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DEPOSITIONAL EVOLUTION OF THE SOMA COALFIELD, WESTERN TURKEY: A PRELIMINARY REPORT

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Abstract. Miocene alluvial/fluvial-lacustrine deposits composed of three lignite successions (Lower, Middle, and Upper) are exposed in Soma coalfield located near the northern Aegean Sea coastline of the Western Anatolia. The total thickness of the coal successions is about 900 m, and they rest unconformably on the Mesozoic carbonate/siliciclastic basement rocks. Recognised lithofacies of coal successions have been arranged to fourteen facies assemblages and interpreted as environments.

Lower Coal succession was deposited in an alluvial fan to plain and perennial forest mire system resulting in a subbituminous lignitic coal, in average 20 m thick. Freshwater carbonate-dominated Middle Coal succession, having lignite beds ranging from 0.5 to 2.5 m, was formed in floodplain environment, including shallow freshwater carbonate lakes and/or ponds, and frequently drying poor forest mires of an anastomosed river system. Volcanism-induced Upper Coal succession was deposited in fluvial channel, floodplain, and probably in allochthonous peat mires of a braided river system that rapidly got buried and/or eroded by volcaniclastic apron deposits, and culminated by large carbonate-dominated perennial shallow lakes.

The Miocene coal successions were probably deposited in the fault-controlled karst-based palaeovalleys and lowlands of the intramountain palaeomorphology that were patterned by the Early Tertiary collision of the Eurasia and Anatolian plates. The coal successions was faulted by the extensionally tectonic regime and covered with Plio-Quaternary deposits.

Key words: facies, stratigraphy, Soma coalfield, Turkey.

INTRODUCTION

The peat formation of an intramountain system may be controlled by various alluvial/fluvial related sedimentary processes, like channel migration, channel avulsion, and overbank floodings, volcaniclastic interactions, catastrophic events, and other depositional agents as reported in geological literature.

The Soma coal basin, the largest economic coal (lignite)-bearing basin of western Turkey, is a good example of coal formation in alluvial/fluvial settings. The Lower and Middle Coal measures (LC and MC) in the Soma basin associate with carbonate-dominated rocks, and Upper Coal measures (UC) — with volcaniclastic-dominated rocks. Each coal succession indicates different character of alluvial-lacustrine subenvironments that were controlled by diverse sedimentary processes, effective biogenic carbonate accumulation, and volcaniclastic sedimentation. This paper summarizes the lithofacies and environmental interpretations of the coal successions of the Soma coalfield.

GEOLOGICAL SETTING

The Miocene Soma coalfield is preserved in a small intramontane basin remnant which is situated in the graben complex of western Turkey (WAGC), occupying an area approximately 150 km in width, bounded by Hellenic and Cyprus Arc (HA, CA) to the south, and dextral North Anatolian Fault zone to the north (Mc Kenzie, 1972; Le Pichon, Angelier, 1979). The extensionally deformed deposits of the Miocene Soma coal basin unconformably overlie the early Cenozoic and older clastic/carbonate rocks of İzmir–Ankara Zone. This tectonic zone is bounded to the north by rocks of the Pontide

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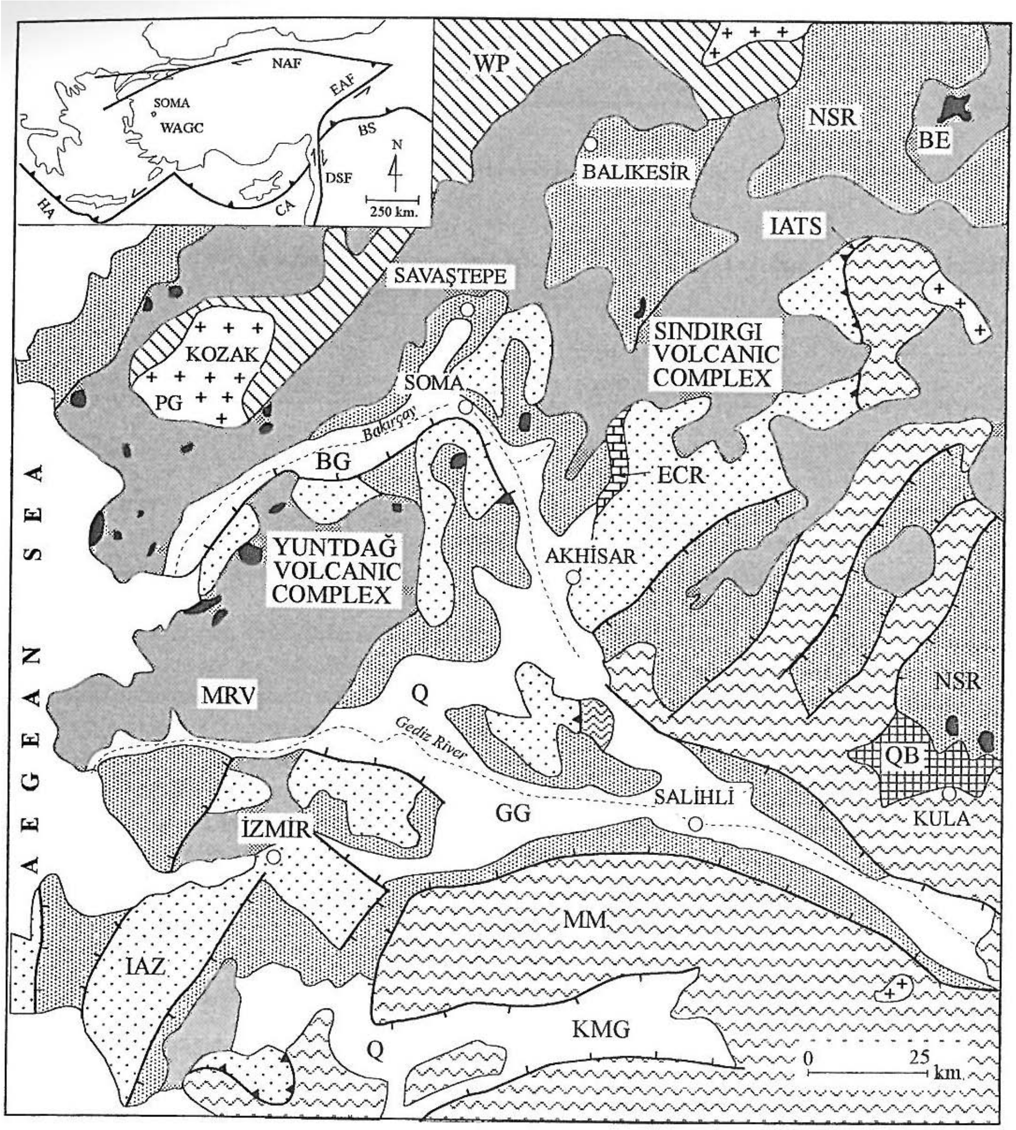

Fig. 1. Geological map of northwestern Anatolia and major tectonic elements (small map) in the eastern Mediterranean region (modified after İnci, 1998a)

Q — Quaternary deposits, QB — Quaternary Kula basalts, BE — late Miocene–Pliocene basalt extrusions, MRV — Eocene–Miocene andesitic, rhyolitic lavas and pyroclastic volcanic rocks, NSR — Neogene clastic and carbonate rocks, ECR — Eocene carbonate rocks, PG — Paleocene–early Miocene granodiorites, IAZ — siliciclastic and carbonate rocks of the İzmir–Ankara zone, WP — Western Pontides, MM — metamorphic rocks of the Menderes massif, IATS — İzmir–Ankara thrust suture, WAGC — Western Anatolian graben complex, BG — Bakırçay graben, GG — Gediz graben, KMG — Küçük Menderes graben, NAF — North Anatolian Fault, EAF — East Anatolian Fault, BS — Bitlis suture, DSF — Dead Sea Fault, HA — Hellenic arc, CA — Cyprus arc

orogenic belt, which is named "Sakarya zone" by Okay and Siyako (1991), and overthrust the Palaeozoic metamorphic complex of the Menderes Massif (Fig. 1).

The Soma coal basin is considered here to have formed on the mainly NE-trending karstic and possibly fault-bounded topographic depressions and synclinal troughs that was patterned after collisional climax of the "Sakarya continent" and "Anatolian continent" throughout early Miocene, to early Pliocene period. The volcanism continued throughout Eocene to Plio-Quaternary period in calc-alkaline character, and volcanogenic alluvial sediments were deposited in the Soma region (İnci, 1998b).

The preserved LC and MC successions (Soma Formation), and UC succession (Deniş Formation) comprise of an approximately 900 m of clastic and carbonate rocks. The thickest coal seam (LC) is 20 m thick and lies in contact between clastic and carbonate rocks. The coal beds (0.1 to 2.5 m) of the MC succession alternate with siliciclastic and/or carbonate rocks. The siliciclastic-dominated UC succession includes several low calorific value (< 2000 kcal/kg) coal beds, ranging from 0.15 to 2 m in thickness.

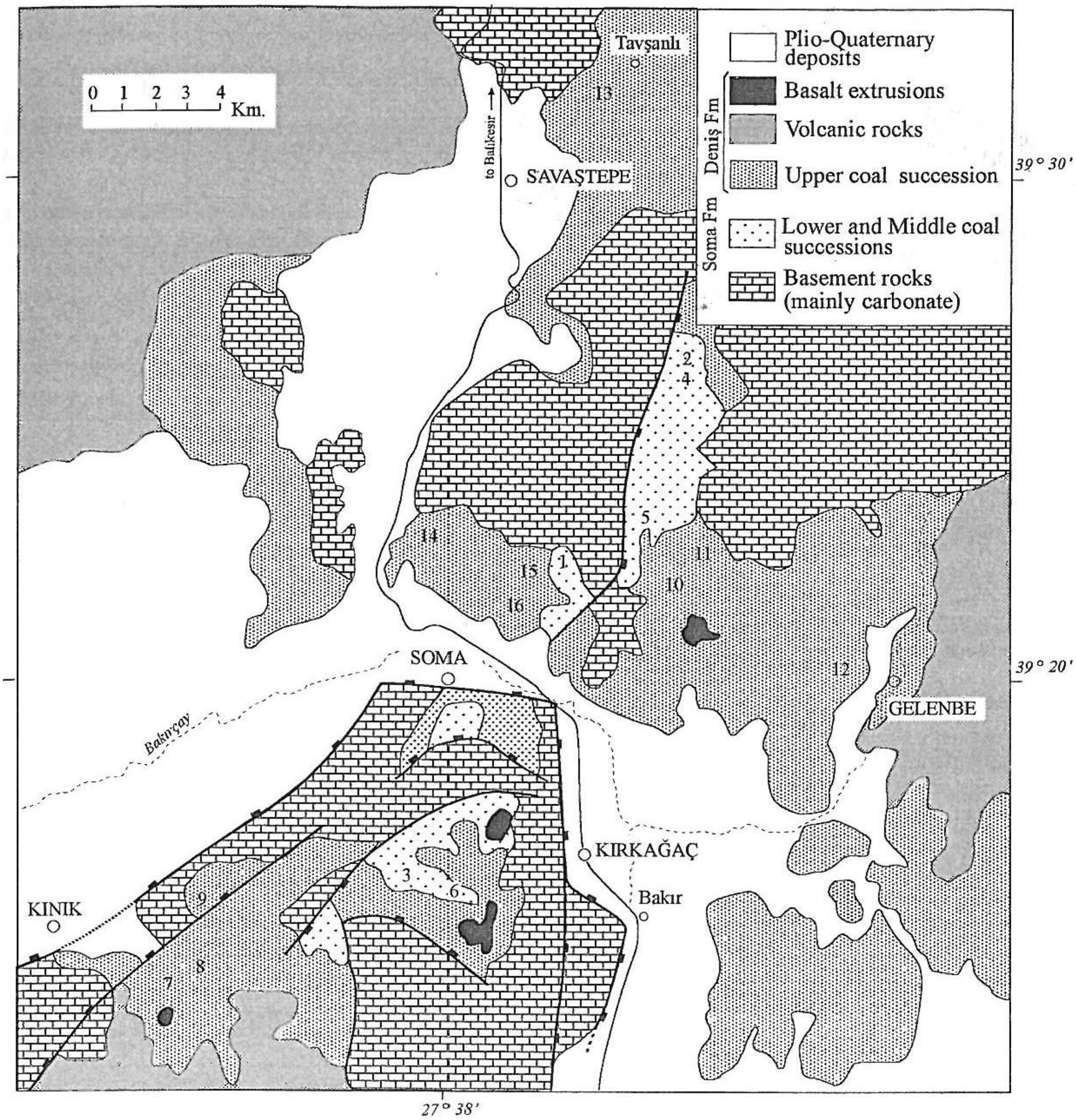

Fig. 2. Simplified geological map of Soma coalfield; numbers show the localities of the sedimentological measured sections and core logs

The main NE–SW, NW–SE, and N–S tensional directions in the coal successions were actived during Miocene, and especially in Pliocene and Quaternary to present day, respectively. The active extension is characterised by N–S and E–W trending major grabens filled in the region with Plio-Quaternary siliciclastic and carbonate sediments (Figs. 1 and 2).

The origin of the extensional tectonism in the western Turkey has been attributed to westward displacement of the Anatolian landmass or microcontinent (tectonic escape model of Dewey and Şengör, 1979), along the dextral North Anatolian Fault (NAF) and sinistral East Anatolian Fault (EAF), as a result of the collision of Arabia and Eurasia plates across the Bitlis Suture (BS) during late middle Miocene (Fig. 1, small map). This extensional system is also related to subduction in the Hellenic Arc (back-arc spreading model of Le Pichôn and Angelier, 1979) with the southward migration of the trench system, caused an extensional regime throughout the late Miocene to Present day in the Aegean region. An alternative, orogenic collapse mechanism (model of Dewey, 1988; Seyitoğlu, Scoot, 1996) suggests that extensional tectonism is related to spreading and thinning of the thickened crust after cessation of the Paleogene collisional shortening of the crust, along the Ízmir–Ankara zone.

FACIES ANALYSIS AND DEPOSITIONAL INTERPRETATIONS

The facies classification used in this study is based on grain size, types of individual beds, primary sedimentary structures, fossil content, and coal lithotypes. The facies diversity has been arranged to facies assemblages and discussed as palaeoenvironmental within LC, MC, and UC successions. Details of the descriptions, sedimentary features, inferred sedimentary processes, and palaeoenvironmental interpretations of the facies/facies assemblages are given in Tables 1 to 3.

Lower Coal succession

This coal succession is represented with alluvial fan, alluvial plain, and lower mire facies assemblages (FA 1, FA 2, and FA 3) (Table 1, Fig. 3).

Sedimentary and faunal/floral evidence suggest that LC succession of the Soma Basin was deposited in an intramountain alluvial fan to plain system, including

Table 1

Facies and facies assemblages of the Lower Coal succession

Facies	Sedimentary features	Interpretation
Gmd, disorganised conglomerate	Thick (> 0.6 m) to massive; sandy/clayey matrix supported; angular granule to pebble-size (sparsely blocky) clasts; sharp and erosive lower boundary	Cohesive and stream debris flows
Gmn, conglomerate-gravelly sandstone	Normally graded; thick (> 2 m); matrix-supported; angular; sandy matrix; gravelly sandstone vertically continuous	Debris and hyperconcentrated flood flows
Sg, gravelly sandstone	Thick (> 1.25 m); irregular geometry; sightly erosive base; large pisoliths	Sand dominated hyperconcentrated flood flows
Ss, stratified sandstone	Thin (0.2–0.5 m); fine to coarse sands; moderately sorted; laterally discontinuous; reddening	
Sn, normal graded sandstone	Generally medium thick; fine to coarse sands; poor to moderately sorted; slightly lower and upper boundaries	
Sv, tuffaceous sandstone	Whitish; thick (2.40 m) to massive; includes amphibole/biotite minerals and less volcanic shards	Synvolcanic floods and ash falls
Fm, massive mudstone	Heterogeneous alternation of thin (average 0.5 m) of mudstone and claystone; include pisoliths	Suspension from flooding waters mixed with gravelly flashings
Fgc, gravelly claystone	Medium to thick bedded (0.3–0.8 m); slightly loaded lower boundary	
Fmc, massive claystone	Up to 0.3 m thick; greenish; silicified tree trunks and roots; gastropod and gastropod shells; pyrite grains	Plant and mollusc-rich shallow water
Fcc, coaly claystone	Thin to thick bedded; thin lenticular fine-grained sandstone intercalated; algal pisoliths; woody fragments; pyrite grains	
La, algal limestone	Thin (average 0.1–0.3 m); algal horizontal lamination; carbonate gastropods	Algal productive small ponds
C, coal	Up to 5 m thick; bright and dull banded bituminous coal, tree trunks and roots, gastropod shells	Peat-forming mire
Facies assemblages	Sedimentary features	Depositional setting
FA1, alluvial fan	Dominantly Gmd/Gmn alternation; common erosional surfaces; irregular fining and coarsening upward; rare sandy deposits (Sg, Ss and Sn)	Debris flow dominated alluvial fan deposits formed in mountain front
FA2, alluvial plain	Generally couplets of the Sn and Fm; rarely Sv, Ss; Sg and Fgc	Fine to coarse-grained hyper-concentrated flood flow processes on the alluvial plain
FA3, lower mire	Lower coal / coaly beds (C, C1 and Fcc) intercalated with algal limestones (La) overlying alluvial plain assemblage; laterally/vertically transitions into impure coal and fine-grained (Fmc) rocks	Coal-forming extensive peat mires included clay and algal carbonate ponds on the alluvial plain

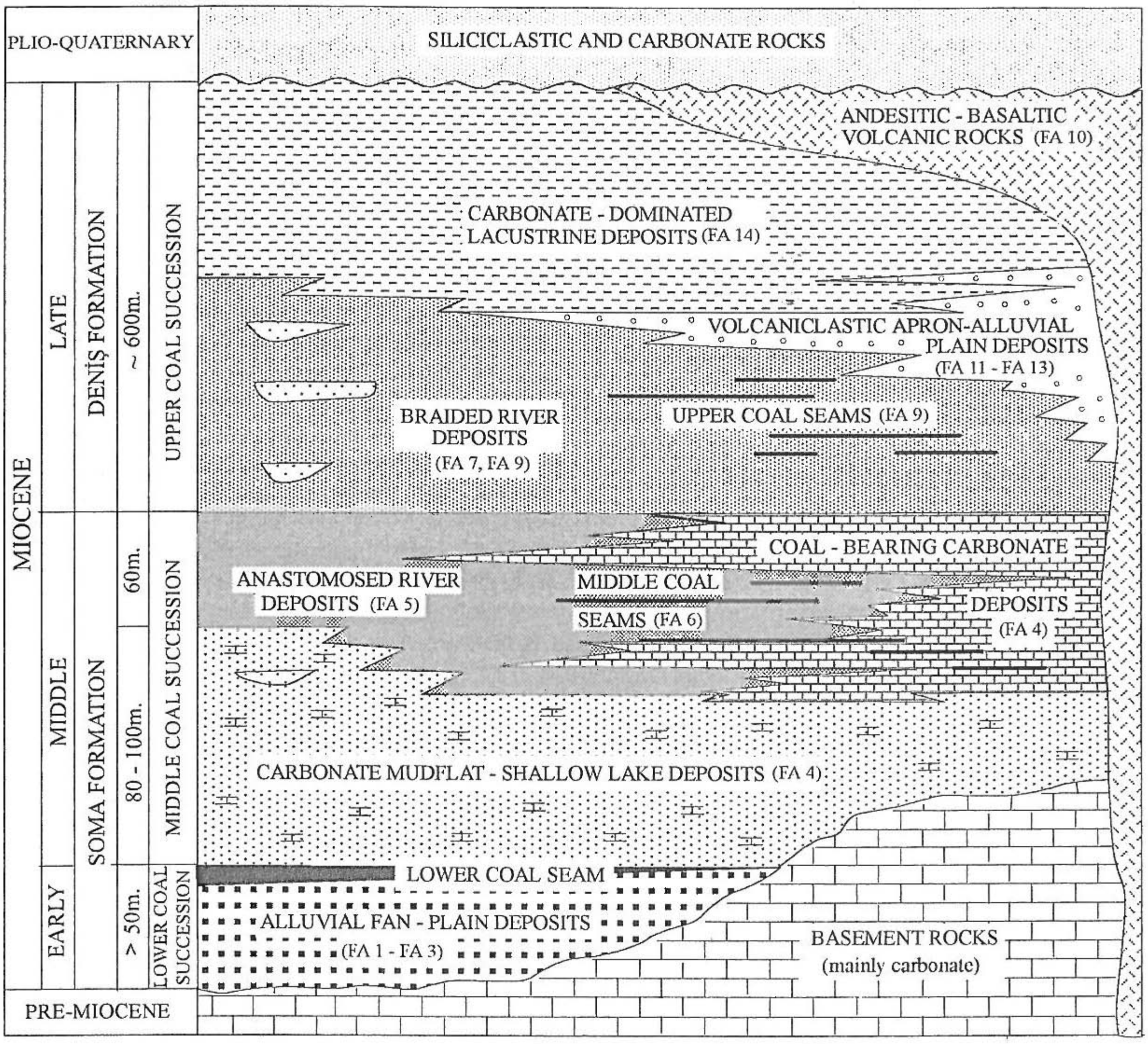

Fig. 3. Stratigraphic column of the Soma coalfield showing vertical and lateral variations of the facies assemblages

coal-forming forest mires associated with carbonate/fine--grained siliciclastic sediment depositing in small ephemeral lakes or ponds fringed with alluvial deposits.

The small mountain-front alluvial fans adjoining alluvial plain deposits were accumulated on the karstic and/or probably fault-block topographic lowlands developed on the Mesozoic carbonate/siliciclastic basement rocks. The areal extend, thickness variation (controlled by outcrops and drill holes), stratigraphic relationships, sedimentological features, bedrock composition, and other field observations indicate dominantly karst-controlled topographic lowlands adjoining uplands during deposition period of the LC succession. The diverse morphological surfaces (sinkholes, closed depressions, dissolution enlarged fractures), bauxites, collapse breccias, red karst soils, and carbonate concretions filling in the cavities or covering the irregular surfaces, dolomites, and other diagenetic features commonly reported from erosional/depositional surfaces of the pre-Miocene carbonate successions in western Turkey (e.g. Özlü, 1979; Atalay, 1991, 1997; Görür, 1991; Okay, Siyako, 1991; Robertson, 1993) and western Mediterranean regions (e.g. Rosales *et al*., 1994; Molina *et al*., 1999), may attribute to karst controlled basement for LC succession.

The alluvial deposits exhibit features of the wet — warm temperate alluvial fans and also unextensive intramountain alluvial plains. Abrupt transitions from coarse-grained debris flow to fine-grained alluvial plain sediments, downfan decrease in the thickness, median grain size and overall clast angularity support continuous alluvial deposition that was considerably controlled by the subaerial erosion and sediment load transported by ephemeral drainage from plant-covered highlands to lowlands.

The mire deposits were formed on the swampy grounds of the alluvial plain in which palaeohydrology was mainly controlled by ephemeral waters that flown from poor-drained mountain valleys and groundwater supply. Thin and laterally discontinuous algal limestones in coal beds may indicate algal productive pond deposition in marginal areas of the peatland. The coaly fine-grained rocks and/or lignitic claystones suggest that the mire has been crossed by a network of small, shallow drained-channels terminated in small lakes/ponds.

Consequently, the LC succession represents a facies relationship, in which an intramountain alluvial fan to plain sedimentation culminated by peat mires ponding in the topographic lows of the alluvial plain.

Middle Coal succession

The MC succession comprises of the carbonate lacustrine, floodplain, and middle mire facies assemblages (FA 4, FA 5, and FA 6) (Table 2, Fig. 3).

Faunal, floral, sedimentary features, and stratigraphical relationships of the MC succession may indicate a mixed carbonate/siliciclastic mudflat environment, including small carbonate ponds/small lake(s) in central parts that was culminated by anastomosing river system, comprising of fine-grained sandy floodplain, coal forming wetland or peat mires, and small carbonate lakes/ponds in distal floodplain (İnci, 1998a)

Sedimentary features of the MC succession, overlapping the Mesozoic carbonate-siliciclastic rocks of the İzmir–Ankara zone (Tethyan belt), suggest deposition in a small forested peneplain and/or fault-controlled karstic-based intramontane region or basin. The source of calcium input is probably from surface run — off derived from carbonate — dominated basement. Carbonate in shallow lakes and/or ponds of the anastomosed river system occurred primarily as biochemical precipitation, as described by Tucker and Wright (1990), Kelts and Talbot (1990), and Talbot and Allen (1996). However, carbonate precipitation may have occurred in distal floodplain areas from carbonate-rich floodwaters. The coal and carbonate

Table 2

Facies and facies assemblages of the Middle Coal succession

Facies	Sedimentary features	Interpretation
M, massive marls	Massive; rarely parallel lamination; abundant plant leaves and fragments; diagenetic gypsum; rarely channelled; ostracods	Shallow lake-margin mudflat, incised channel stream flows
Lm, massive limestone	Tabular strata; mudstone to wackestone; carbonate dissolution; coalified/uncoalified roots/stems and plant fragments; gastropods and ostracods; micro-desiccation cracks	Biologically productive shallow freshwater lakes and ponds nearer to peat mires
La, algal limestone	Algal laminations, mounds and concretions; root traces; abundant gastropod	
Lb, brecciated limestone	Massive; brecciation; micritic clasts; dissolution cavities and/or micro-karstification; sedimentary cracks; rootlet	Subaerial exposure-related shallow carbonate lakes and/or ponds
Gm, channel-form conglomerate	Massive or crude bedding; normal grading; pebble sized carbonate clasts; transported lignite, coalified wood and shell fragments	Anastomosed channels, interchannel backswamps
Sl, laminated sandstone	Parallel lamination; fine sands; arenitic; micaceous; hematitic concretions and plant debris	Sandy sheet-floods in floodplain environment
Sr, rippled sandstone	Cross-laminated; fine sands	
Fm, massive mudstone	Massive; oncolitic carbonate nodules; thin lignite lenses; rare secondary gypsum and plant debris; rootlet	Muddy floods and suspension from flooding waters in ephemeral lakes and/or ponds on floodplain
Fmc, massive claystone		
Fgc, gravelly claystone	Scattered chert and carbonate pebbles	
Fcc, coaly claystone	Darkish; gastropod/gastropod shells; paleosoil trace	Poorly vegetated, dry and wet, fluvial influenced forest peat mires
C, coal	Dominantly dull coals (lignite); thin biogenic carbonate layers; high ash content	
Facies assemblages	Sedimentary features	Depositional setting
FA 4, carbonate lacustrine	Marl (M) and freshwater carbonate (Lm, La) domination; carbonate brecciation (Lb); rare sand/gravel-filled incised channels; biological productivity; rootlet; desiccation cracks	Shallow and frequently dried lake and lake-margin carbonate mudflats in distal floodplain environment
FA 5, well-drained floodplain	Cosets of sandy facies (Sl and Sr) up to 2 m thick; fining upward muddy units (Fm and Fmc); slightly erosional bases; locally gravelly channels	Floodplain and ephemeral small lakes/ponds in anastomosed river system
FA 6, middle mire	Coal (C) and impure coal alternation topped with fine-grained siliciclastics and carbonates	Autochthonous peat mires nearer to carbonate lakes/ponds

alternations may suggest peat mire terminations by covering with carbonate-rich lake waters during flooding periods of the river system. Exposure-related sedimentary features and mire conditions indicate intrabasinal reworking and resedimentary processes.

The Upper Coal succession

The facies assemblages of the UC succession, identified as Deniş Formation by Nebert (1978), are channel/near channel, floodplain, upper mire (FA 7, FA 8 and FA 9), overburden deposits of volcaniclastic apron (FA 10 to FA 13) and lacustrine (FA 14) (Table 3, Fig. 3).

The UC succession was formed in a continental intravolcanic depositional area, situated between Miocene "Yuntdağ volcanic complex" in southern, and "Sındırgı volcanic complex" in northern side of the coalfield (Fig. 1). Both multi-vent volcanic complexes comprise similar calc-alkaline, extrusive/intrusive, andesitic/basaltic pyroclastic volcanic rocks and lavas. Volcanic clasts of the coal depositing braided-river system were derived from Yuntdağ volcanic complex by surface sedimentary processes and transported into river depositional system trending NE – direction. Abundance of volcanic clasts, micaceous sands derived probably from metamorphic rocks of Menderes Massif, and palaeocurrent directions suggest the sediment contribution dominantly from the volcanic (Yuntdağ volcanic complex) and metamorphic provenance. The river depositional area was probably naturally-dammed by Sındırgı volcanic complex, and volcaniclastic apron deposits of continued explosive volcanism were flown into depositional system. The river deposits were covered and locally eroded by these volcaniclastic deposits. Intrabasinal subvolcanic dome-shaped olivine basalt intrusions and lavas are common in the coalfield. During volcanic quiescence, the lacustrine carbonate-dominated deposits were accumulated, and they covered the volcaniclastic apron and other older deposits of the river system.

TECTONICS

The main deformation structures of the coal successions are high-angle oblique-slip normal faults, meso-scale strike-slip faults, small and meso-scale asymmetric folds, small-scale synsedimentary normal and reverse faults, and soft-sediment deformations comprising load casts, flame structures, gravitational related slumps/slides, and sand injections.

The major tectonic structures in the coalfield are high-angle oblique-slip normal faults with a small-lateral component with dominantly SW–NE, SE–NW, S–N and W–E trendings (Fig. 2). The slickenlines and/or tool marks, shatter marks, and ridges and troughs are well preserved on the fault planes of the Mesozoic carbonate rocks. The fault planes are highly dipped ($> 70^o$) and include thick (up to 0.7 m) compact fault breccia composed of angular carbonate clasts of the basement. The cavities, joints, small faults, and fissures are common in slip planes. The fault scarps developed between basement and Miocene coal-bearing sequence are covered by Quaternary unconsolidated sediments, indicating tectonic reactivity during late Quaternary period (Arpalıyiğit, İnci, 2000).

The meso-scale strike-slip faults, developed perpendicularly and diagonally to normal fault trends, can be observed in MC succession and in carbonate basement rocks only. The fault planes comprise of well-preserved lateral slickenlines and thin (0.10–0.15 m), fine-grained carbonate breccia.

The small-scale synsedimentary normal and reverse faults are common in MC and UC successions.

The meso-scale asymmetric folds are rarely present in normal fault zones and their axes are diagonal to the faults.

The well-preserved small and large-scale load casts are common in fine-grained rocks and coal horizons of the UC succession. The small-scale flame structures formed between tuffaceous sandy and muddy beds of the volcaniclastic apron deposits. The flames are mostly 7–8 cm high and resemble regular type of flame structures described by Brodzikowski and Haluszczak (1987). The fine-grained volcaniclastic apron deposits and coal beds of the UC succession include abundant meso-scale slumps and slides. Their lateral movements are not apparent and amount of flow seems to decrease rapidly in short lateral distances. The slumped/slided beds display a chaotic picture. The sand/mud injections are commonly observed in coal horizons of the MC and UC successions.

The LC succession is rarely exposed in the coalfield. Exposed outcrops and coal drill cores do not provide reliable data with respect to deformation structures.

The small-scale synsedimentary faultings in MC succession may indicate slow and repeated subsidence during the Middle Miocene. The relatively high anastomosing fluvial deposition in MC succession may be related to more or less continuous subsidence, probably caused by activity of the ancestral faults and local depressions. These shallow depression areas were occupied by carbonate lakes supplied with large amounts of calcium carbonate by solutions deriving from the surrounding karstic carbonate provenance. The homogeneous thickness of the MC succession indicates small vertical displacements during Middle Miocene.

During deposition of the coal-bearing lowermost part of the UC succession, the depositional environment was increasingly filled with braided-river deposits. The subsidence rate was relatively low during this deposition period and conditions were favourable for upper peat accumulation.

The Late Miocene–Early Pliocene is characterised by intense volcanic and extensional tectonic activity. The structural pattern of the coalfield begun to be determined from this deposition time. The vertical and horizontal movements and volcano-tectonic influences obviously affected the coal successions and basement rocks. The changes in the major fault directions are considered to be results of changes in the regional stress pattern, originated from westward displacement of the Anatolian micro-continent along the North Anatolian Fault or northward progradation of the Hellenic Arc in southern

Table 3

Facies and facies assemblages of the Upper Coal succession

Facies	Sedimentary features	Interpretation
Gm, massive conglomerate	Thick (2–10 m); erosional bases; clast-supported; upward grading; cobble to pebble size subrounded volcanic/carbonate clasts	Bedload stream flow deposits
Gt, cross-bedded conglomerate	Up to 2 m thick; large-scale trough crossbeds; clast-supported; rounded pebble clasts; deep erosional bases; upward grading; sandy matrix	Braided channel-fill deposits
Gmsu, massive volcaniclastic conglomerate	Thick (> 10 m); matrix-supported; ungraded; cobble/boulder clasts; non-erosive bases; laterally continuous	Volcaniclastic debris flow and rock fall/avalanche deposits
Gmsn, normal-graded volcaniclastic conglomerate	Thick (> 5 m); matrix-supported; normal-graded; planar basal contacts; erosional features; evenly stratified	Volcaniclastic debris and mudflow deposits
Gmsi, inversely-graded volcaniclastic conglomerate	Thick (> 5 m); matrix-supported, inverse grading	
Gmss, stratified volcaniclastic conglomerate	Thick (0.5 to 3 m); normal/inverse grading; matrix-supported	
Gcsu, clast-rich massive volcaniclastic conglomerate	Thick (< 4 m); massive; oriented clasts parallel to flow; clast-supported; graded; laterally extensive; includes tuffaceous sandstone lenses	Clast-rich debris flow/hyperconcentrated stream/flood flow and fluidised debris flow deposits
Gcsn, clast-rich graded volcaniclastic conglomerate	Average 0.3 to 1 m thick; normal graded; erosional bases; tuffaceous sandstone interbeds	Hyperconcentrated stream/flood flow and fluidised debris flow deposits
Gcsi, clast-rich inverse graded volcaniclastic conglomerate	Massive; clast-supported; erosional basal surfaces	Hyperconcentrated stream/flood flow, clast-rich debris flow deposits
Gcst, cross-bedded volcaniclastic conglomerate	Large-scale trough cross beds	Locally channelled deposits
Smgv, tuffaceous gravelly sandstone	Up to 0.20 m; normal/inverse grading; laterally discontinuous/continuous; fine to coarse-grained	Volcaniclastic hyperconcentrated flood flow deposits
Smg, gravelly sandstone	Thin to thick (1 to 8 m); crude bedding; normal grading	Bedload channel deposits
St, trough cross-bedded sandstone	Thick (> 1 m); large-scale cross-bedding; fine to coarse-grained; erosional bases	Braided channel deposits
Sp, planar cross-bedded sandstone	Up to 0.7 m thick; medium-scale cross-beds; fine to coarse sands	Transverse bar deposits
Sr, rippled sandstone	Up to 1 m thick; fine sand to silt; cross-laminated sets; rare burrows	Standing-water bodies and flood plain deposits
Shv, horizontal-bedded tuffaceous sandstone	Thick (0.5–4.5 m); crude horizontal-bedding; laterally extensive; nonerosive basal contacts	Sand-rich volcaniclastic hyperconcentrated flood flow deposits
Sh, horizontal-bedded sandstone	Thick (> 0.5 m); crude horizontal-bedding; fine to coarse sands; slightly erosional bases	Sandy sheetflood, bedload channel sand deposits
Sl, laminated sandstone	Parallel lamination and low-angle cross-beds; fine-grained sands	Flooding sand sheet, crevasse splay deposits
Smc, sandy channel mudstone	Massive; medium-scale sandy mudstone channel-fill	Swampy channel deposits in peat mires
Fm, massive mudstone	Thick (> 0.5 m); includes claystone intercalations	Suspension deposits in standing-water bodies
Fmc, massive claystone	Thick (> 0.5 m); homogeneous claystone sets	
Fmcg, gravelly claystone	Scattered chert pebbles in claystone	Standing water conditions disturbed by flashings
Fcc, coaly claystone	Dark greyish; abundant plant debris, gastropod/gastropod shells; thin coal lenses	Clastic wetland with shallow standing water bodies
C, coal (lignite)	Dull and bright banded lignite; gastropod shells	Peat forming mire (wetland)
La, algal limestone	Algal lamination and mounds; micritic	Biologically productive small lakes/ponds
M, marlstone	Massive and laminated; includes plant materials and load casts; locally stramotolitic structures	Marl lake deposits
Ll, laminated limestone	Parallel lamination; includes freshwater gastropods; locally oolitic	Carbonate lakes associated with marl lakes
Ls, silicified limestone	Thin irregular chert bands; micritic	
Vba, basaltic/andesitic lavas	Thin and thick lava layers; locally brecciated	Primary pyroclastic and/or lava flows

Table 3 (continued)

Facies assemblage	Sedimentary features	Depositional setting
FA 7, channel/near channel	Dominantly thick cosets of conglomerates (Gm, Gt) and sandstones(St, Sp, Smg and Sh); prominent erosional bases; fining upward sequences	Proximal and medial bedload braided-river environment
FA 8, floodplain	Dominantly complete/incomplete Sh, Sl and Sr facies successions and massive mudstones (Fm); slightly erosional bases; abundant transported tree stems and plant remains; fining upward sequences	Near-channel belt and distal floodplain or braidplain environments
FA 9, upper mire	Upper coal beds (0.3–2 m) associated with impure coals and claystones/mudstones (Fmc and Fm); alternation with floodplain sandy units; abundant transported plant materials; sandy/muddy channels	Allochthonous peat mires fringed with floodplain and siliciclastic ponds
FA 10, near-vent	Complex of andesitic, dacitic, rhyolitic, basaltic lavas; pyroclastic breccias and ashfall deposits	Multi-vent low-relief volcanic terrain
FA 11, proximal volcaniclastic apron	Dominantly clasr-rich matrix-supported massive conglomerates (Gmsu, Gmss, Gmsi and Gmsn); large volcanic clasts; rarely limestone and mudstone interbeds	Volcaniclastic debris flows, lavaflows, small carbonate/mud depositing lakes/ponds in proximal areas of the volcanic vents
FA 12, medial volcaniclastic apron	Dominantly clast-supported, massive, channelled conglomerates and less tuffaceous sandstones (Gcsu, Gcsn, Gcsi, Smgv, Shv)	Channelled volcaniclastic debris flows, hyperconcentrated flood flows
FA 13, distal volcaniclastic apron-alluvial plain	Dominantly tuffaceous sandstones (Smgv and Shv) and less clast-poor massive conglomerates (Gmsu); common soft-sedimentary structures; locally brecciated lavas	Dominantly hyperconcentrated flood flows, locally debris flows in distal parts of apron and alluvial plain
FA 14, lacustrine	Carbonate domination; silicification; tuffaceous sandstone interbeds; common soft-sedimentary structures	Volcanism-influenced perennial shallow carbonate lakes

Aegean region (Mercier *et al*., 1989). Common soft-sediment deformations in UC succession, compression-related strike--slip faultings in MC succession, and asymmetric foldings may indicate downward displacements, changed into strike-slip or even wrench faulting in the coalfield. This tectonism repeated extensionally during the Late Pliocene through Quaternary periods, and graben-like depressions were filled with Plio-Quaternary sediments.

CONCLUSIONS

The facies recognition and assemblages of the three coal successions of the Soma coalfield display carbonate and siliciclastic dominated alluvial/fluvial-lacustrine settings. The LC succession is a coarse-grained alluvial fan and plain environment formed in extensive forest peat mire. The coal beds of the LC succession were deposited in a carbonate-dominated anastomosed river system. Low calorific-value coal beds of the UC succession were accumulated in allochthonous peat mires of the volcanism-induced braided river environment. Miocene coal successions were deformed with extensional tectonic regime and developed Plio-Quaternary graben complex on the coalfield.

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