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Miocene lacustrine succession of the Hoyran Lake Basin, Isparta, southwest Turkey

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ABSTRACT:

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The Hoyran Lake Basin is an example of a Neogene rift basin in southwest Turkey. Initially red coloured, poorly-sorted, angular cobble to pebble conglomerates were deposited close to the boundary faults. These conglomerates then passed into the finer-grained, calcite-cemented pebble to granule conglomerates towards the basin interior. The distributions of other lacustrine lithofacies (siltstone/claystone, marlstone, limestone and magnesite) appear to have been dependent on the proximity of the lake margins. These occurrences show that the basin was subject to some climatic and tectonic controls. Humid seasons and/or tectonic activities resulted in increased clastic input from the lake margins, drier conditions enhanced evaporation and significantly modified the water chemistry. Ultramafic and dolomitic older rocks around the basin are considered to have been an important source for the ion concentrations implicated in the precipitation of dolomite and magnesite in the Hoyran Lake deposits.

Keywords: Miocene; Tectonic; Silisiclastic feeding; Magnesite; Hoyran Lake; Turkey.

INTRODUCTION

The Neogene tectonic evolution of Turkey is attributed to the activity of the North Anatolian and East Anatolian strike-slip faults (Text-fig. 1) (Şengör and Yılmaz 1981; Savaşcın and Oyman 1998). Differential movements of the Anatolian and surrounding plates resulted in an extensional regime and the formation of several horst-graben structures in the southwestern and western parts of the country (Barka and Reilinger 1997; Koçyiğit and Beyhan 1998). Continuation of the Cyprus and Hellenic Trenches onland created a special geomorphological structure in southwest Turkey, referred to as the Isparta Angle (Blumenthal 1944). This area is divided into several small basins by normal and strike-slip faults (Robertson *et al.* 2003). The northern part of the Isparta Angle hosted several important lacustrine basins, such as the Eğridir, Beyşehir, Salda and Hoyran basins, referred to geographically as the "Lakes Region" (Blumenthal 1944; Gutnic *et al.* 1968; Şengör and Yılmaz 1981; Koçyiğit 1983).

The aim of the present paper is to characterize the Miocene lacustrine sediments of the Hoyran Lake, in the northern part of the Isparta Angle. Some general geological studies were carried out in and around the Hoyran Lake since the mid-1970s (Dumont and Kerey 1975; Demirkol 1981, 1984; Demirkol and Yetiş 1983; Yağmurlu 1991a). All of these emphasized the onset of lacustrine sedimentation as early as the Miocene. No detailed studies were, however, undertaken so far.

Lacustrine deposits are the source of several important raw materials, such as evaporites, bituminous shale, uranium, coal, iron, magnesite and hydrocarbons

(Reading 1996; Önalan 1997; Caroll and Bohacs 1999; Bohacs *et al.* 2000).

STRATIGRAPHY OF THE STUDY AREA

The geological units in the study area can be divided into three groups; pre-Miocene, Miocene, and post-Miocene (Text-fig. 2).

Pre-Miocene group

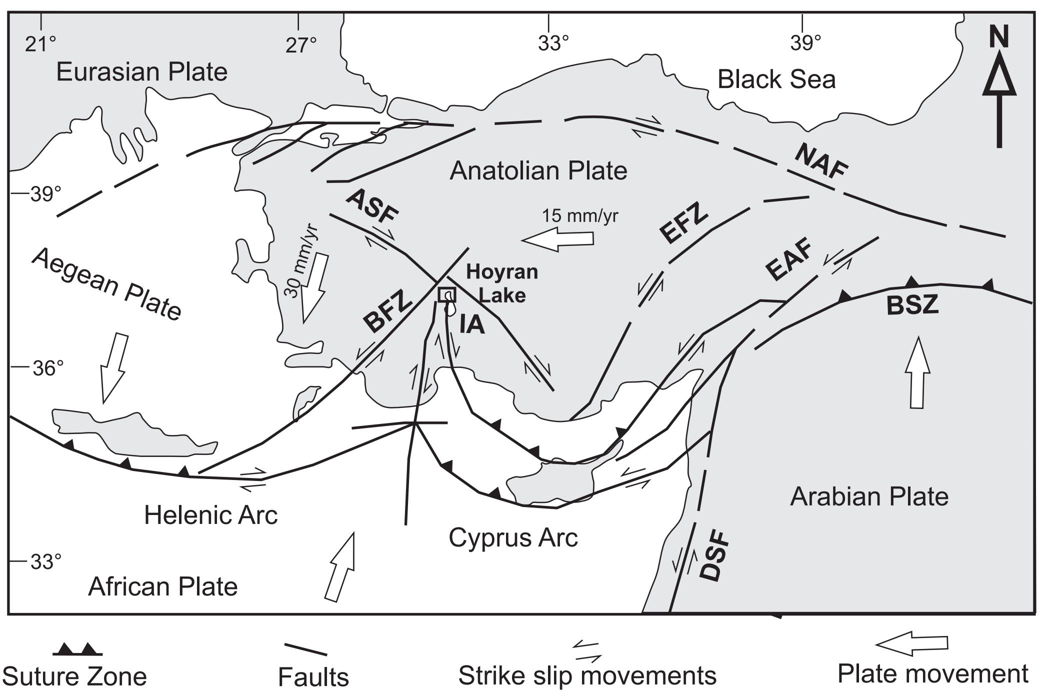
The oldest unit of the group is the Cretaceous Taşevi Formation, which is composed of grey to dark grey, crystallized and dolomitic limestone and dolomite. This formation overlies the Hoyran Carbonate Platform (Koçyiğit 1983). The other pre-Miocene unit is the Hoyran Ophiolitic Melange, composed of serpentinite, radiolarite, serpentinized peridotite and pyroxenite, and limestone olistoliths. The Hoyran Ophiolite was thrust onto the Taşevi Formation late in the Lutetian, and was a relict of the Inner Tauride Ocean (Koçyiğit 1983) (Text-figs 2, 3).

Miocene group

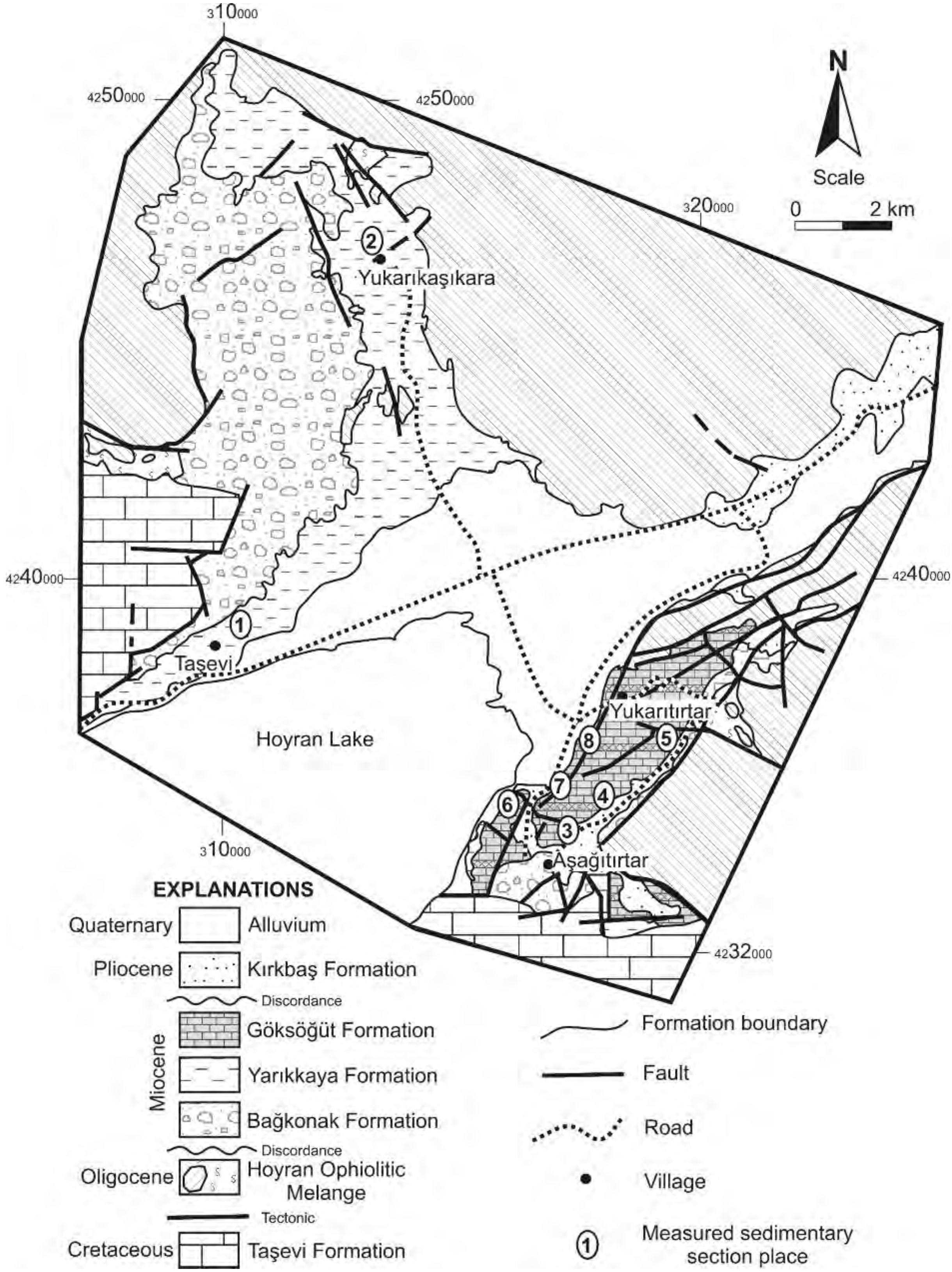
The Miocene group is represented by continental deposits comprising the Bağkonak, Yarıkkaya and Göksöğüt formations. Eight measured sedimentary logs (Text-figs 2, 4) from various parts of the study area show the lateral and vertical variations within the Yarıkkaya and Göksöğüt formations.

Bağkonak Formation: It is exposed mainly in the west-southwestern part of the study area and crops out locally in the southeast margin of the basin (Text-fig. 2). It evolved generally in front of the boundary faults and formed moderately inclined slope foothills (Text-fig. 3). The formation differs from the other units in its red and reddish-yellow colour, coarser grain and its weathering properties. It overlies various units of the Pre-Miocene group discordantly and towards the basin interior it interfingers with the Yarıkkaya Formation (Text-fig. 3B).

The Bağkonak Formation comprises two different types of sedimentary deposits (Table 1): (1) coarse conglomerate occurring close to the palaeomargin of the Hoyran Lake Basin (Text-figs 2, 3), with intercobble to pebble spaces filled by medium- to coarse-grained sands, with a similar composition to that of the larger clasts; and (2) finer sediments, being a lateral continuation of the coarser, including pebble- to granule-size conglomerates and coarse to medium-grained sandstones with calcite cement. The clasts of this formation were derived mainly from the sediments of the Taşevi Formation and of the Hoyran Ophiolitic Melange.



Text-fig. 1. Main tectonic features of Turkey and surrounding region (modified from Savaşcın and Oyman 1998); IA – Isparta Angle, BFZ – Burdur-Fethiye Fault, ASF – Akşehir-Simav Fault, NAF – North Anatolian Fault Zone, EFZ – Ecemiş Fault Zone, DAF – East Anatolian Fault Zone, DSF – Dead Sea Fault Zone, BSZ – Bitlis-Zağros Suture Zone



Text-fig. 2. General geological map of the study area

Palaeocurrent directions were measured from the clast imbrication were towards the basin interior.

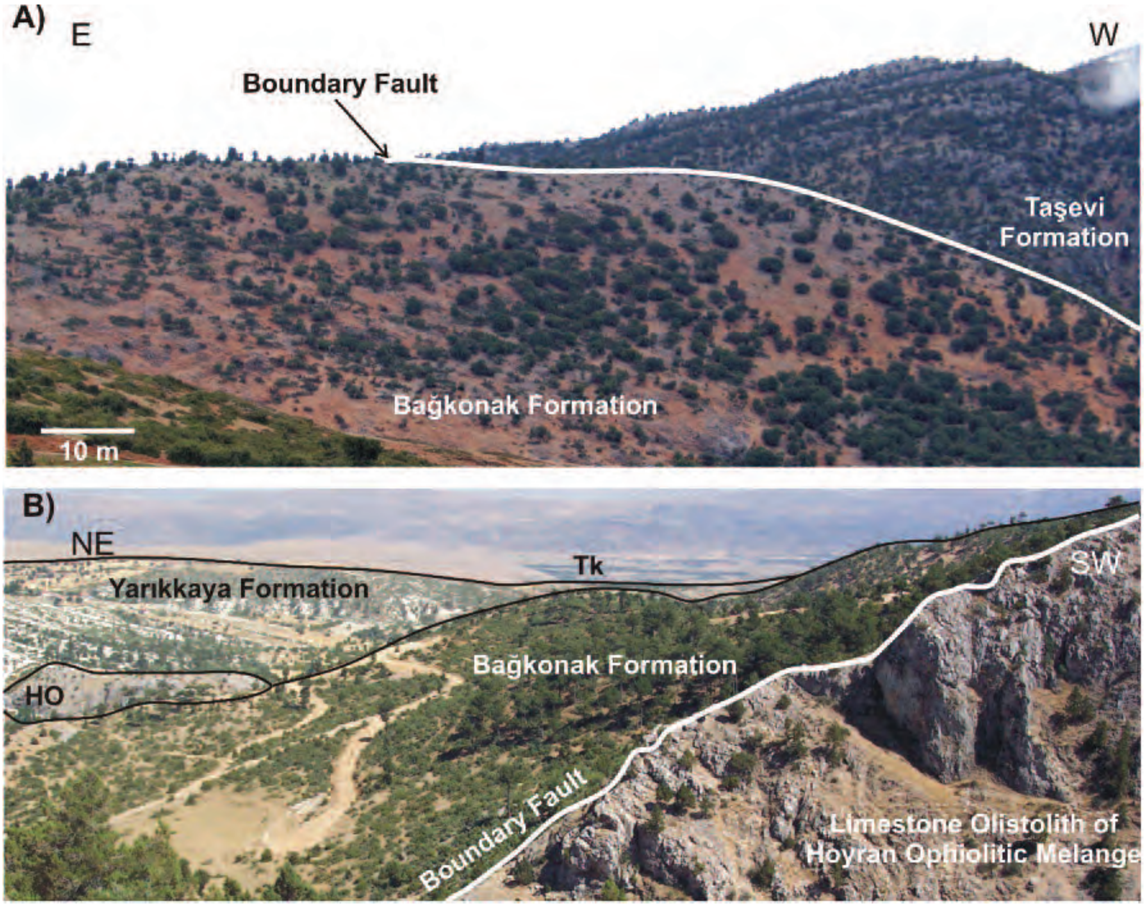
Clast types, palaeocurrent directions and downdip lithological variation indicate that the formation was initially deposited as alluvial fans in front of the bounding faults at the basin margins. Subsequently, these clastics were transported to the subaqueous environment through the down-fan, interfingering with the lacustrine fossiliferous, fine-grained clastics of the Yarıkkaya Formation. Consequently, it may represent a fan delta environment. However, the transition between fan delta and alluvial fan environments is unclear due to heavy weathering in the study area.

The Bağkonak Formation has been dated as early Miocene (Yağmurlu 1991a).

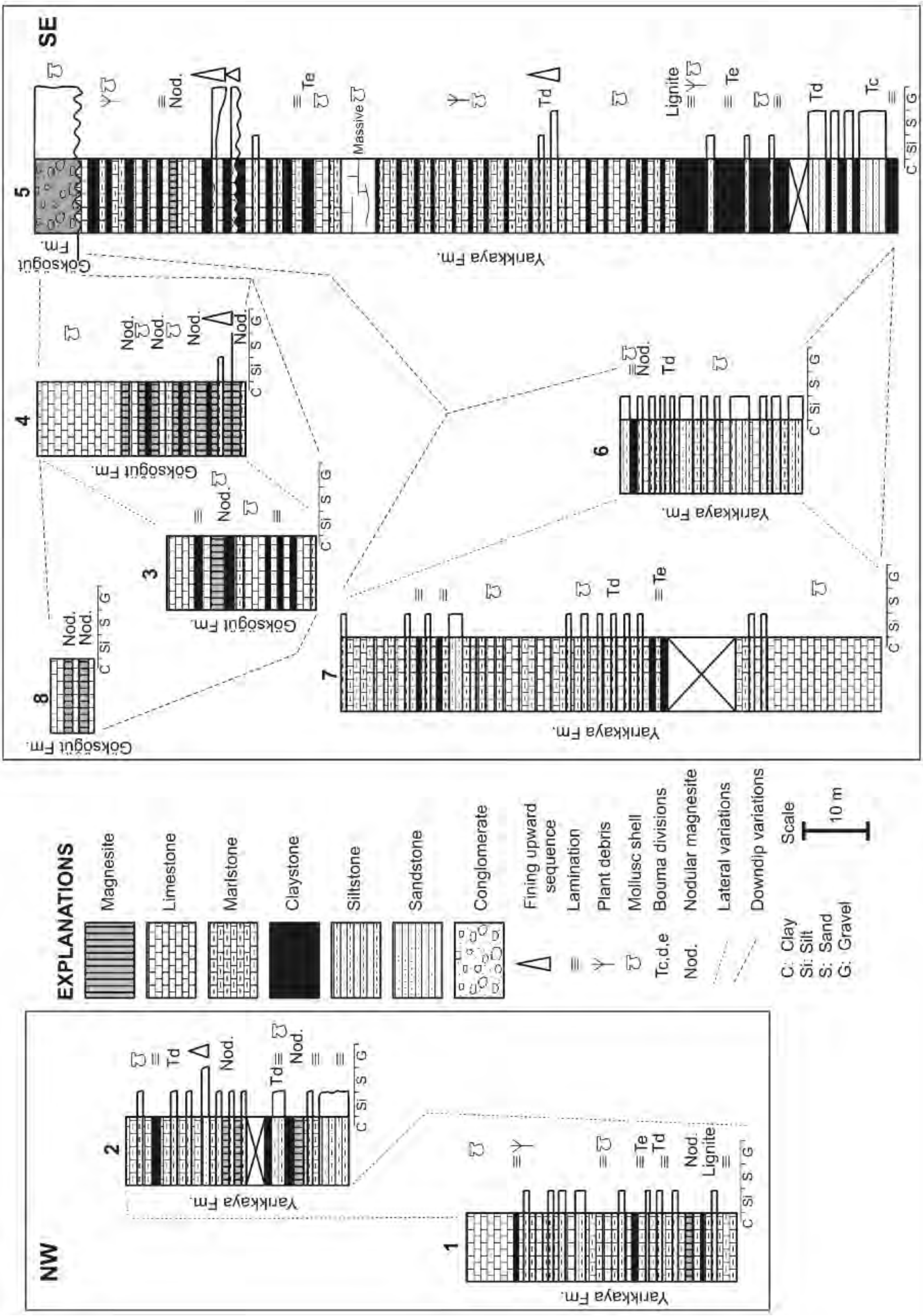
Yarıkkaya Formation: it crops out mainly in the northwestern part of the study area (Text-fig. 2), but it also occurs in the southeastern part, where it appears from beneath the Göksöğüt Formation (Text-figs 3 and 4). It has the widest distribution of all the formations in the Hoyran Lake Basin (Text-figs 2 and 3B) and represents a transgressive succession. In the central part of the basin it overlies the pre-Miocene rocks discordantly. It interfingers with, and/or conformably overlies the Bağkonak Formation.

Lithologically, the Yarıkkaya Formation varies from the lake margin through to the basin interior (Table 1). The northwestern part of the study area includes siltstone, fine-grained sandstone (Bouma divisions: Tc, Td), claystone (Te) and marlstone alternations at the bottom (Table 1; Text-fig. 4). Locally (near the village of Yukarıkaşıkara) these clastics also include dark brown to black lignite horizons. The quantity of fine-grained clastics decreases towards the top.

The Yarıkkaya Formation is over 100 m thick near the village of Yukarıtırtar (log 5; see Text-figs 2 and 4). There, the succession is composed of fine- to medium-grained sandstone with Tc–Td Bouma divisions at the bottom. Laminated claystones (Te) alternate with fossiliferous lacustrine limestone and marlstone towards the top (Text-fig. 4). Lignite hori-



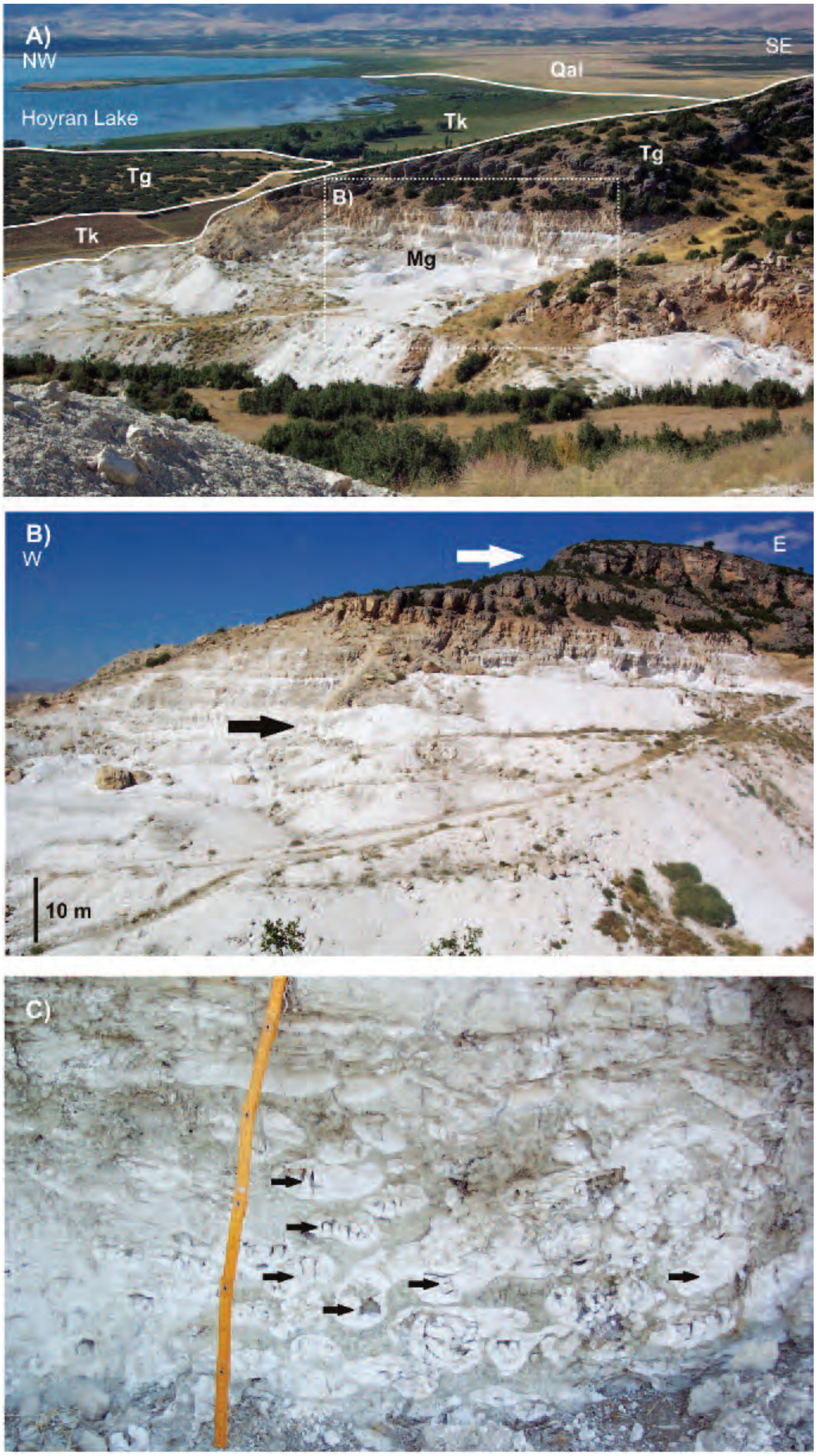
Text-fig. 3. **A** – Boundary faults restricting the Miocene lacustrine deposits south of the village of Aşağıtırtar; **B** – Field photo of the Miocene lacustrine sediments, Pliocene continental deposits (Tk: Kırkbaş Formation) and limestone olistoliths in the Hoyran Ophiolitic Melange (HO) near the village of Yukarıkaşıkara



Text-fig. 4. Sedimentary logs measured in different part of the Hoyran Lake Basin

Formation	Lithological Properties	Depositional Process and Environment
Bağkonak Formation	Red to reddish-yellow, very poorly- to poorly-sorted, angular to subangular, unfossiliferous (except for plant rootlets), very weathered, mostly clast- and sand-supported, disorganized, laterally extensive but poorly exposed, crudely-bedded cobble- to pebble-size polymictic conglomerates (close to lake margin).	Gravity flow (Önalan 1997), debris flows and stream floods (Deynoux *et al.* 2005). Alluvial fan.
	Reddish-yellow to reddish-white, moderately-sorted, subangular to rounded, laterally extensive but heavily weathered, loose, crudely-bedded, disorganized pebble- to granule-size conglomerates and small-scale cross-laminated coarse- to medium-grained sandstones with calcite cement (towards the basin interior). Locally interfingering with the fine-grained clastics of the Yarıkkaya Formation.	Inertia flow (Cronin and Kidd 1998; Shanmugam 1997, 2002), subaqueous grain flow and debris flows (Deynoux et al. 2005). Fan delta environment
Yarıkkaya Formation	Yellowish-white, green and greenish-grey, fossiliferous, plant debris-bearing, mostly thin- to medium-bedded, medium- to fine-grained sandstone (Tc and Td), alternating with laminated claystones of the same colour, locally with lignite (basal part, close to the lake margin).	The sandstones are the products of a low- to high-density turbidity current depending on grain size (Middleton and Hampton 1976). Fine-grained turbidites are products of a low-density turbidity current, bottom current and suspension in a pelagic-hemipelagic environment (Mutti and Lucchi 1972). Lacustrine environment close to lake margin.
	Yellowish-green, green and grey, thin-bedded mollusc shell-bearing limestone, marlstone, siltstone (Td) and claystone alternations (Te) (upper part, towards the basin interior (offshore)).	Fine grained turbidites are products of a low density turbidity current, bottom current and suspension in a pelagic-hemipelagic environment (Mutti and Lucchi 1972).
Göksöğüt	Grey, cream and beige, medium- to thick-bedded and massive, mollusc shell-bearing limestone and nodular magnesite.	Deeper lacustrine environment. Chemical deposition. Shallow lacustrine environment with evaporation.

Table 1. Lithological properties, depositional process and environment of the Miocene lacustrine deposits of the Hoyran Lake Basin



Text-fig. 5. **A** – Field photos of the Göksöğüt Formation (Tg – limestone, Mg – magnesite) and Post-Miocene deposits (Tk – Kırkbaş Formation, Qal – Alluvial deposits) north of the village of Aşağıtırtar; **B** – Close-up view of the magnesite quarry in the Göksöğüt Formation, white arrow shows the lacustrine carbonate, while black arrow indicates magnesite; **C** – Close-up view of the nodular magnesite level (black arrows) in the claystone in the road-cuttings near the village of Yukarıkaşıkara zons occur locally in the upper part. In this area, the Yarıkkaya Formation is overlain by conglomerates of the Göksöğüt Formation. Toward the south, the formation is overlain by magnesite-limestone alternations (logs 3 and 4: see Text-figs 2 and 4). The amount of clastic material decreases towards the northwest (through the basin interior); mostly fossiliferous, laminated marlstone and limestone alternation are observed in the sixth and seventh log (Text-figs 2 and 4). Only magnesite–limestone alternations of the Göksöğüt Formation (eighth log) overlie the Yarıkkaya Formation in the basin interior (Text-fig. 4).

The lignite horizons of the Yarıkkaya Formation yielded *Laevigatosporites haardti* (Potonie and Venitz 1934) Ibr. 1953; *Leiotriletes microadriensis* Krutzsch 1959; *Baculatisporites primarius* (Wolf 1934); *Gleichenidites* (Ross 1949) Krutzsch 1959; *Monocolpopollenites* Nakoman 1966; *Monoporopellinite gramineoides* Meyer 1956; *Inaperturopollenites hiatus* (Potonie 1931); *Inaperturopollenites dubius* (Potonie and Venitz 1934); *Pityosporites microalatus* (Potonie 1931); *Triatripollenites rurensis*, 1953, as well as pine and *Alnus* pollens and rare Cyrillaceae, chestnut and Myrica pollens (Yağmurlu 1991a). Demirkol and Yetiş (1983) also reported ostracods (*Heterocypris* cf. *ponticus* Krstic), bivalves and gastropods. The fossils suggest an early to middle Miocene age (Yağmurlu 1991a) and indicate a fresh water, lacustrine environment (Demirkol and Yetiş 1983; Yağmurlu 1991a).

The lignite horizons of the Yarıkkaya Formation originated in marshy or ponded environments close to the lake margin. The greater part of the formation consists of rhythmic alternations of marls and siltstones dependent on changes in siliciclastic input, climatic changes and tectonic activities (Text-figs 3B and 4). Local erosively-based coarse-grained sediments show that the relatively higher-energy small distributary channel deposits and the fine clastics (with different Bouma divisions) were the products of turbidity currents and suspension in relatively deeper and lower energy environment (Table 1; Text-fig. 4).

Göksöğüt Formation: It crops out mainly in the southeastern part of the study area, where it generally forms a small hill (Text-fig. 5); and also locally in the northwestern part (Text-figs 2, 4). This formation interfingers with, and/or conformably overlies the Yarıkkaya Formation, and is overlain by the post-Miocene deposits with angular unconformity (Text-fig. 2, 5A).

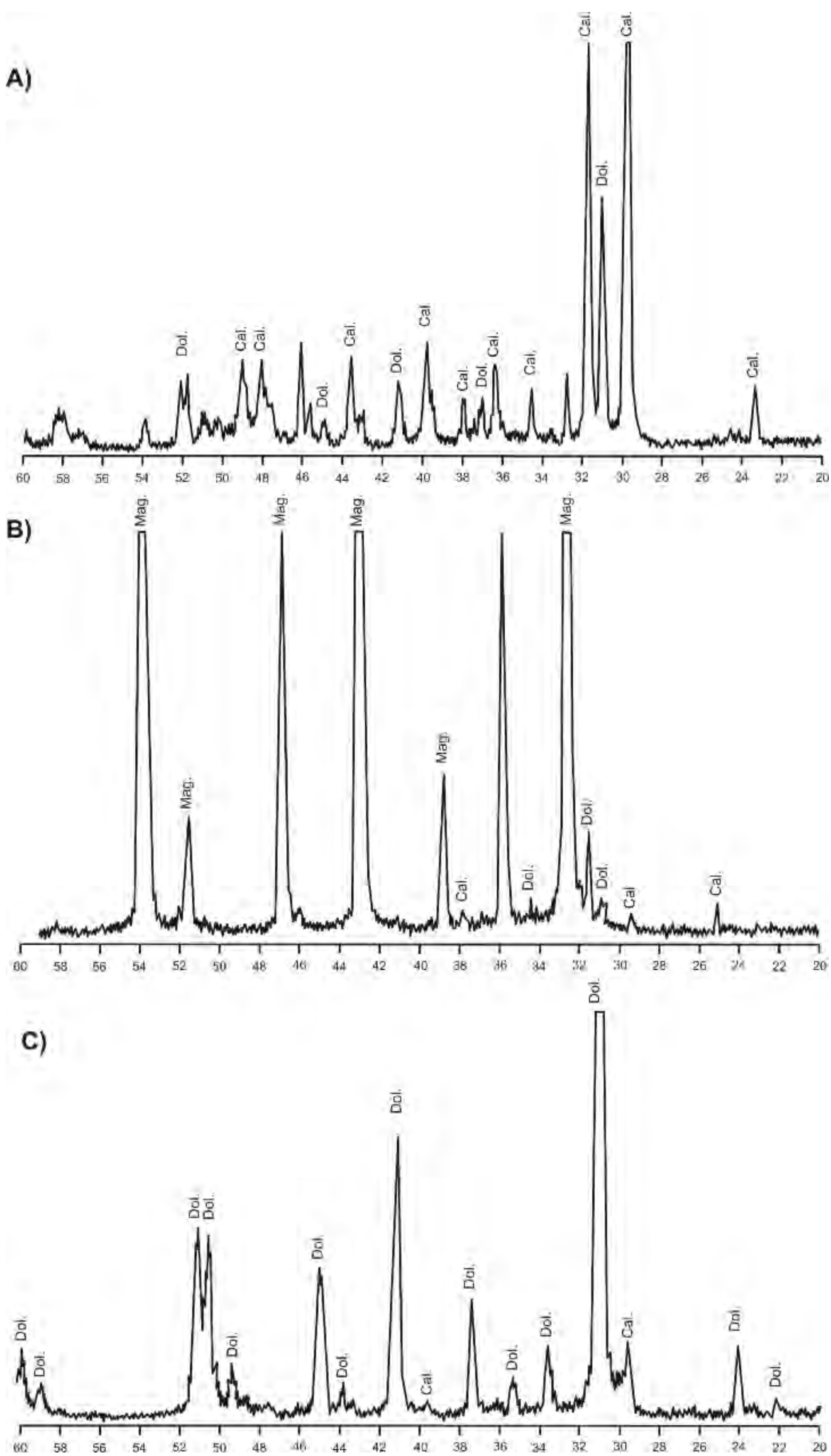
The formation includes mainly medium- to thick-bedded and massive limestone and nodular magnesite (Table 1; Text-fig. 5). It interfingers with the Yarıkkaya Formation in the northwestern part of the study area (in the first and second log: Text-fig. 4). In the southeastern part of the study area (logs 3, 4, 5; see Text-fig. 4) the limestone and nodular magnesite of the Göksöğüt Formation are characterized by siliciclastic input. The clastics pinch out towards the basin interior (are not observed in log 8; Text-fig. 4). XRD analyses were performed on samples belonging to the pre-magnesite, magnesite and post-magnesite levels (Text-fig. 6). These analyses were carried out in the Çukurova University, Geological Engineering Department Geochemistry Laboratory using Philips device. Mineral paragenesis of the pre-magnesite level contains mostly dolomite and, to a lesser extent, calcite (Text-fig. 6A). The magnesite level primarily contains magnesite, and secondarily calcite and dolomite (Text-fig. 6B). The post-magnesite level contains dominant calcite and subordinate dolomite minerals (Text-fig. 6C). Mg^{2+}/Ca^{2+} ratios in lacustrine water control calcite-dolomite-magnesite deposition (Renaut and Stead 1991). Initial precipitation of the calcite increased the Mg^{2+}/Ca^{2+} ratios and led to high-Mg calcite, dolomite and magnesite precipitations respectively. A decrease in the Mg^{2+}/Ca^{2+} ratios after the precipitation of magnesite and related minerals lead to calcite and/or dolomite evolution.

Freshwater ostracods (*Heterocypris* cf. *ponticus* Krstic), bivalves and gastropods (*Limnea* sp., *Planorbis* sp.) were found in this formation (Demirkol and Yetiş 1983; Yağmurlu 1991a). The fossil assemblage indicates a Late Miocene age and a shallow lacustrine depositional environment (Yağmurlu 1991a). As seen in the southeastern lake margin, the quantity of clastics decreased towards the basin interior. The different types of chemical rock deposition (limestone, dolomite, magnesite) indicate the effects of climate, water chemistry and/or tectonic activities on the shallow lacustrine environment of the Hoyran Lake.

Post-Miocene group

The post-Miocene deposits include the Kırkbaş Formation and alluvial deposits (Text-fig. 2). They overlie the pre-Miocene units discordantly at an erosion surface and the Miocene sediments with angular unconformity.

The Kırkbaş Formation (Pliocene) is widely exposed in the northeastern part of the study area (Text-fig. 2) and forms topographically low areas (Text-fig. 3B, 5A). It consists of red-coloured, poorly-sorted, loose conglomerate, sandstone, siltstone and claystone. The constituents of this formations were derived from both Miocene and pre-Miocene units. *Hipparion*



Text-fig. 6. Results of XRD analysis; **A** – Pre-magnesite level; **B** – Magnesite level; **C** – Post-magnesite level; Cal – Calcite, Dol – Dolomite, Mag – Magnesite minerals) sp., *Mastedon* sp. and other vertebrate fossils indicate its Pliocene age and continental environment (Yağmurlu 1991a). Quaternary deposits are developed around the streams and brooks, and have a limited distribution in the study area.

CONTROLLING FACTORS OF THE MIOCENE SEDIMENTATION IN THE HOYRAN LAKE BASIN

Factors controlling sedimentation in a lacustrine environment are climate, chemical composition of a drainage area, water level fluctuations, tectonics, siliciclastic input and biological activity (Kelts and Hsü 1978; Thompson and Ferris 1990; Thompson *et al.* 1990; Allen and Collinson 1991; Kempe *et al.* 1991; Ferris *et al.* 1997; Arp *et al.* 1999; Verschuren 1999, 2002; Abdul Aziz *et al.* 2003). In the Hoyran Lake the most important of these were tectonics, siliciclastic input, water chemistry and climate.

Tectonics

Tectonic activity determines the rate of subsidence, influences the drainage pattern in a catchment area, the location of the clastic input and, consequently, the differentiation of sedimentary facies (Platt and Wright 1991). The Hoyran Lake developed in a depression basin, bordered by NE–SW and NW–SE extensional faults (Text-figs 2, 3, 7). The faults actively controlled the shape, geometry and size of the depositional area as well as the water level fluctuations. Pre-sedimentation tectonic activity cracked and fractured the older rocks, and created discontinuities. They greatly affected the underground water circulation around the Hoyran Lake and thus the lake water chemistry. Reactivation of the boundary faults also caused destabilization of the loose siliciclastic material accumulated at the lake margin. The tectonically active periods are marked by coarser material, whereas fine-grained deposits typify the tectonically quiescent periods. The initial large amount of coarse clastics (Bağkonak Formation) was derived from the lake margin because of movement on the boundary fault; the clastics were subsequently derived mostly from the southeast (Text-fig. 7).

Silisiclastic input

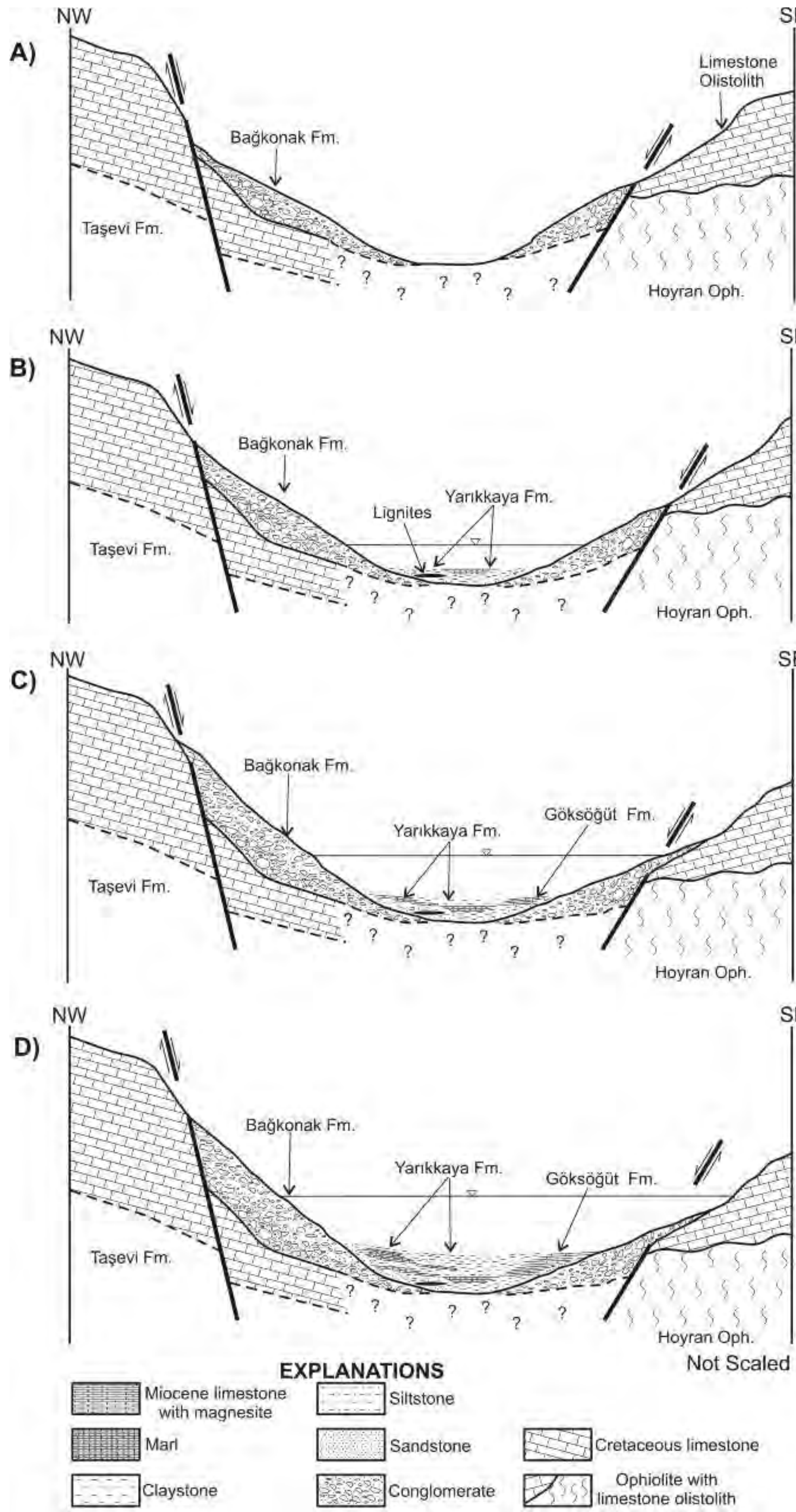
In the deeper part of a lake, siliciclastic sedimentation may be due to three processes: mass flow, turbidity flow and pelagic suspension (Allen and Collinson 1991). Clasts derived from lake margins formed by the Hoyran Ophiolitic Melange and Taşevi Formation were deposited initially as alluvial fans and fan deltas around the Hoyran Lake. They formed the angular-subangular, poorly sorted clast- and sand-supported pebble conglomerates. These clasts were transported to the lake by gravity and/or mass flows. They pass into the granule and rarely pebble conglomerates and medium- to coarse-grained sandstones with calcite cement in the fan delta environment. These initial deposits formed the Bağkonak Formation (Text-fig. 2, 3). Successive siliciclastic input formed sandstone and conglomerates close to the nearshore area (products of the high energy process) in both the Yarıkkaya and Göksöğüt formations (Text-fig. 4). Most of them related to the distributary channels in a subaqueous system. Fine-grained clastics with Bouma divisions are the product of turbidity currents. Clay-size particles were deposited from suspension in relatively deeper and low energy environment (Table 1). The amount of siliciclastic input also controls the sediment thickness. The locations of siliciclastic input were mainly controlled by the tectonic features of the study area.

Water chemistry

Lakes collect water from surface run-off and/or underground springs, thus the chemistry of the lake water reflects the chemistry of the water catchment areas (Picard and High 1972; Allen and Collinson 1991; Altınkale 2001). Carbonate minerals in the lacustrine enviroment are sourced from the input of detrital limestone clasts, as well as from Ca^{2+}, Mg^{2+} and HCO_3^- in solution via surface or ground water flow (Platt and Wright 1991). Magnesite, dolomite and calcite deposition in the Hoyran Lake depended on the Mg^{2+}/Ca^{2+} ratios. Enrichment in Mg^{2+} and Ca^{2+} ions in the study area indicates the effect of the host rock on the water chemistry. Ophiolitic rocks and limestone-dolomite surround the Hoyran Lake Basin (Text-fig. 2, 3) and water circulation from these rocks supplied the alkaline characters of the Hoyran Lake. Climatic changes also controlled the Hoyran Lake water chemistry.

Climate

In the lacustrine environment, climate controls the organic activity, quantity of run-off water, weathering in the drainage area and evaporation (Platt and Wright 1991). It thus actively controls the size of a lake and the rhythmicity of the lacustrine sediments (Text-fig. 4). The clastic and chemical deposits of the Hoyran Lake Basin represent different climatic seasons. A humid sea-



Text-fig. 7. Geologic evolution of the Hoyran Lake Basin during the Miocene time; A – Lower Miocene; B – Lower-Middle Miocene; C – Middle-Upper Miocene; D – Upper Miocene son, with increased weathering in the drainage area, caused lake expansion and increased siliciclastic input. Dry seasons are characterized by lower siliciclastic and water input (energy and water transportation decreasing of river), and by increased evaporation in the lake (lake regressed). Thus dry seasons are represented by marlstone, limestone, dolomite and magnesite deposition, depending on the water chemistry and the amount of material in suspension. Karakaya and Kadir (1998) additionally emphasized that, based on XRD, SEM and other petrographical data, lacustrine carbonates represented wet conditions, and dolomitic limestone and dolomite dry conditions, in the Neogene lacustrine deposits in the Konya (Central Turkey). Anadon *et al.* (1991) also indicated that laminated aragonite was deposited during high water level (wet season), while non-laminated dolomite was deposited during low water level (dry season) in the Miocene Rubielos de Mora Basin (northeast Spain).The limestone and magnesite alternations of the Göksöğüt Formation thus indicate small-scale climatic changes in the Hoyran Lake Basin.

Biological Activity

Biological activity (mostly cyanobacteria) in the lacustrine sediments of the Isparta lakes was recognized by Zedef *et al.* (2000) on the basis of the patchy distribution of the magnesite levels. Some traces of cyanobacteria, albeit not very clear (probably destroyed during diagenesis), were observed directly in thin sections.

TECTONO-SEDIMENTARY EVOLUTION OF THE HOYRAN LAKE BASIN DURING MIOCENE TIME

The history of lacustrine sedimentation in the Hoyran Lake is similar to that of the other lacustrine environments in the “Lakes Region” in Turkey. All of them were developed under an extensional regime in the Isparta Angle. The extensional conditions started in the mid-Oligocene and continued up to the present (Koçyiğit 1983); they are responsible for the development of normal faults (and depression basins) also bordering the Hoyran Lake area (Text-figs 2, 3, 7).

Picard and High (1981) indicated that the initial coarse, angular and poorly sorted conglomerate at a basin margin, directly overlying the basement rocks, are the effect of erosion of the steep coastline. Similarly, the Hoyran Lake Basin was initially filled by the coarse-grained particles (the Bağkonak Formation). This is supported by a few palaeocurrent measurements showing transport towards the basin interior, with a consequent downdip decrease in clast size. The sand-supported conglomerates are followed by carbonate-cemented conglomerates and sandstones. The carbonate-cemented clastics of the Bağkonak Formation interfinger with finer-grained fossiliferous deposits of the Yarıkkaya Formation (Text-fig. 7B).

Consequently, it is suggested that the Bağkonak Formation represents the alluvial fan (close to the lake margin) – fan delta (towards the basin interior) environment. The formation varies considerably (Text-fig. 7A, B), and its total thickness is estimated at 245–250 m (Demirkol and Yetiş 1983, Yağmurlu 1991b).

The evolution of the lowermost part of the Yarıkkaya Formation, including the distributary channel deposits, was closely related to the reactivation of the boundary faults and/or the start of the local small fluvial input. The upper part of the formation includes rhythmic marlstone-siltstone-claystone alternations (Text-fig. 7C). The latter indicate seasonal climatic changes and/or tectonic activity. The increased weathering in the drainage area during humid periods caused the increase in the amount of siliciclastic supply. Tectonic activity of the boundary faults caused destabilization of this material at the lake margin. The coarser materials of the Yarıkkaya Formation were deposited from turbidity currents, the laminated finer-grained material from suspension in quiet, relatively low-energy and deeper parts of the lacustrine environment. Thin and parallel lamination as seen in the claystones of the Yarıkkaya Formation developed below wave base in the central part of the lake (Picard and High 1972, 1981). Excess evaporation and shoreline regression occurred during dry seasons. These periods are characterized by a decrease in siliciclastic supply and an increase in chemical rock deposition. Thus, in the Yarıkkaya Formation, the siltstone and sandstone intercalations thin towards the basin interior, while the thicknesses of marlstone beds increase. Local lignite deposition in the northwest and southeastern part of the study area indicates marshy or local pond environments at the lake margin. Towards the top of the Yarıkkaya Formation, the siliciclastic deposits are replaced by marlstone, suggesting the transgressive nature of the Hoyran Lake basin.

The late Miocene magnesites of the Göksöğüt Formation display an asymmetrical distribution in the study area (Text-fig. 2, 7D). They crop out mainly in the southern part of the basin, with very limited exposures in the northwestern part (Text-fig. 4). This asymmetry may reflect shifting of tectonic activity during its deposition. Relatively strong uplift in the southeastern part of the study area, and a humid climate, increased the chemical weathering of the older limestone and ophiolitic mélange; water circulation from these rocks caused the alkaline characters of the Hoyran lake water. Progressive evaporation increased the Mg^{2+}, Ca^{2+} and carbonate saturations in the Hoyran Lake. Calcite was deposited initially, followed by dolomite and magnesite. The alternation of nodular magnesite and limestone occurrences relate to changes of the Mg^{2+}/Ca^{2+} ratios dependent on small-scale climatic fluctuations, and/or tectonic activities, and/or biological activity during the Late Miocene (Text-fig. 7C, D).

After the Miocene, the whole northern part of the study area was uplifted. Post-Miocene sediments were deposited under continental conditions. Lacustrine sedimentation moved towards the south, to its present position.

CONCLUSIONS

The development of the Miocene Hoyran Lake (southwest Turkey) was controlled by various factors. Normal boundary faults created a graben-type depression basin, the Hoyran Lake Basin. Initial sedimentation close to the basin margin includes poorly-sorted, angular to subangular conglomeratic facies (Bağkonak Formation). Subsequent climatic change and tectonics caused the development of rhythmic claystone-siltstone / marlstone alternations (Yarıkkaya Formation). The upper part of the Miocene lacustrine sediments in the Hoyran Lake Basin consists mainly of chemical rocks (limestone, dolomite, magnesite of the Göksöğüt Formation) deposited from the saturated lake water. Climatic conditions, the geology around the lake and the circulation of surface and underground water all affected the chemical composition of the Hoyran Lake water, resulting in alternations of limestone, dolomite and magnesite deposits, related to the Mg^{2+}/Ca^{2+} ratios.

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