pebble conglomerates, rich in detrital carbonates (Naz, Çuhadar & Yeniay, 1991). Although totally qualitative, these data help to substantiate a possible connection between these two basins.

The short-lived marine transgression (Langhian) identified in the south of the Dikme basin constitutes stronger evidence of connection with the marine-dominated southern basins. Since this marine facies dies out further north in the Dikme basin, it suggests that the transgression arrived from the south. In Langhian times, the Adana Basin experienced a rapid relative sea-level rise that shifted depositional environments from shelf to basin (Naz, Çuhadar & Yeniay, 1991; Gürbüz, 1999). As a result, the onset of deep-sea fan deposition occurred in a transgressive context and mainly under the control of tectonic uplift in the hinterland (Gürbüz, 1999). It seems that the signature of this relative rise of sea-level corresponds to the thin marine/coastal plain interval overlying the braid-river gravels in the Dikme basin (Fig. 8).

In addition to this palaeogeographic aspect, the Dikme area is also promising for a better understanding of tectonic controls on the development of the basins to the south. The extensional tectonics controlling deposition of Early–Middle Miocene sediments in the Adana basin was previously documented (Ünlügenç, Williams & Kelling, 1992; Williams & Ünlügenç, 1992; Williams *et al.* 1995; ITU, 1998). However, the geographic extent of this tectonic regime in the hinterland is poorly known, and this point seems to be a problematic subject from which at least two contrasting geodynamic hypotheses are derived. Williams *et al.* (1995) considered the Adana Basin as initially a foreland basin developed in front of the south-verging Tauride thrust sheets. This means a compressional realm existed high in the Taurides range during early Miocene times. Another hypothesis regards the Adana Basin as a fore-arc basin north of the Cyprus trench where extension is more widespread and related with

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the downward and backward migration (roll-back) of subducting African slab (Eaton & Robertson, 1993; Dhont, Chorowicz & Yürür, 1999). The extensional or transtensional tectonics identified as a major control in the Miocene Dikme basin seem to support the second hypothesis. As yet unpublished data collected by the present author from the north of Dikme, between Develi and Pınarbaşı (Fig. 1b) also indicate the influence of extensional tectonics all over this region from Middle Miocene to Pliocene times. Geodynamic evaluation of the Central Anatolian Volcanic Province (CAVP) to the west of the Ecemiş Fault zone produced very similar conclusions (Toprak & Göncüoğlu, 1993). Those authors determined a NE- to ENE-trending Middle Miocene–Early Pliocene extensional fault system and the related formation of basins where continental sediments and interlayered ignimbrites were deposited. It seems that the information drawn from the Dikme basin helps to close the geotectonic gap between the southern basins and the Central Anatolian Volcanic Province, and shows that there is continuity of structural styles in these two regions, without any intervening compressional realm.

7. Conclusions

Sedimentological and structural analyses, combined with the study of relict morphology, have elucidated the history of a fault-bounded sedimentary basin, the Dikme basin, of Early–Middle Miocene age, located northeast of Aladağ Mountain, south Turkey. The main structural style controlling the deposition in the Dikme basin is a widespread block faulting, although some evidence for strike-slip movement was also substantiated. Adjacent to active border faults to the east and west, sheet- and debris flow-dominated alluvial boulder conglomerates accumulated. In places, intraformational unconformities also developed. As indicated by the palaeocurrent data and the overall facies changes, the marginal alluvial fan bodies prograded toward the centre of the basin, where a series of NE-striking depressions and uplifts roughly parallel to the border faults determined the basin floor topography, and focused fluvial sedimentation. This axial fluvial system flowed generally to the south, and ultimately merged with another confined fluvial system incised into the basement carbonates to the southwest. During the Langhian age, a marine inundation from the south deposited a thin interval of coastal deposits that include marine fossils and carbonized wood fragments, overlain by further fluvial conglomerates. The proposed palaeogeography and basin fill model demonstrates that the Dikme basin and similar Miocene remnants, all controlled mainly by a northeast-trending tensional or transtensional fault system, may have been parts of the terrestrial hinterland that supplied sediment to rapidly subsiding marine areas further south, such as the Adana Basin.

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