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Sedimentology and Miocene-Pliocene depositional evolution of the stream-dominated alluvial fan deposits at circum-Sultandağları region

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Research Article

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Yalvaç Basin, Ilgın Basin, Braided River, Meandering River, Forced Regression.

ABSTRACT

Yalvaç and Ilgın basins surrounding Sultandağları were opened due to the orogenic collapse in the early Miocene. The NW-SE trending Çakırçal and Akşehir fault zones, forming boundaries with these basins, caused both the opening of the basins and uplifting of Sultandağları. During the Miocene-Pliocene period, the alluvial fans fed from Sultandağları developed on the basin margins, while the lacustrine carbonate and clastic depositions formed in the basin's interior. The alluvial fan deposits are laterally and vertically transitional with lacustrine sediments and alternate several times in the sequence. The alluvial fans, widespread in the region, consist of debris flow, hyperconsantrated stream flood, braided river and meandering river deposits. Fan deposits that pass from high-energy fluvial facies at the basin margin to the low-energy fluvial facies towards the basin interior have been interpreted as stream-dominated alluvial fan deposits. The age data obtained from the fan deposits of the Yalvaç and the Ilgın basins show that Sultandağları concurrently feeds the alluvial fans on both flanks. Alluvial fan deposition around Sultandağları formed under the control of tectonic and climatic processes. The tectonism led to the formation of basins and source areas. Simultaneously, the climate maintained the streams to be perennial by precipitation, thus proving a continuous sediment supply to the basins. Tectonism and climate-controlled base-level changes determined the quantity of sediments carried to the basin from the source area, causing regressive or transgressive developments.

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1. Introduction

Many studies have been published in the last 50 years on the stratigraphic significance, sedimentological and geomorphological features of the alluvial fan deposits, and their identification criteria (Bull, 1977; Leeder et al., 1988; Nemec and Postma, 1993; Ridgway and DeCelles, 1993; Blair and McPherson, 1994; Harvey et al., 2005; Ghinassi and Ielpi, 2016). Such high interest in researching alluvial fans may be attributed to the fact that they are sensitive recorders of allogenic processes such as tectonism, climate and the base level changes ongoing in a basin (Blair and Bilodeau, 1988; Leeder et al., 1988; Colella and Prior, 1990; Gawthorpe and Colella, 1990; Paola et al., 1992; Nemec and Postma, 1993; Sarıkaya et al., 2015*a, b*; Yıldırım et al., 2016). The alluvial fans, which are the basin margin systems, contain traces of many processes that a basin undergoes throughout its development since its opening. Defining these processes that have developed in the basin allows obtaining main data in basin analysis and establishing the basin evolution (Miall, 1996).

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Syn-sedimentary tectonic activity is one of the most important processes controlling the basin evolution. The tectonism while on one hand provides the formation of the accommodation space by causing subsidence in the basin and the deposited fan sediments to be protected; it determines on the other hand the amount sediment supply to the basin by controlling the emergence of the source area surrounding the basin, the extent and the capacity of the drainage area, and the fluvial erosion occurring in this area. The syn-sedimentary tectonic activity thus shapes the facies types deposited at the basin margin and the depositional evolution in active extensional basins (Leeder and Gawthorpe, 1987; Alexander and Leeder, 1987). Depending on the climatic processes, the amount of precipitation falling on a basin and the evaporation occurring in the basin also control the deposition in the basin. The quantity, size and continuity of the drainage systems developed in the source area due to the precipitation are determinant on the sediment supply into the basins. The intensity of the evaporation occurring in hydrologically closed basins such as the lacustrine basins directly affects the chemical sedimentation developing in the basin.

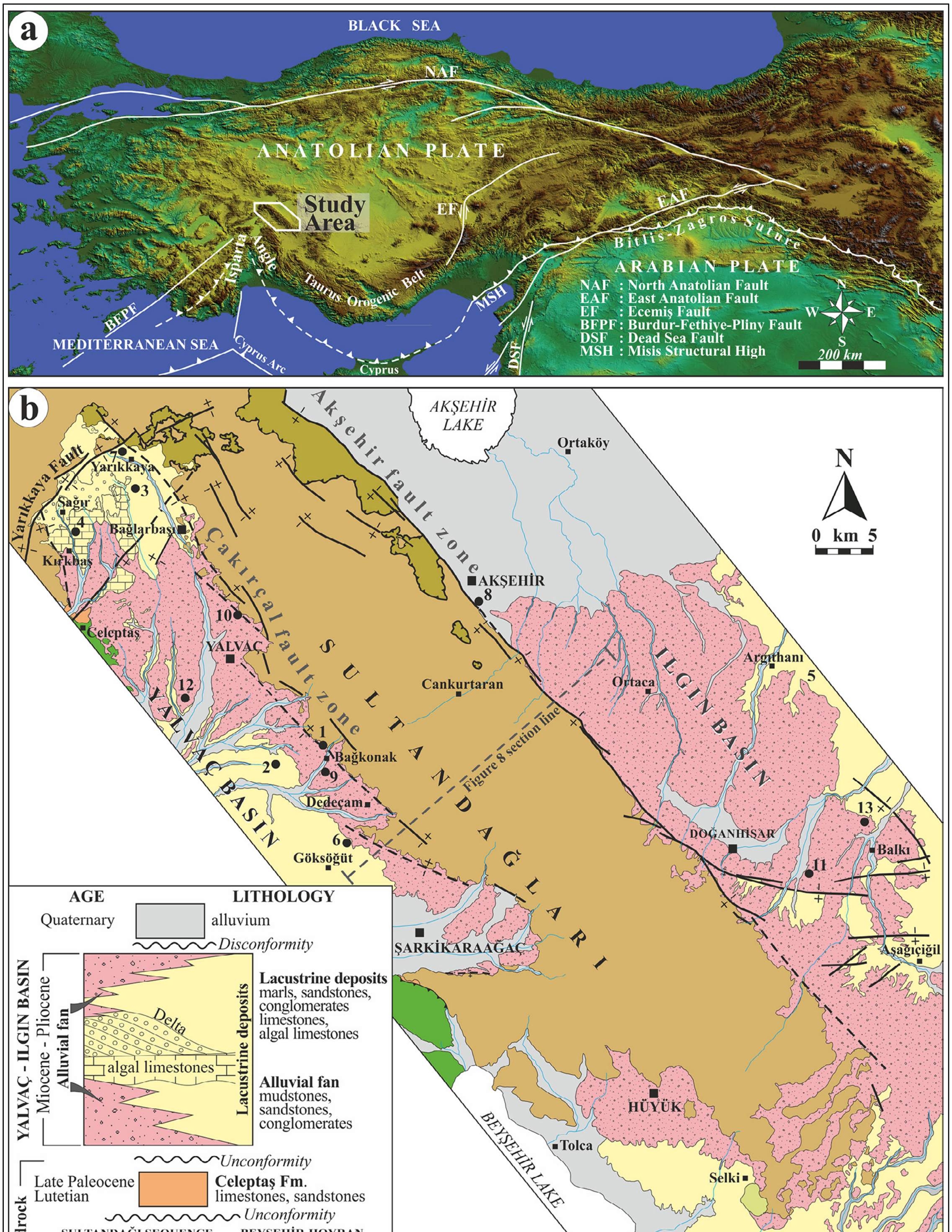
The Yalvaç Basin in the west and the Ilgın Basin in the east of Sultandağları located on the NE edge of Isparta Angle (Figure 1) started to open in the early Miocene depending on the extensional tectonic regime (Koçyiğit and Deveci, 2007; Koçyiğit et al., 2013; Koç et al., 2014; Ilgar et al., 2021). The alluvial fan and lacustrine depositions occurred in these basins in the Miocene-Pliocene period (Demirkol et al., 1977; Demirkol, 1982; Demirkol and Yetiş, 1983, 1984; Yağmurlu, 1991; Tuncer, 2020; Ilgar et al., 2021). The alluvial fan deposits constitute the first sedimentary products of Yalvaç and Ilgın basins. The alluvial fans deposited around Sultandağları with a wide spatial distribution consist of many facies and facies associations. The alluvial fans and the accompanying lacustrine carbonate and clastics deposited in basin interior alternate several times in the stratigraphic sequence. The alternation of these sediments reflects the rate and recurrence interval of tectonic subsidence-basin margin uplift and precipitation changes due to climatic processes (Alexander and Leeder, 1987; Kazancı, 1988; Astin, 1990; Carroll and Bohacs, 1999; Gawthorpe and Leeder, 2000; Changsong et al., 2001; Ilgar and Nemec, 2005; Akıska and Varol, 2020).

In this study, the sedimentary facies of the alluvial fan deposits around Sultandağları were studied in detail. The facies changes of the fan deposits from the basin margin towards the basin interior were determined, and the Miocene-Pliocene tectono-stratigraphic evolutions of the Yalvaç and Ilgın basins surrounding Sultandağları were revealed. In addition to the sedimentary processes prevailing in the basin, the control of the tectonism- and the climate-controlled water level changes and sediment supply over the sedimentological and paleogeographic development of basin margin sedimentation systems were also discussed.

2. Regional Geological Setting and Stratigraphy

The Yalvaç and Ilgın basins are intramontane molasse basins and it is considered that these basins were opened due to the orogenic collapse in the early Miocene after nappe emplacements in the Central Taurides (Koçyiğit and Deveci, 2007; Koçyiğit et al., 2013; Koç et al., 2014; Ilgar et al., 2021). The pre-Miocene units forming Sultandağları extend in NW–SE direction between the Yalvaç and Ilgın basins and constitute the bedrock of both basins (Figure 1b). The activities of the NW–SE trending Çakırçal and Akşehir fault zones (Figure 1b) which restrict Sultandağları caused the opening of the Yalvaç and Ilgın basins, while at the same time resulting in Sultandağları to rise as a horst structure. These faults have controlled both the tectono-sedimentary development of the basins and the geomorphology of Sultandağları.

The bedrock of the Yalvaç Basin within the study area is consisted by Sultandağları Sequence, the Beyşehir-Hoyran Nappes and their common-cover Celeptaş formation (Figure 1b). Sultandağları Sequence consists of Sultandağı Unit comprising early Cambrian-Late Cretaceous sedimentary and volcanic metamorphic rocks and the overlying Çay Unit, which is constituted by Late Devonian-Late Cretaceous metasedimentary rocks (Özgül et al., 1991; Göncüoğlu et al., 2007; Güngör, 2013; Ergen et al., 2016, 2017, 2021). The Beyşehir-Hoyran Nappes, tectonically overlying Sultandağı Unit, consist of nappes represented by Mesozoic aged ophiolite, ophiolitic mélange, neritic-pelagic carbonate and clastic rocks (Gutnic et al., 1968; Brunn et al., 1971;



Location No	1	2	3	4	5	6	7	8	9	10	11	12	13
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Figure 1- Location map of the study area; a) the location of Yalvaç and Ilgın basins and main tectonic lines on the topographic view of Anatolia (SRTM image with 90 m resolution; after Jarvis et al., 2008) and b) geological map of Yalvaç and Ilgın basins around Sultandağları (simplified from Ergen et al., 2021). The numbers on the map indicate outcrop locations to which other figures of the article refer.

Özgül, 1976; Monod, 1977). The Celeptaş Formation consists of late Paleocene-Lutetian turbidites. The bedrocks belonging to Sultandağları Sequence form the bedrocks of the Ilgın Basin within the study area. Sultandağları has undergone polyphase deformation during its tectonic evolution (Demirkol et al., 1977; Eren, 1987, 1990; Özgül et al., 1991; Ergen et al., 2021).

In Yalvaç and Ilgın basins, the alluvial fans were initially deposited unconformably on the pre-Miocene rocks of Sultandağları (Figure 2a). The alluvial fan deposits mainly consist of red-brick colored conglomerate, sandstone, siltstone and mudstone in both basins. The alluvial fan sediments deposited in the Yalvaç Basin were named as Bağkonak and Kırkbaş formations (Demirkol et al., 1977; Demirkol, 1982; Demirkol and Yetiş, 1983, 1984; Yağmurlu, 1991), and the alluvial fan sediments of the Ilgın Basin were defined as Ayaslar, Belekler and Doğanhisar formations by Umut et al. (1987). Since all alluvial fan deposits around Sultandağları, defined as different formations, are parts of a common depositional process, they have been investigated under the title alluvial fan deposits circum-Sultandağları region in this study.

The alluvial fans are transgressively overlain by lacustrine carbonate and clastic rocks in both basins. The lacustrine sediments mainly consist of mudstone, marl, clayey limestone, algal limestone (Figures 2b, c, d, e), sandstone, conglomerate and coal. These units were deposited in offshore, offshore-transition, shoreface, beach, Gilbert-type delta, shoal-water delta and swamp sub-environments within the basin (Ergen et al., 2021; Ilgar et al., 2021). The facies assemblages reflecting these environments in the Yalvaç Basin were studied under the name of Göksöğüt, Madenli and Yarıkkaya formations by previous researchers (Demirkol et al., 1977; Demirkol, 1982; Yağmurlu, 1991) while the lacustrine sediments deposited in the Ilgın Basin were named as Aşağıçiğil and Derviş formations (Umut et al., 1987). However, these facies associations reflecting the sub-environments, have been defined as lacustrine deposits in this study, since they are laterally and vertically transitional and alternate several times in the sequence.

The alluvial fans and the lacustrine sediments deposited in the Yalvaç and Ilgın basins are in alternation in the stratigraphic sequence (Figure 2f) which ends with alluvial fan deposits (Figure 2g).

3. Structural Geology of Circum-Sultandağları Region

The Çakırçal fault zone and the Akşehir fault zone, respectively (Figure 1b), bound the western and eastern edges of Sultandağları. The Çakırçal fault zone forms the boundary of the bedrock units of Sultandağları and the Neogene sediments of the Yalvaç Basin (Figure 3a). This fault zone has a length of approximately 65 km in N40°-50°W direction and consists of four fault segments (Figure 1b). These segments, which extend in a parallel to sub-parallel direction with respect to the main direction, make a stepped structure by displacing in NE or SW directions. There are relay ramps between the fault segments. The plunge of slickenlines measured on faults are generally between 80°-90°. The slickenlines, vertical or almost vertical corrugation axes and chatter marks indicate normal faulting. The alluvial fan deposits around Yalvaç and the lacustrine carbonate deposits around Yarıkkaya were deposited on the footwall blocks of the Çakırçal fault zone (Figure 1b). These deposits present an onlapping geometry on fault planes and indicate that the normal faulting occurred prior to the deposition. The Çakırçal fault zone, which is one of the most important fracture systems causing the opening of the Yalvaç Basin to the southwest of Sultandağları, consists of steeply inclined faults. Pre- and syn-depositional activities of these faults caused the development of a consistent steep basin margin morphology to the north of the basin. Syn-sedimentary activities of the faults also provided with the preservation of accommodation space on the northern margin of the basin, thus giving rise to deposition of a thick sequence of lacustrine carbonates and alluvial fan deposits. The activity of the Çakırçal fault zone has also continued after the deposition. Depending on this activity, travertines were deposited on the alluvial fans through the waters from the fault zone.

The Akşehir fault zone, which is almost parallel to the Çakırçal fault zone, forms a boundary between the basement units of Sultandağları and the Ilgın Basin in the east (Figures 1b and 3b). The Akşehir fault zone, approximately 90 km long, extends in N40°W

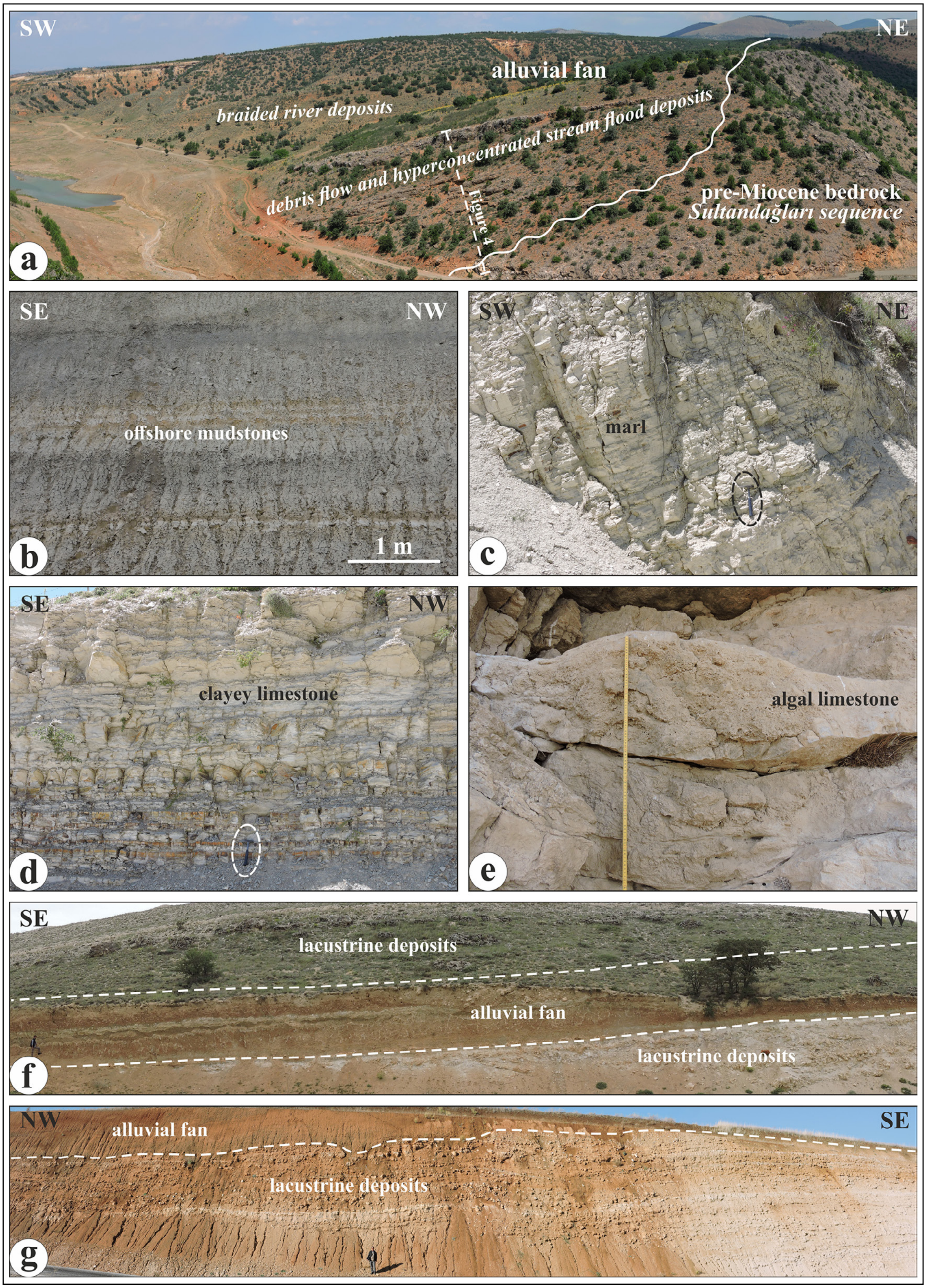

Figure 2- a) Facies belonging to alluvial fan deposits unconformably overlying pre-Miocene bedrocks of Sultandağları in the Yalvaç Basin. The section line of Figure 4 is seen on this figure. b, c, d, e) Facies belonging to lacustrine sediments transgressively overlying alluvial fan deposits, f) a repetitive view of the alluvial fan and the lacustrine sediments deposited in Yalvaç and Ilgın basins within the succession and g) alluvial fan deposits overlying the lacustrine sediments during the closure of the basins. Numbers in Figure 1b indicates the locations of the figures in the basin.

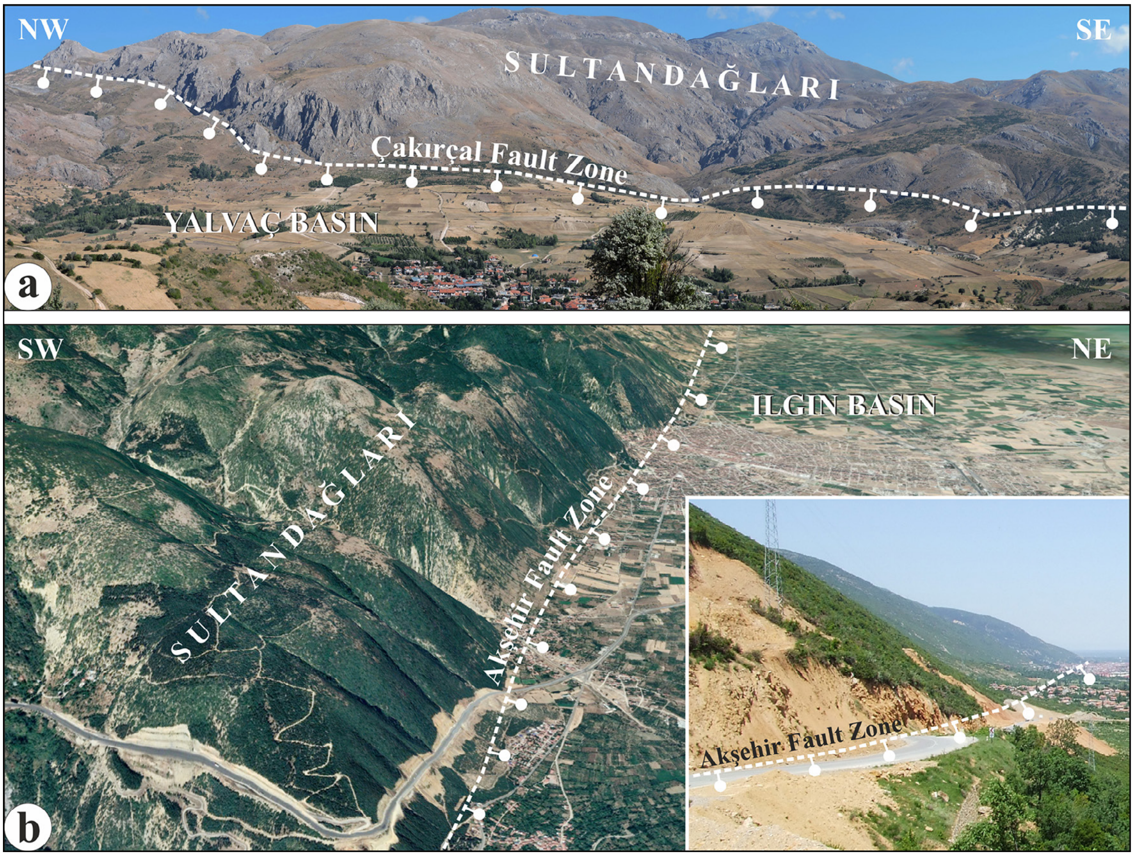

Figure 3 - A view of; a) Çakırçal fault zone forming the boundary between the bedrock units of Sultandağları and the Neogene sediments of the Yalvaç Basin in the west and b) a Google Earth view of the Akşehir fault zone forming the border of the Neogene sediments of the Ilgın Basin in the east. A photograph illustrating some parts of the Akşehir fault zone is placed in this figure. Numbers in Figure 1b indicates the locations of the figures in the basin.

direction. The Akşehir fault zone is an active normal fault and its last activity with a magnitude of Mw = 6.5 occurred on February 3, 2002 (Emre et al., 2003; Kalafat et al., 2020). With this activity, a surface rupture of approximately 26 km was formed and a vertical displacement of 30 cm occurred on this fracture (Kalafat et al., 2020). Depending on the activity of the Akşehir fault zone, the Ilgın Basin began to open. The alluvial fan sediments were deposited in front of the fault scarps within this basin. The slickenlines, vertical or almost vertical corrugation axes and chatter marks observed on the Akşehir fault zone indicate normal faulting. The onlapping geometry on the Akşehir fault zone, which has a steep basin margin morphology, indicates that the normal faulting occurred prior to the deposition, as well as the Çakırçal fault zone. With the activity of the fault in the Miocene-Pliocene period, the accommodation space on the basin margin basin was continuously preserved and a thick alluvial fan sequence and lacustrine carbonates were deposited in the Ilgın Basin.

4. Alluvial Fan Deposits

4.1. General Characteristics

The alluvial fan deposits limited by Sultandağları crop out in very large areas in the Yalvaç and Ilgın basins. The alluvial fan deposits are distributed between Bağlarbaşı and Şarkikaraağaç in the Yalvaç Basin and crop out around Hüyük in the south. In the east, these deposits crop out along Akşehir, Argıthanı, Doğanhisar and Aşağıçiğil in the Ilgın Basin. Thus, the fan deposits surround Sultandağları (Figure 1b). The fan deposits have a width of 1-7 km in the Yalvaç Basin and 3-18 km in the Ilgın Basin. While the alluvial fan deposits have an apparent thickness of approximately 300 m at their contact with Sultandağları, this thickness gradually decreases in basinward direction. The

Paleozoic-Mesozoic rocks of Sultandağları form the source areas of the alluvial fans. The drainage systems developed on Sultandağları eroded Sultandağları sequence and provided clastic material to the fan sediments. Today, the extension of the deep valleys on Sultandağları towards the basin is in compatible with the main distributary channel systems of the Miocene-Pliocene alluvial fans. The alluvial fans deposited in the Dedeçam village and around Yalvaç in the Yalvaç Basin are the best examples of this relationship (Figure 1b). This situation has been interpreted as some of the current drainage systems used the old river beds. The average difference between the recent heights of Sultandağları and the surrounding basins is over 1000 m. Since a thick delta package with Gilbert-type delta architecture was deposited on the northern margin of the Yalvaç Basin during the Miocene period (Ilgar et al., 2021), it is considered that a similar height difference between the source area and the basin floor could have also existed in the Miocene-Pliocene period as well.

4.2. Facies Assemblages

Alluvial fan deposits, which present different facies characteristics from the basin margin to the basin interior, consist of many facies and facies associations. In this study, four facies associations were defined as debris flow deposits, hyperconsantrated stream flood deposits, braided river deposits and meandering river deposits. Debris flow and hyperconsantrated stream flood deposits are observed in a narrow area in the Yalvaç Basin just in front of the fault plane that limits the basin. Although there is no outcrops, these facies are thought to have been deposited in the Ilgın Basin according to the grain size distribution of the fan deposits on the basin margin. These facies gradually pass into braided river and then to meandering river deposits in the basinward direction. The dominant facies assemblage of alluvial fan sediments deposited in the Yalvaç and Ilgın basins consists of braided river and meandering river deposits, which have similar facies characteristics in both basins. The facies assemblages were described below in detail without making any basin discrimination. The facies assemblages were defined under their interpretive genetic labels in this study as they reflect the transport-deposition environment and conditions. But their descriptions are separated from interpretations in the text.

4.2.1. Debris Flow Deposits

This facies assemblage consisting entirely of conglomerates is found together with hyperconsantrated stream flood deposits in conglomeratic sequence outcropping at the basin margin and alternates with those sediments (Figure 4). These conglomerates are generally thick bedded (120-250 cm) and the beds are planar or mound-shaped (Figure 4). The lower boundaries of the beds are nonerosional. The conglomerates, which are generally composed of medium to coarse pebbles and cobbles, have a clast-supported texture (Figures 4, 5a, b). Boulders with a size of up to 115 cm are also commonly observed (Figure 4). The spaces between the gravels are filled with sands, granules and fine pebbles. No stratification is observed within the poorly sorted conglomerates, consisting of angular, sub-angular grains, they are massive or roughly inversely graded (Figures 4, 5a, b). The pebbles that make up this facies assemblage are mostly derived from the Jurassic-Cretaceous dolomitic limestones of Sultandağları (Figure 5b).

Massive or inversely graded, clast-supported, planar or mound-shaped conglomerates have been interpreted as noncohesive debris flow deposits (Nemec and Steel, 1984; Nemec, 1990). The deposition of alluvium carried by debris flow processes, which is a dense, viscous flow, occurred due to en masse freezing (Johnson, 1984; Nemec and Steel, 1984; Kim et al., 1995).

4.2.2. Hyperconsantrated Stream Flood Deposits

This facies assemblage, which is found together with the debris flow deposits in the sequence, consists entirely of conglomerates (Figures 4, 5c, d, e). The conglomerates are generally thick-bedded (50-150 cm), and to a lesser extent thin to medium-bedded (Figures 4, 5c, d, e). The basal surfaces of the conglomerate beds are sharp and erosional with an erosion rate reaching up to 50 cm (Figures 4, 5c). It shows lenticular geometries in the parts where basal erosion is high (Figure 5e). These clast-supported conglomerates consist of fine pebble to boulder-sized grains (Figures 4a, b). The blocks with a grain size of up to 70 cm are also commonly observed in the

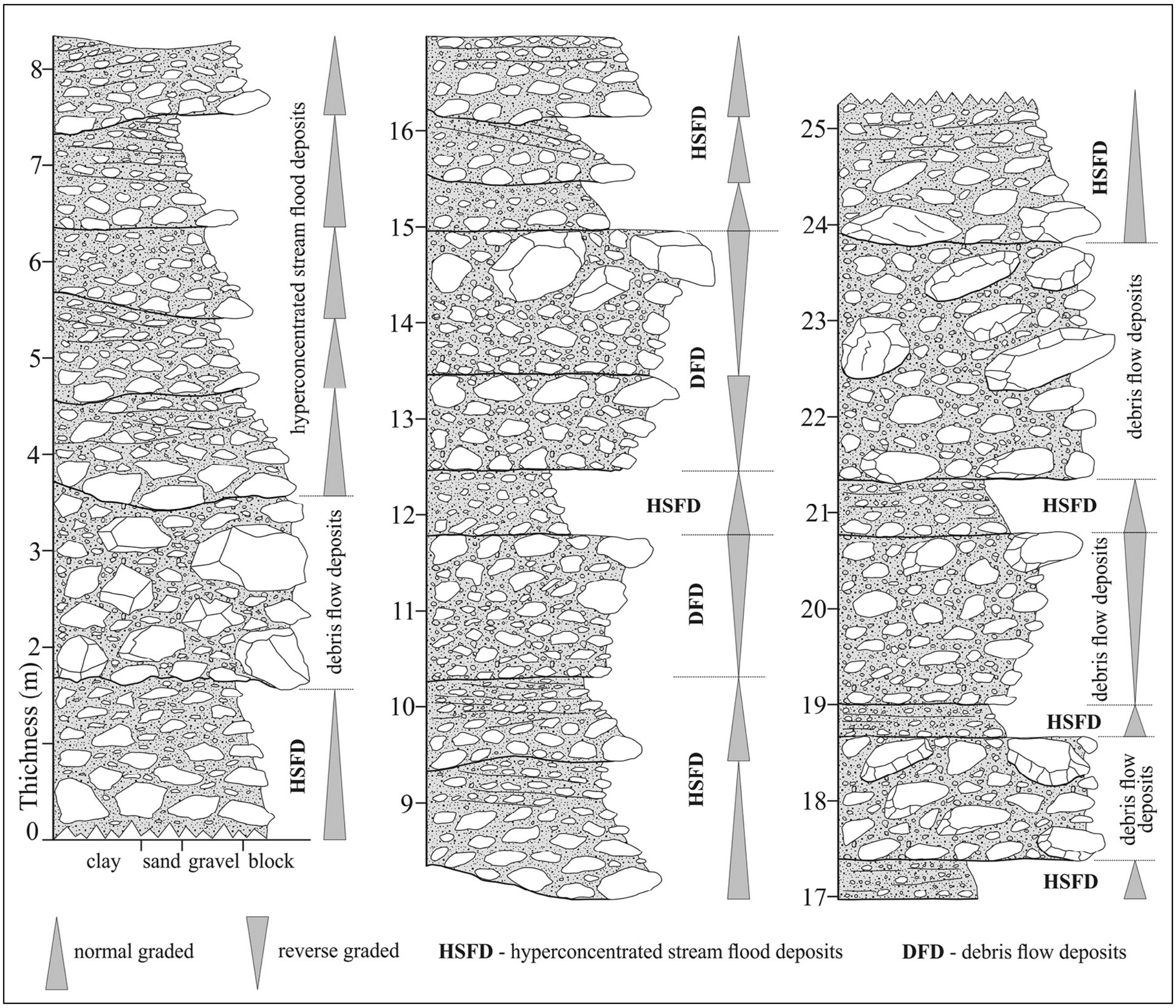

Figure 4- Sedimentological log of alluvial fan deposits outcropping in a limited area just in front of the fault plane at the basin margin of the Yalvaç Basin and consisting of debris flow and hyperconsantrated stream flood deposits. This section is taken from location 1 in Figure 1b.

rocks. The interstitial spaces between the pebbles are filled by sands and granules. The conglomerates defined within this facies assemblage consist of angular, sub-angular and slightly subrounded grains, and are generally poorly sorted. No stratification is observed in thick-bedded conglomerates, however; it has a weak or well-developed normal grading (Figures 4, 5c, d, e). Particularly in the uppermost parts of the normal graded conglomerates, a significant reduction in grain size is observed (Figure 5e). The thinner bedded conglomerates, generally normal-graded, consist of fine to coarse pebbles (Figures 4, 5e). These conglomerates, a generally normal-graded, starting with cobble-sized gravels on erosional bottom surfaces and the grain size passes into granule to fine pebble upwards (Figure 5e). In the middle-upper parts of the conglomerates, planar parallel- and planar cross-stratifications are observed. The gravels forming this facies association are mostly derived from the Jurassic-Cretaceous dolomitic limestones of Sultandağları in the Yalvaç Basin, and from the Paleozoic-Mesozoic quartzite, marble and schists in the Ilgın Basin.

It is thought that since the thick-bedded and clast-supported conglomerates described within this facies assemblage have lenticular geometries, erosional bottom surfaces and normal grading, they indicate very strong fluvial bedload deposits that can cause erosion. These thick-bedded conglomerates have been interpreted as hyperconsantrated stream flood deposits

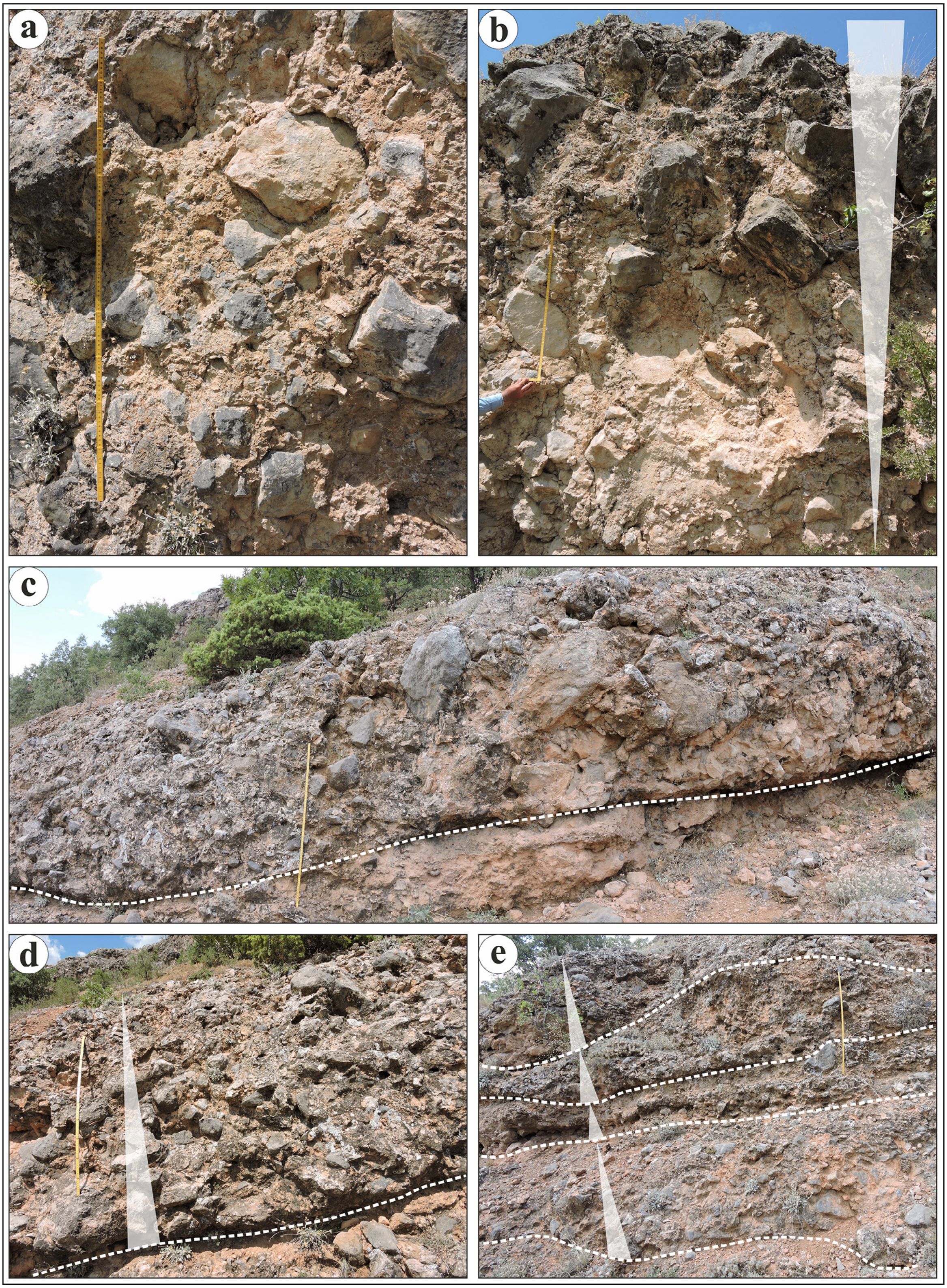

Figure 5- a), b) Debris flow deposits consisting of medium-coarse pebble to boulder conglomerates deposited at the basin margin just in front of the fault plane. The conglomerates are a) massive or b) inversely graded. Thick bedded hyperconsantrated stream flood deposits found in the sequence with debris flow deposits have, c) erosional bottom surfaces and d, e) normal grading, e) erosional lenticular geometries are observed in fine to medium pebble, thin to medium-bedded conglomerates. Numbers in Figure 1b indicates the locations of the figures in the basin.

(Nemec and Muszyński, 1982; Ballance, 1984; Wells, 1984; Todd, 1989; Sohn et al., 1999). The flows forming these deposits have a high viscosity flow rheology between Newtonian fluid and Bingham plastic (Nemec and Muszyński, 1982). Hyperconsantrated stream flood deposits have a rheology between debris flows and river flows and represent a transitional facies between these flows (Nemec and Muszyński. 1982; Ballance, 1984; Nemec and Steel, 1984; Wells, 1984; Todd, 1989; Sohn et al., 1999). Therefore, massive or inverse graded deposition reflecting debris flow processes or well-developed parallel cross-stratification reflecting grainflows in rivers has not been developed in these deposits. The fact that thin- to medium-bedded conglomerates found together with thick-bedded conglomerates having erosional bottom surfaces, normal grading, planar parallel and planar cross-stratification in the uppermost parts of the beds indicate a transport in river channels as bedload and a deposition (Todd, 1989; Collinson, 1996; Miall, 1996). Planar parallel- and planar cross-stratified conglomerates defined in the upper parts of these deposits form bar deposits (Smith, 1974; Boothroyd and Ashley, 1975; Miall, 1985; Nemec and Postma, 1993). The thin-bedded planar parallel cross-stratified conglomerates were deposited at the uppermost parts of thick-bedded conglomerates due to the decrease in the grain concentration in the flow due to the deposition from hyperconsantrated stream flood flows.

4.2.3. Braided River Deposits

This facies assemblage is observed in the sequence as multistorey fluvial channel deposits (Figures 6a, b). The channel deposits possess a large scale erosional bottom surface and lenticular geometry in sections parallel to the basin margin (Figure 6a). In sections perpendicular to the basin margin, it is observed as planar-bedded with basinward inclination (Figures 6c, d). The width of the channel deposits reaches 50 m and the erosion rate on the bottom surfaces reaches up to 5 m in places. In addition, the smaller scale channel deposits have also been identified within the sequence. The braided river facies assemblages consist of channel lag deposits and channel bar deposits.

Channel Lag Deposits: The channel lag deposits underlying the channel bar deposits on uneven erosional surfaces are observed as a single or as several rows of gravels (Figures 6b, e, f). These sediments, which are laterally discontinuous, consist of sub-rounded to rounded, coarse pebbles to cobbles and, in places, boulders. These clast-supported lag deposits lacks stratification and the interstitial spaces is filled by coarse sand, granule and fine pebbles.

The thin-bedded conglomerates located on erosional paleochannel bases have been interpreted as the channel lag deposits (Miall, 1985; Nemec and Postma, 1993).

Channel Bar Deposits: The channel bar deposits, predominating the alluvial fan sequence, are mainly composed of conglomerates and a lesser amount of and sandstone and pebbly-sandy mudstones (Figures 6a, b, e, f). The conglomerates consist of angular to sub-angular, mostly bladed, to a lesser extent rod- and spherical-shaped, fine to coarse pebbles, which are mostly derived from metamorphic rocks and limestones. The conglomerates have a clast-supported texture and are moderately sorted. The interstitial spaces between the gravels is filled with coarse sand and gravel. Conglomerates have a bedding thickness of 15-45 cm and are planar parallel stratified or planar cross-stratified (Figures 6a, b, e, f). The stratifications within the beds are recognizable by differences in grain size, sorting and matrix. Conglomerates pass upwards into brick-colored, granule to fine pebbly, medium to coarse grained sandstones (Figures 6e, f). These low-angle planar cross-stratified sandstones have a thickness of 10-30 cm and are laterally discontinuous due to the erosion of the overlying new channel deposits. Conglomerates and sandstones form fining-upward bedsets which are bounded by the erosional surfaces at the top and the bottom, by being deposited upon one another (Figures 6a, b, e, f).

The fining-upward bedsets bounded by erosional surfaces were interpreted as the channel fill deposits of braided rivers (Collinson, 1996; Miall, 1996). These river channels form distributary channels on alluvial fans. The planar parallel-stratified and planar cross-stratified conglomerates within the channel deposits form longitudinal, transverse or oblique bar deposits in braided rivers (Smith, 1974; Boothroyd and Ashley, 1975; Miall, 1985; Nemec and Postma, 1993). The sandstones observed in the upper parts of bar deposits

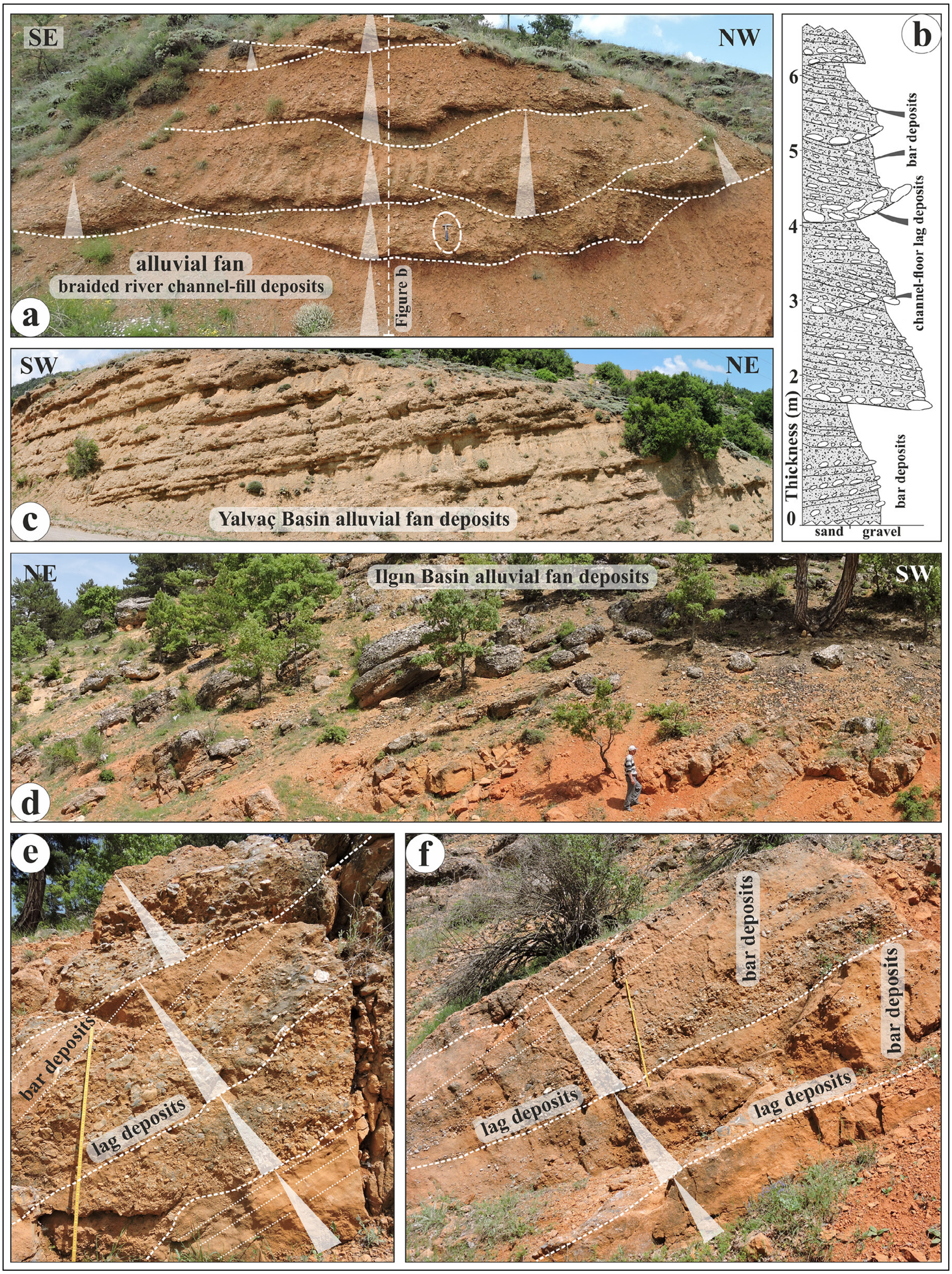

Figure 6- Braided river channel deposits of alluvial fans are deposited in the Yalvaç and Ilgın basins; a) these deposits have lenticular geometry in sections parallel to the basin margin, b) channel floor lag and bar deposits are seen on the sedimentological log of the braided river sediments. The section line is shown in Figure 6a. c), d) Braided river sediments consist of planar-bedded deposits with basinward inclination in the sections perpendicular to the basin margin and e), f) channel deposits, which are overlain by planar parallel or planar cross-stratified bar deposits, start with channel floor lag deposits in the form of a single or several rows of gravel on the erosional surfaces. Numbers in Figure 1b indicates the locations of the figures in the basin.

were interpreted as transverse bar sediments deposited due to small currents in periods when the alluvial fan distributary channels migrate laterally and hence their strength decreases (Miall, 1985).

4.2.4. Meandering River Deposits

The meandering river deposits defined in the distal part of the alluvial fan system consist of red-brick colored conglomerate, sandstone, siltstone and mudstone (Figure 7). Within this facies assemblage, the point bar deposits, chute deposits and flood plain deposits have been defined.

Point Bar Deposits: Point bar deposits, which are mainly composed of sandstones and conglomerates, have erosional bottom surfaces and the rate of erosion reaches 1.5 m in places (Figures 7a, b). Groove marks are often observed on erosional surfaces. Point bar deposits start with a laterally discontinuous isolated gravel beds on the uneven erosional surfaces. These

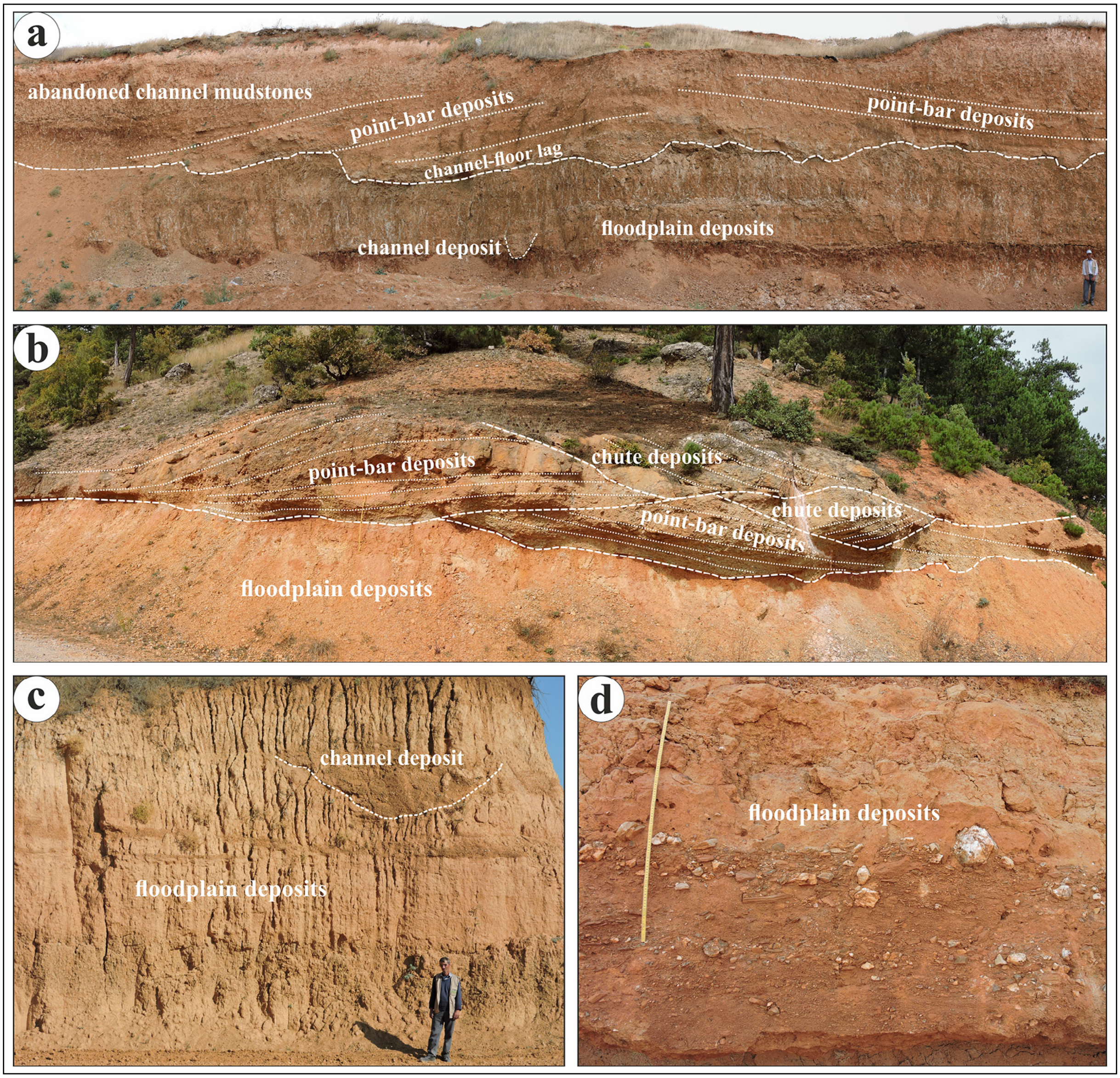

Figure 7- Meandering river sediments identified in the distal parts of alluvial fans are composed of red-brick colored conglomerate, sandstone, siltstone and mudstone. Point bar and floodplain deposits of the meandering rivers from; a) Yalvaç and, b) Ilgın basins. Chute deposits consisting of planar cross-stratified conglomerates can be seen upon the point bar deposits with a diagonal erosional surface, c), d) floodplain deposits consisting of alternation of planar horizontal bedded, light brown-brick mudstone, siltstone and sandstone above and below the point bar deposits. Numbers in Figure 1b indicates the locations of the figures in the basin.

sediments, which consist of medium to coarse pebbles and have a clast-supported texture, form the channel-floor lag deposits. These lag deposits lacks stratification and the interstitial spaces is filled by medium to coarse sand and granules. Point bar deposits placed on the channel-floor lag deposits consist of sandstones, pebbly sandstones and conglomerates (Figures 7a, b). Point bars observed as planarly inclined and sigmoidal geometry in cross sections have a bedset height reaching 2.5 m and inclination angles varying between 15°-25° (Figures 7a, b). As they have a sigmoidal geometry, the slope angles of the point bars decrease in the upward and downward directions and pass tangentially to the stream floor (Figure 7b). These beds are generally planar parallel and occasionally planar cross-stratified. Point bar deposits developed in different directions and separated from each other by erosional surfaces can be observed in the sequence (Figures 7a, b). The inclinations, bedding thickness and grain size of the point bar deposits gradually decrease in dip direction in the channel and these deposits pass into horizontal and very thin-bedded sandstone, siltstone and mudstone (Figure 7a).

Sigmoidal point bar deposits determined in the meandering river deposits have been interpreted as meandering belt deposits formed by lateral growth due to the lateral displacement of the meandering river channels (Jackson, 1976; Nanson, 1980; Brierley, 1991). The channel-floor lag deposits underlying the point bar deposits on an erosional surface are associated with laterally migrating channel bottoms (Ghinassi et al., 2014). The very thin and horizontally bedded sandstone, siltstone and mudstone covering the point bars are thought to be the sediments deposited in lakes formed due to the abandonment of the meandering channel.

Chute Deposits: There are channel deposits up to 1 m in depth and 3 m in width on the sigmoidal sandstones and conglomerates of point bar deposits (Figure 7b). These channel deposits with erosional bottom surfaces developed obliquely to the dip directions of the planarly inclined beds. Channel deposits consisting of fine pebbly conglomerates and coarse-grained sandstones are generally planar cross-stratified (Figure 7b).

The small channel sediments deposited on point bar deposits by eroding them in the oblique direction have been interpreted as the chute deposits. Chute deposits represent channel deposits that were eroded and filled during the flood periods of river (McGowen and Garner, 1970). The cross-stratified sandstones deposited in chute form the chute bars accumulated in the flow direction of the river (McGowen and Garner, 1970; Ghinassi et al., 2014).

Flood Plain Deposits: Flood plain deposits underlying and overlying the point bar deposits in the stratigraphic sequence consist mainly of light brown-brick colored mudstone, siltstone and sandstone alternation (Figure 7). The very thin planar beds of these deposits form laterally continuous sheet-like beds (Figures 7c, d). There are also very thin bedded (5-15 cm thick), fine pebbly conglomerates, which are laterally discontinuous in the sandstones and mudstones (Figure 7d). These conglomerates have a small scale erosional bottom contact. In several levels, the V shaped channel deposits with a depth of 1 m were defined in this sequence. The channel deposits are composed of slighltly inclined planar cross-stratified fine pebble conglomerates.

This facies assemblage is a product of deposits that occur in flood plain areas at the edges of river channel during flooding periods of meandering rivers (McGowen and Garner, 1970; Miall, 1985). The decrease in the energies of non-channelized sheetfloods caused mudstone deposition from the suspension (Collinson, 1996; Tooth, 1999). The V shaped channel conglomerates identified in flood plain deposits probably reflect small stream channel opened due to the rupture of meandering river channel and the sedimentation in this channel.

5. Age of the Alluvial Fan Sediments

The age of the alluvial fan sediments deposited on the bedrock around Sultandağları was determined by compiling the age data obtained in this study and the previous studies. Since the alluvial fan deposits in Yalvaç and Ilgın basins have lateral and vertical relationships with lacustrine deposits, the age data obtained from lacustrine deposits have also enabled the relative aging of fan deposits.

No age data could be obtained from the first fan deposits overlying the bedrock units in the Yalvaç

Basin. The lacustrine deposits transgressively overlying these alluvial fan sediments were dated as the mid-late Miocene by Yağmurlu (1991). Late early Miocene-early middle Miocene ages were obtained for the lower levels of the same deposits carried out in the same sediments by Tuncer (2020) based on ostracod, mammals and palynological dating, while the late Miocene-Pliocene ages were obtained for the upper levels of the lacustrine sequence (Table 1). In this study, the late Miocene-early Pliocene age was determined based on the ostracod assemblage of the mudstone and marl samples taken from the upper levels of the lacustrine sequence (Table 1). The age of alluvial fan deposits, which overlie the lacustrine deposits with a forced regression in the closure period of the Yalvaç Basin, was determined as the late Miocene based on mammals content (Table 1; Usta et al., 2019). According to all these studies, the age of the

Table 1- The fossil content and ages of the alluvial fan and lacustrine sediments outcropping in the Yalvaç Basin.

Sediments		**Fossil Assemblage and Age**
Yalvaç Basin	**Alluvial Fan**	**Upper levels of the alluvial fan sediments:** **Dedeçam village, Pamuklu locality:** Gompotheridae *Choerolophodon pentelici,* Equidae *Hipparion* cf. *philippus,* Equidae *Hipparion* sp. (small form), Rhinocerotidae *Chilotherium* sp., Rhinocerotidae *Ceratotherium neumayri,* Bovidae *Prostrepsiceros syridisi,* Bovidae *Gazella* sp., Bovidae *Palaeoryx,* Giraffidae *Palaeotragus* sp. **Kuyucak village, İldere locality:** Gompotheridae *Choerolophodon pentelici*, Equidae *Hipparion* sp., Bovidae *Gazella* sp., Bovidae *Palaeoryx pallasi*, Giraffidae *Helladotherium duvernoyi*, Giraffidae *Palaeotragus rouenii* **Kuyucak village, South of Belez:** Hyaenidae *Adcrocuta eximia*, Gompotheridae *Choerolophodon pentelici*, Equidae *Hipparion* cf. *mediterraneum* Equidae *Mediterraneum*, Rhinocerotidae *Ceratotherium neumayri*, Bovidae *Gazella* sp. **Tokmacık village:** Hyaenidae *Adcrocuta eximia,* Mammutidae *Zygolophodon* sp., Equidae *Hipparion mediterraneum,* Equidae *Hipparion* sp. (small form), Rhinocerotidae *Chilotherium* sp., Rhinocerotidae *Ceratotherium neumayri,* Cervidae *Pliocervus* sp., Bovidae *Gazella* sp., Bovidae *Palaeoryx pallasi,* Giraffidae *Palaeotragus rouenii,* Giraffidae *Helladotherium duvernoyi* **Age:** Late Miocene, MN 11 mammals zone (Usta et al., 2019)
	Lacustrine Sediments	**Lower levels of the lacustrine sediments:** *Democricetodon franconicus* Fahlbusch, 1966 **Age:** MN 4 mammals zone, middle Orleanian (late Early Miocene) (Tuncer, 2020) *Herpetocyprella mongolica, Mediocypris candonaeformis, Fabaeformiscandona pokornyi, Cyclocypris ovum, Leucocythere sieberi, Herpetocyprella auriculata, Lineocypris lunata, Lineocypris inflexa* **Age:** late Early – Middle Miocene (Tuncer, 2020) **Upper levels of the lacustrine sediments:** *Arctocypris fuhrmanni, Candonopsis arida, Ilyocypris gibba, Potamocypris gracilis, Fabaeformiscandona pokornyi, Cyclocypris ovum, Leucocythere immigrata, Heterocypris steinheimensis, Zonocypris membranae, Neglecandona angulata decimai, Cypris pubera, Potamocypris zschokkei, Cypria ophtalmica, Pseudocandona marchica, Herpetocypris brevicaudata, Neglecandona altoides, Neglecandona angulata, Limnocythere inderica, Fabaeformiscandona acuminata, Tonnacypris convexa* **Age:** Late Miocene–Pliocene (Tuncer, 2020) **The uppermost levels of the lacustrine sediments:** *Heterocypris salina* (Brady), *Heterocypris salina salina* (Brady), *Heterocypris salina barneri* (Luttic), *Candona parallela pannonica* (Zalanyi), *Candona* aff. *parallela pannonica* (Zalanyi), *Candona* aff. *iliensis* Mandelstam, *Candona candida* (Koch), *Candona* aff. *candida* (Koch), *Cypridopsis* aff. *vidua* (O. F. Müller), *Candona (Candona)* cf. *churmensis* Freels, *Candona (Candona)* aff. *iliensis* Mandelstam, *Darwinula cylindrica* Straub, *Candona neglecta* Sars, *Darwinula stevensoni* (Brady ve Robertson), *Candona (Candona)* cf. *marchica marchica* Hartwaing, *Candona (Pseudocandona) compressa* (Koch), *Candona (Pseudocandona)* cf. *compressa* (Koch), *Ilyocypris gibba* (Ramdohr), *Cyclocypris ovum* (Jurine), *Ilyocypris bradyi* Sars, *Zonocypris membranae* Livantel, *Candona (Candona)* aff. *gracilis* Livental, *Cyclocypris ovum* (Jurine), *Ilyocypris* sp., *Candona* sp., *Candona (Caspiocypris)* sp., *Cypridopsis* sp., *Heterocypris* sp. **Age:** Late Miocene–Early Pliocene (this study)

alluvial fan and lacustrine sediments deposited in the Yalvaç Basin has been accepted as Miocene-Pliocene.

Similarly, there is no age data obtained from the first alluvial fan deposits in the Ilgın Basin. Umut et al. (1987) determined an age of latest Oligocene or the earliest Miocene with mammals dating from the lower levels of the lacustrine deposits which transgressively overlie the alluvial fan deposits (Table 2). An Early Miocene age was determined based on the ostracod content of marl samples taken from the lower levels of the sequence (Tuncer, 2020; Table 2). Tuncer (2020), determined a Late middle Miocene (Serravallian)-Early late Miocene (Tortonian) from the middle levels of the lacustrine sequence based on the ostracod assemblage. Umut et al. (1987) and Tuncer (2020) assigned a Late Miocene-Pliocene age to the middle-upper levels of the sequence; Umut et al. (1987), on

Table 2- The fossil content and ages of the alluvial fan and lacustrine sediments outcropping in the Ilgın Basin.

<table>
<tr><th colspan="2">Sediments</th><th>Fossil Assemblage and Age</th></tr>
<tr><td rowspan="2">Ilgın Basin</td><td>Alluvial Fan</td><td>Belekler village: Hipparion sp., Vertebrate gen. et. sp. indet, Testude sp., Gompotheridae gen. et. sp. indet
Age: Late Miocene (Umut et al., 1987)

2.5 km south of Argıthanı: Hipparion gracile, Rhinoceras sp., Gazella sp., Antilope (Carnasiere), Ruminantia
Age: late Miocene or Pontian (Yalçınlar, 1953)

2.5 km south of Argıthanı: Hipparion sp.
Age: Early Pliocene (Sickenberg et al., 1975)</td></tr>
<tr><td>Lacustrine Sediments</td><td>Lower levels of the lacustrine sediments:
Mirabella intermedia, Eumyarion aff. bifidus, Eumyarion sp. II, Eumyarion sp. III, Eumyarion sp. IV, Paleosciurus sp., Brausatoglis sp., Gliridae gen. et sp. indet
Age: latest Oligocene or earliest Miocene (Umut et al., 1987)

Gölyaka village: Ilyocypris boehli, Cyprinotus turcica, Metacypris gokcenae, Moenocypris cf. francofurtana, Fabaeformiscandona sp. A
Çeltek village: Virgatocypris virgata, Metacypris gokcenae, Heterocypris aff. parva, Stenocypris sp. A, Fabaeformiscandona sp. B, Fabaeformiscandona sp. juv. ve Pseudocandona sp. juv.
Age: Early Miocene (Tuncer, 2020)

Middle levels of the lacustrine sediments:
Strandesia spinosa, Darwinula stevensoni, Vestalenula cylindrica, Candonopsis arida, Ilyocypris gibba, Paralimnocythere rostrata, Potamocypris gracilis, Pseudocandona compressa, Fabaeformiscandona pokornyi, Cyclocypris ovum, Cypris falki, Cyprinotus inaequalis, Leucocythere immigrata, Amnicythere nodigera, Heterocypris steinheimensis, Paracandona euplectella, Cavernocypris subterranea, Zonocypris membranae, Neglecandona angulata decimai, Cyprideis sublittoralis, Heterocypris glozaniensis, Cypria ophtalmica, Heterocypris rotundata, Herpetocypris cf. brevicaudata, Scottia pseudobrowniana
Age: Late-Early Miocene (Serravalian)?–Early-Late Miocene (Tortonian) (Tuncer, 2020)

Middle-upper levels of the lacustrine sediments:
Arctocypris fuhrmanni, Paracandona euplectella, Ilyocypris bradyi, Vestalenula cylindrica, Candona sp. C ve Mixtacandona? sp. A, Bithynia glabra, Bithynia pseudemmericia
Age: Late Miocene–Pliocene (Tuncer, 2020)

Middle-upper levels of the lacustrine sediments:
Cyprinotus salinur BRADY, Hydobia vitrella STEF., Hydrobia syrmica NEUM., Candona sp., Candoniella sp., Prionocypris sp., Zonocypris sp., Pseudamnicola (Andrussowiella) carasiensis JEK., Valvata sp.
Age: upper levels of the Miocene - Pliocene (Umut et al., 1987)

Upper layers of the lacustrine sediments:
Heterocypris salina salina (BRADY), Ilyocypris cf. gibba RHAMDOR, Candona cf. altoides PETKOVSKI, Pseudocandona sp., Candona sp., Gastrodlar, Valvata (Valvata) cristata MÜLLER, Caecilioides sp., Opercule, Heterocypris salina salina (BRADY), Zonocypris sp., Candona cf. altoides, Candona sp., Chara, Hydrobia vitrella STEF., Techochora cilindrica MÖD.

Age: Pliocene (Umut et al., 1987)</td></tr>
</table>

the other hand, determined the Pliocene ages from the uppermost levels of the same sequence (Table 2). Late Miocene age assigned by Umut et al. (1987), Late Miocene or Pontian age by Yalçınlar (1953) and an Early Pliocene age by Sickenberg et al. (1975) to the alluvial fan deposits overlying the lacustrine deposits with a forced regression in the closure period of the Ilgın Basin (Table 2). According to all abovementioned studies, the age of the alluvial fan and lacustrine sediments deposited in the Ilgın Basin has been accepted as the Miocene-Pliocene in age.

6. Depositional Evolution and Discussion

Sultandağları, located on the NE edge of the Isparta Angle, and the surrounding Yalvaç and Ilgın basins are placed in a horst-graben system. These basins started to open in the Early Miocene under the control of an extensional tectonic regime (Koçyiğit et al., 2013; Koç et al., 2014). The formation of Yalvaç and Ilgın basins occurred due to the orogenic collapse (Koçyiğit and Deveci, 2007; Koçyiğit et al., 2013). The region, which had been subjected to compressional deformation during the Late Cretaceous-Eocene period, was subjected to orogenic collapse due to the disappearance of the regional force forming the compressional tectonism (Koçyiğit and Deveci, 2007; Koçyiğit et al., 2013). Thus, while on one hand Sultandağları were rising, on the other hand the normal fault controlled basins started to open on both sides of Sultandağları. The alluvial fan and lacustrine carbonates were deposited in these basins in the Miocene-Pliocene period (Figure 8).

With the opening of the Yalvaç and Ilgın basins, first the alluvial fans began to be deposited in these basins. The river systems flowing from the watershed boundary of Sultandağları towards SW and the drainage systems flowing towards the NE formed the alluvial fans of the Yalvaç and Ilgın basins, respectively (Figure 8a). These fan deposits show significant changes from the basin margin to the basin interior in terms of grain size, bedding thickness and sedimentary facies. Thick bedded debris flow and hyperconsantrated stream flood deposits, which are deposited at the basin margin and composed of coarse pebbles-boulders pass into conglomerates and sandstones formed by the braided river facies assemblage in the basinward direction. The proximal and medial parts of the alluvial fan are composed of mainly braided river facies assemblages. This facies assemblage has well preserved lenticular shaped stream channel geometries with erosional bottom surfaces in sections parallel to the basin margin. In these channel deposits that form the main distributary channels, there are braided river bar deposits accumulated on top of each other with lateral displacements. The braided river deposits gradually pass into the meandering river deposits towards the distal parts of the alluvial fans. The meandering river deposits consist of point bars and widespread flood plain deposits.

These facies assemblages from the basin margin towards the basin interior display changes ranging; a) from high energy fluvial facies to lower energy fluvial facies; b) from thick bedded and laterally discontinuous rocks to thin bedded and laterally continuous rocks and c) from coarse grained sediments to fine grained sediments. The river deposits having these facies changes from the basin margin towards the basin interior were interpreted as stream dominated alluvial fan deposits (Nemec and Postma, 1993; Ridgway and DeCelles, 1993). In stream dominated alluvial fans, perennial streams are the dominant sediment transport agents on the fan surface (Collinson, 1996). Rapid and frequent displacements are observed in the stream channels that form these alluvial fans. With the decrease seen in the river bed slopes in the basinward direction, the braided rivers pass into the meandering rivers (Leeder, 1999).

The alluvial fan deposits, which have a very wide spatial distribution around Sultandağları, are not the product of a single fan, but reflect a combination of many fans (Figure 8a). The combination of fan deposits that have developed side by side in the stream dominated alluvial fans and the covering of one fan the other are common features (Mukherji, 1990). The presence of concurrent alluvial fans, independent from each other, indicates that many drainage systems have developed on Sultandağları. These drainage systems also indicate that the region received abundant precipitation during the Miocene-Pliocene period. The development of stream dominated alluvial fans due to the many drainage systems feeding the basin and the coal formation in the basins reflect the presence of humid climatic conditions in the Miocene-Pliocene period. In the palynology study conducted by Akgün

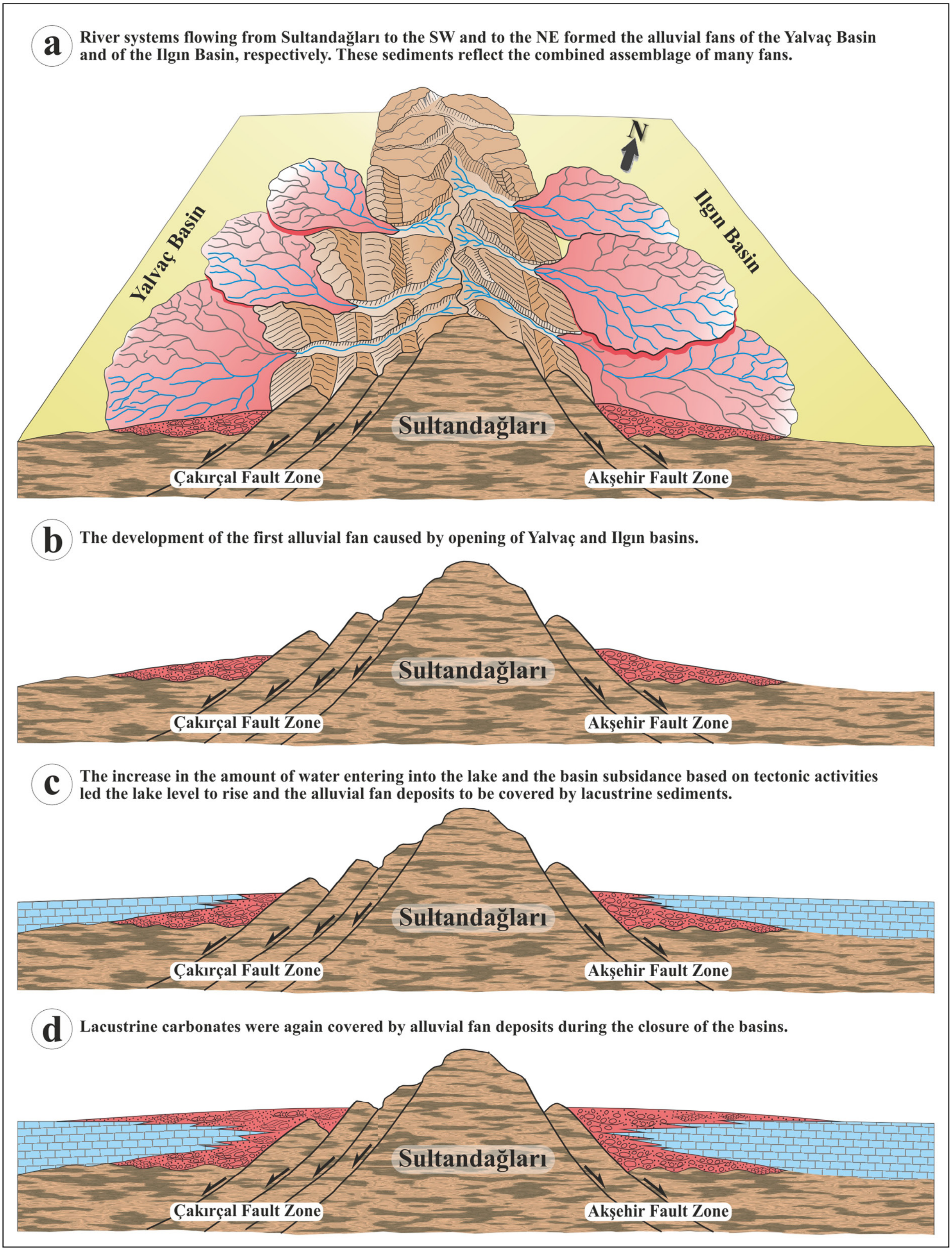

Figure 8- a) Block diagram showing alluvial fans deposited in Yalvaç and Ilgın basins around Sultandağları. The cross-section line of the block diagram is given in Figure 1b. b, c, d) The schematic illustration of the development of alluvial fans and lacustrine depositions depending on the tectonism and climate in the Miocene-Pliocene period in these basins (not to scale).

and Akyol (1992) in the region, the temperate and humid climatic conditions were determined for the Miocene period.

Debris flow and hyperconsantrated stream flood deposits deposited just in front of the basement rocks and fault scarp in the Yalvaç Basin form the proximal facies of alluvial fans. The clastic sediments derived from the source areas were transported to the basin as floods during flooding periods due to the steep slope caused by the fault scarps and gravity effect. These floods accumulated the sediments they dragged, increased the amount and density of sediments and deposited them in front of fault planes by hyperconsantrated stream flood flows (Figure 8b). Hyperconsantrated stream flood deposits are characteristic for tectonically active, alluvial fan sediments deposited on steep slope basin margins (Nemec and Muszyński, 1982; Ballance, 1984). According to Blair (1987), the deposition of hyperconsantrated stream flood deposits at the contact with the bedrock at the basin margin constitutes the first records of the subsidence in the basin. Since these flows have a high viscosity flow rheology, they show a limited lateral distribution in front of the fault scarps (Nemec and Muszyński, 1982).

Hyperconsantrated stream flood deposits pass into the braided river sediments both in the basinward direction and in the vertical sequence. The braided river facies assemblage shows that the sediment supply from Sultandağları into the basin occurred with well-channelized flows. Thus, the alluvium transported to the basin were deposited as well-organized channel sediments. It is estimated that the transport distance of the alluviums derived from Sultandağları is approximately 10-20 km. Since it is not very long distances, the conglomerates are not well rounded. However, the fluvial processes enabled the sediments to have relatively better sorting, the development of sedimentary structures such as planar parallel and planar cross-bedding, and better organized depositional architectures such as the fining upward sequence. During the occasional flooding periods, the alluviums overflowing from braided river caused the deposition of thin bedded, sandstone, siltstone and mudstone flood sediments. Thus, significant part of the alluviums transported by the streams from Sultandağları are deposited in the proximal and medial parts of the fan.

The braided river facies decreases towards the inner parts of the Yalvaç and Ilgın basins. Thus, the point bar and flood plain deposits of the meandering rivers become the predominant facies in the inner parts of the basin, reflecting that the energy and sediment carrying capacities of rivers with high energy flowing in the proximal and medial parts of the basins begin to decrease towards the basin interior.

The age data obtained from alluvial fan sediments of Yalvaç and Ilgın basins show that Sultandağları concurrently fed these alluvial fan deposits. This also reveals that Çakırçal and Akşehir fault zones, which limit Sultandağları and open the Yalvaç-Ilgın basins, are most likely contemporaneous. The ongoing activities of these fault zones enabled the subsidence of the basins and the creation of a continuous accommodation space (Figure 8b). Thus, while new erosional areas were formed with the uplift of Sultandağları, the subsidence of the basins enabled the deposition of clastic materials derived from these erosional areas and the protection of the deposited sediments (Figure 8).

The relay ramps developed within the fault zones also controlled the position and development direction of the alluvial fans in the basin by directing the flow direction of the drainage systems fed from Sultandağları. The relay ramps developed especially in the east of Yalvaç and the south of Dedeçam in the Yalvaç Basin caused the development of alluvial fans in the N-NW direction with morphological control (Figure 1b).

The fact that an alluvial fan sequences with a thickness of approximately 300 m were deposited in the Yalvaç and Ilgın basins during the Miocene-Pliocene period indicates a thin sedimentary sequence deposition in a large geological time. The probable reasons for this situation were interpreted as; 1) that the deposition did not always occur in the same locality, that there were lateral displacements within the same fan and between different fans; 2) there might be partial erosions on fan surfaces where the active deposition did not occur; 3) there were changes in the amount of sediment supply over time. The changes in sediment supply and the reasons and consequences of these changes are discussed in detail below.

Drainage systems developed on Sultandağları both fed the alluvial fans on one hand and enabled the formation of lacustrine basins in front of the fans on the other hand. Thus, clastic and carbonate rocks started to be deposited in lacustrine basins. The increase in lake level due to both the increase in the amount of water entering the lake and the subsidence of the basin caused by the activities of the Çakırçal and Akşehir fault zones led the alluvial fan sediments to be covered with lacustrine sediments (Figure 8c). However, there is a significant decrease in the amount of clastic material transported to Yalvaç and Ilgın basins during trangressive periods. During this period, carbonate deposition prevailed in the basins and no clastic deposition except for a few small localities occurred. Only foreshore, shoreface and shoal water deltas as clastic facies were deposited in a narrow belt on the basin margins of these basins. These deltas with low set height and small spatial distribution rapidly pass into the carbonate sediments towards the basin. In the periods when the lake level reached its maximum height, there is almost no detrital supply occurred into the basin.

It is thought that the absence of a significant progradation in clastic shoreline at the basin margin during maximum transgression periods is associated with decrease in the sediment supply into the basin. The decrease in the sediment supply did not allow a progradation in clastic shoreline and a significant regression. Despite the fact that clastic material can be transported to the basin to a large extent and to form thick alluvial fans around Sultandağları, the reason for the sudden decrease in the amount of clastic material during the development of lacustrine transgressions can be explained by different processes and mechanisms such as; a) decrease in precipitation over Sultandağları due to climatic changes, b) displacement of drainage systems due to catchment in river drainage systems, c) increase in the base level due to the transgression seen at the basin margin, and thus reduction in the erosion in the source area. Among these mechanisms, the rise in the lake level and the lacustrine transgression seen in the basin are incompatible with the decrease in precipitation due to the climate. In case of displacement of the river bed systems due to the catchment, it is expected that the abundant clastic material was transported to different parts of the basin. The absence of this situation also eliminates the possibility of catchment. It is thought that the most probable mechanism could be the decrease in the clastic sediment supply to the basin due to the base-level rise. The base level, which is an imaginary and dynamic equilibrium surface between the erosion and deposition, is theoretically accepted as the sea or lake level and controlled by the changes in this level (Catuneanu, 2006). Below and above the base level, the deposition and erosion occurs, respectively. The drainage systems discharging into the basin especially during the periods when tectonism paused or slowed down (assuming that there is no change in the amount of rainfall in the basin) caused the drowning of alluvial fans by increasing the lake water level (Figure 8c). The increase in the lake level also caused the base level rise, thus reducing the erosion at the basin margin and accordingly the sediment supply to the basin. During the periods when the lake level increased, with the decrease in the amount of detritus entering the basin, clastic deposition at the basin margin either occurred in very limited areas or did not occur. Thus, deposition of the carbonate rock were dominated instead of clastics in Yalvaç and Ilgın basins. The algae in the lake also significantly contributed to the carbonate-dominated sedimentation.

In cases when the lake level relatively decreases, it was seen that alluvial fan sediments were deposited with sharp contact on the lacustrine deposits and prograde towards the basin (Figure 8d). The forced regressive periods in which the alluvial fan deposits prograde on the lacustrine carbonates were repeated several times, especially in the Ilgın Basin. This clearly reveals that the base level change controls the amount of clastic material entering the basin. The decrease of the lake water level due to the climatic processes or the displacement of the lake shoreline by tectonic reasons led to the fall in the base level, and thus an abundant sediment supply to the basin due to erosion on the basement units. The increase in the lake level on the other hand caused a decrease in the amount of sediment entering the basin with the rise of the base level. Periodic changes and alternations observed in alluvial fans and lacustrine deposits have also been described in different basins (Heward, 1978; Wilson, 1980; Mack and Rasmussen, 1984; Ilgar and Nemec, 2005). During the closure of the lacustrine basins around Sultandağları, the repetition of this process one more time and the fall in the base level due to tectonic-climatic origin caused the lacustrine carbonates to be covered with alluvial fan sediments due to intense erosion at the basin margin and the abundant clastic input into the basin (Figure 8d).

7. Results

Yalvaç and Ilgın basins, which are located on the NE edge of the Isparta Angle and surround Sultandağları, are intramontane molasse basins that were opened due to the orogenic collapse under the extensional tectonic regime in Neogene period. Activities of NW-SE trending Çakırçal and Akşehir fault zones provide the opening of the Yalvaç and Ilgın basins, restrict Sultandağları and uplift it as a horst structure as well.

The lacustrine carbonates and the alluvial fans fed from Sultandağları during the Miocene-Pliocene period were deposited in these basins.

The age data obtained from lacustrine deposits and alluvial fans in both basins show that Sultandağları concurrently fed these alluvial fans.

In this study, the debris flow, hyperconcentrated stream flood, braided river and meandering river deposits have been defined in the alluvial fan deposits around Sultandağları. The braided river and meandering river deposits constitute the dominant facies assemblages of the alluvial fans. These facies assemblages from the basin margin towards the basin interior display changes ranging; a) from high energy fluvial facies to lower energy fluvial facies; b) from thick bedded and laterally discontinuous rocks to thin bedded and laterally continuous rocks and c) from coarse grained sediments to fine grained sediments.

The alluvial fan deposits surrounding Sultandağları have been interpreted as the stream dominated alluvial fan deposits according to these facies characteristics. These alluvial fans are not the product of a single fan, but reflect a combined assemblage of many fans. The presence of coeval alluvial fans indicates that many drainage systems were developed on Sultandağları and that the region received abundant precipitation during the Miocene-Pliocene period.

This study, in addition to the sedimentary processes prevailing in the basin throughout the basin evolution, contributes in comprehending the issue of the tectonism- and climate-controlled water level changes and the rate of sediment supply on the control of sedimentological and paleogeographic development of basin margin deposition systems. While the tectonic-climatic- origin base level fall causes intense erosion at the basin margin and the transportation of abundant clastics into the basin, the rise of the base level causes a decrease both in the erosion rate at the basin margin and accordingly the amount of sediment supply to the basin, in the fields examined in this study. As a result normal or forced regression or transgression developed at the basin margin depending on the amount of clastic sediment supply.

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