DOI: 10.1017/S0016756804009148 *Printed in the United Kingdom*

Planktonic foraminiferal biostratigraphy of the Neogene sequence in the Adana Basin, Turkey, and its correlation with standard biozones

ATIKE NAZIK*

Department of Geology, Engineering and Architecture Faculty, Çukurova University, 01330, Balcalı, Adana, Turkey

(*Received* 10 March 2003; *accepted* 23 December 2003)

Abstract – The aim of this study is to describe the biostratigraphic, chronostratigraphic and ecostratigraphic relationships of the Neogene sequence in the Adana Basin. The Adana Basin is located in southern Turkey, and bordered by the Tauride Orogenic Belt to the north, the Amanos Mountains to the east, the Mediterranean coast to the south and the Ecemiş Fault Zone to the west. From base to top, the Neogene sequence consists of the Gildirli Formation (continental redbeds), the shallow marine Kaplankaya Formation, the reefal limestones of the Karaisalı Formation, the shales of the Güvenç Formation (slope to deep marine), a thick submarine fan complex (Cingöz Formation), the shallow marine and fluvio-deltaic Kuzgun Formation and the shallow marine lagoonal–continental Handere Formation. The planktonic foraminiferal biozones identified within the Neogene sequence of the Adana Basin are *Globigerinoides trilobus* and *Praeorbulina glomerosa curva* (Burdigalian), *Globorotalia fohsi peripheroronda/Orbulina suturalis* (Langhian), and *Globorotalia mayeri* (Serravallian). The Late Tortonian is characterized by the first occurrence of *Globorotalia suterae*. There are no planktonic foraminiferal zones in the Messinian, but this level may be correlated with a non-distinctive zone in the Mediterranean region. The Pliocene is represented by the *Sphaeroidinellopsis* Acme Zone.

Keywords: foraminifera, biostratigraphy, Neogene, Adana Basin, Turkey.

1. Introduction

The Adana Basin is located in southern Turkey and bordered by the Tauride Orogenic Belt to the north, the Misis Mountains to the east, the Mediterranean coast to the south and the Ecemiş Fault Zone to the west (Fig. 1).

The Adana Basin Tertiary sequence is represented by many different facies types and lithostratigraphic units from base to top. The lithostratigraphy, biostratigraphy, ecostratigraphy and chronostratigraphy of this sequence have been studied in detail by Schmidt (1961); Özer *et al*. (1974); Görür (1979, 1982, 1985); Nazik & Toker (1986); Gökçen *et al*. (1988); Yetiş (1988); Nazik & Gürbüz (1992); Ünlügenç, Kelling & Demirkol (1991); K. G. Gürbüz (unpub. Ph.D. thesis, Univ. Keel, 1993); Şafak (1993*a*,*b*); U. C. Ünlügenç (unpub. Ph.D. thesis, Univ. Keel, 1993); Özçelik & Yetiş (1994); Williams *et al*. (1995); Yetiş *et al*. (1995); Nazik *et al*. (1997); Gürbüz, Nazik & Cronin (1998) and Öğrünç, Gürbüz & Nazik (2000).

The purpose of this study to is describe the biostratigraphic, chronostratigraphic and ecostratigraphic relationships of the Neogene sequence in the Adana Basin by synthesizing previous planktonic foraminiferal biostratigraphy studies.

* Author for correspondence: anazik@cu.edu.tr

2. General Neogene lithostratigraphy

This study refers to Neogene sequences along a N–S-trending Gildirli–Karaisalı–Kuzgun line across the Adana Basin. These units are described in the following paragraphs.

The Gildirli Formation was first defined by Schmidt (1961), and contains terrestrial redbeds, including conglomerates, sandstones, siltstones and mudstones. The Gildirli Formation passes upwards and laterally into the shallow marine Kaplankaya Formation and is concordantly overlain by the reefal Karaisalı Formation. No fossils have been identified as yet within the Gildirli Formation. The age of the Gildirli Formation probably ranges from the Oligocene to earliest Miocene (Aquitanian(?)–Early Miocene: Yetiş *et al*. 1995) (Fig. 2).

The Kaplankaya Formation has been differentiated by H. Lagap (unpub. M.Sc. thesis, Univ. Çukurova, 1986) and Yetiş (1988) as a sequence mainly comprising pebbly sandstones, sandstones, sandy limestones and silts. Environmentally, this formation consists of a variety of shallow marine deposits which occur between the Miocene reefal carbonates of the Karaisalı Formation and the deep-marine turbidite sequences in the northern part of the Adana Basin (including the Köpekli shale unit of Schmidt, 1961, and the lower part of the Güvenç Formation of Yetiş, 1988), as defined by Ünlügenç, Kelling & Demirkol (1991),

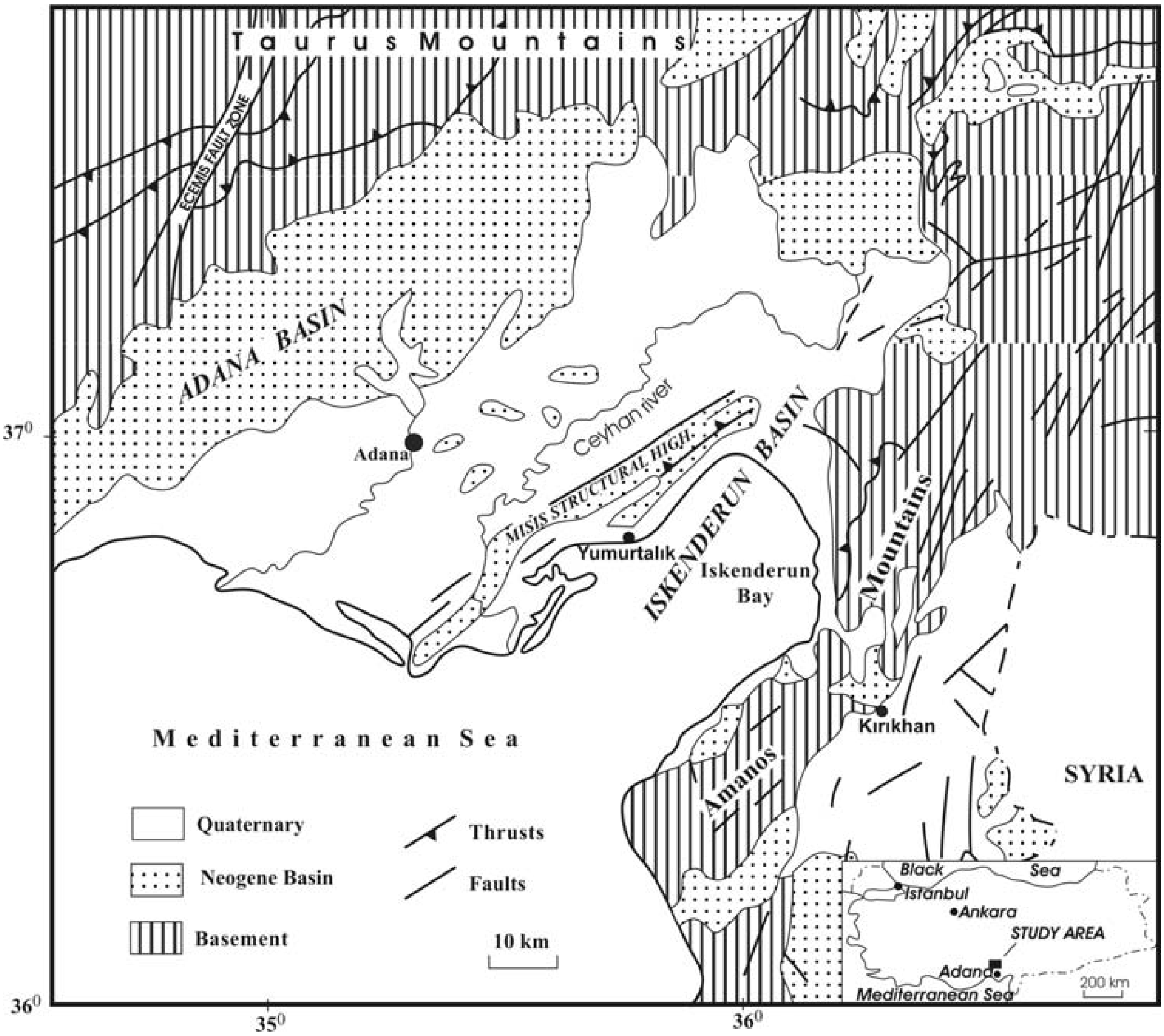

Figure 1. Geological location map of the study area (from Gürbüz, 1999).

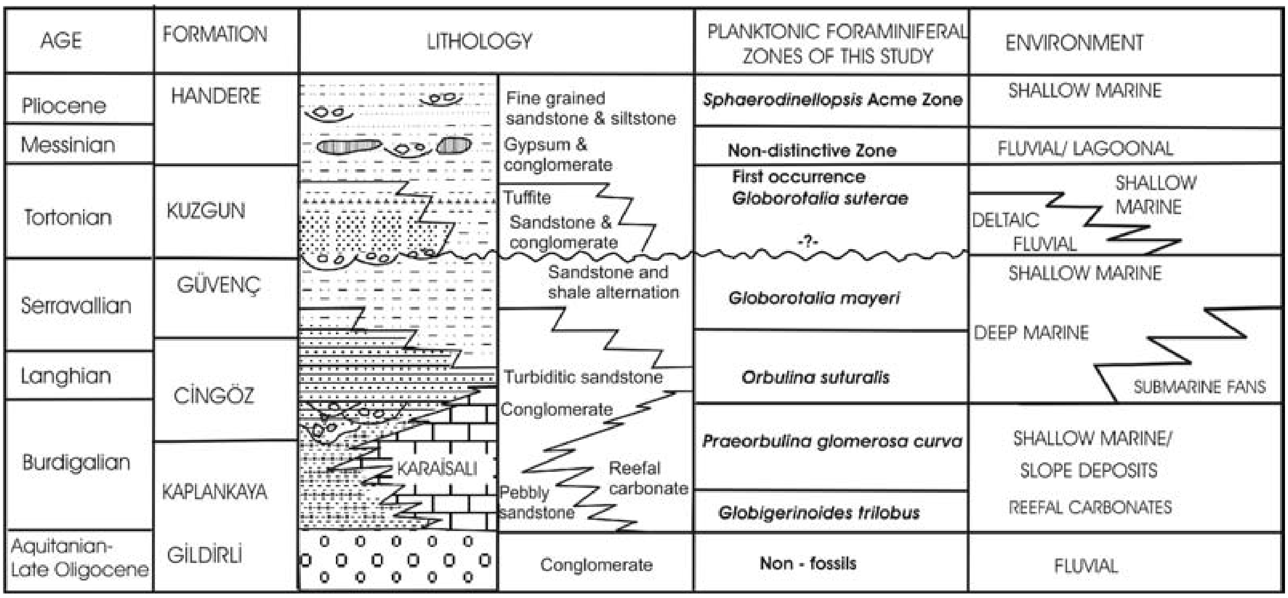

Figure 2. Correlation of lithologic, biostratigraphic and environmental features of the Adana basin.

https://doi.org/10.1017/S0016756804009148 Published online by Cambridge University Press

Nazik & Gürbüz (1992) and Gürbüz & Kelling (1991, 1993). This unit was deposited in the Late Burdigalian–earliest Langhian within relatively shallow marine conditions.

The Karaisalı Formation was first defined by Schmidt (1961), who named it the Karaisalı Limestone. Recent workers have preferred to use the term Karaisalı Formation rather than Karaisalı Limestone because of its dolomite and dolomitic limestone content. The unit is mainly composed of reefal carbonates (Yalçın & Görür, 1984), assigned to six subfacies, namely: coral packstone and boundstone, small benthic foraminiferal–algal packstone, coral wackestone and packstone, large benthic foraminiferal–algal packstone, globigerinoid algal packstone and globigerinoid argillaceous wackestone by Görür (1979). The coral packstone and boundstone and small benthic foraminiferal algal packstone subfacies were attributed by Yalçın & Görür (1984) to the main reef body which was deposited on structural highs, while the coral wackestone, coral packstone and large benthic foraminiferal biofacies formed as talus deposits on the submarine fore-reef slopes. The age range for the Karaisalı Formation is Burdigalian to Langhian (Görür, 1979), according to small benthic foraminifera and algae and observations of vertical and lateral transitions of the lower part of the Karaisalı Formation into the upper Kaplankaya units and transitions between the upper Karaisalı units and the Güvenç and Cingöz formations (Yetiş *et al*. 1995).

The Cingöz Formation was first named by Schmidt (1961), who divided it into three members: the Köpekli Shale Member, the Ayva Member and the Topallı Member. Yetiş (1988) assigned the Ayva and Topallı members to the Cingöz Formation, while the Köpekli Shale Member was placed in the lower part of the Güvenç Formation. Ünlügenç, Kelling & Demirkol (1991) assigned the Köpekli Member to the Kaplankaya Formation, because of its stratigraphic situation. This unit is located normally beneath the Cingöz Formation and must be older than the main Güvenç deposits. The Cingöz Formation was described by Yetiş (1988) and Ünlügenç & Demirkol (1988) as turbiditic in character, with strongly lobate geometry, characterized by a large lobe to the east and a smaller lobe to the west. Later studies by Gürbüz (1999), Satur *et al*. (2000) and Cronin *et al*. (2000) explained the development of these submarine fans and relationships with surrounding units in the northern part of the basin. The age of the Cingöz Formation has been assigned to the Late Burdigalian–Serravalian time interval (Nazik & Gürbüz, 1992).

The term 'Güvenç Shales' was first used as a lithostratigraphic name by Schmidt (1961) for a group of olive grey sandstones, interbedded with shales. Yetiş (1988) described this formation as forming two main outcrops, one on the northern side of the Cingöz Formation, which is older than the Cingöz, and the other one on the southern side, which is younger than the Cingöz. Subsequently, Ünlügenç, Kelling & Demirkol (1991), Gürbüz & Kelling (1991) and Nazik & Gürbüz (1992) have included the sediments of the northern Güvenç belt in the Kaplankaya Formation, and equivalent to the Köpekli shale member of the Cingöz Formation as defined by Schmidt (1961). Therefore, the Güvenç Formation was deposited during the Langhian–Serravallian interval.

The Tortonian-age siliciclastics, detrital carbonates and other carbonates of this succession were named the Kuzgun Formation by Schmidt (1961), and the name has been retained by later researchers. Yetiş, Demirkol & Kerey (1985) carried out a sedimentological study on the unit and subdivided the formation into three members: the Kuzgun, Salbaş Tuff, and Memişli members. As reported by Yetiş, Demirkol & Kerey (1985) and Yetiş (1988), this unit displays lateral and vertical facies changes between the meandering river deposits and the shallow marine deposits.

The Handere Formation was also named by Schmidt (1961). This sequence of Upper Miocene–Pliocene sediments consists dominantly of sandstones and mudstones with conglomerates in some places (Öğrünç, Gürbüz & Nazik, 2000). This formation is relatively coarse in the western part of the Adana Basin with finer clastics abundant further east. A few layers of gypsum-bearing mudstones occur in the western part. Yetiş (1988) distinguished the principal gypsum level as the Gökkuyu Gypsum Member of the Handere Formation. The Handere Formation is covered by alluvium, terrace conglomerates and caliches. Gürbüz & Gökçen (1985), Yetiş (1988) and Öğrünç, Gürbüz & Nazik (2000) have described fossil assemblages which suggest a Messinian–Late Pliocene age for these sediments.

3. Chronostratigraphy and biostratigraphy of Neogene planktonic foraminifera

The planktonic foraminiferal biozones are described from different Neogene localities and levels in the Adana Basin by Nazik & Toker (1986); Nazik & Gürbüz (1992); Şafak (1993*a*,*b*); Özçelik & Yetiş (1994); Gürbüz, Nazik & Cronin (1998) and Öğrünç, Gürbüz & Nazik (2000). In the present study, the planktonic foraminiferal zones of the Neogene in Adana Basin have been evaluated in terms of previous and new research. These zones have also been correlated with the standard zone of Blow (1969), studies of other basins and some other localities in Turkey (Fig. 3).

General information dealing with biozones is given according to Bolli, Saunders & Perch-Nielsen (1985). Chronostratigraphy and planktonic foraminiferal biozones of the Neogene in the Adana Basin are given below.

3.a. Burdigalian

The Burdigalian was introduced by Deperet (1892) for marine strata overlying Aquitanian in the Aquitanian Basin (France). In the Mediterranean region, the Burdigalian stage includes the tope of Zone N5, Zone N6, Zone 7 and Zone N8 (Steininger *et al*. 1985). In the Adana Basin this stage has been defined in the Kaplankaya Formation by the *Globigerinoides trilobus* Zone and in the Kaplankaya, Cingöz and Güvenç formations by the *Praeorbulina glomerosa curva* Zone.

3.a.1. Globigerinoides trilobus *Zone*

Category. Interval zone.

Age. Burdigalian, Early Miocene.

Author. Bizon & Bizon (1972).

Definition. Interval from last occurrence of *Catapsydrax dissimilis* to first occurrence of *Praeorbulina glomerosa s.l.*

Correlation and interpretation. It is identified within the Kaplankaya Formation by Şafak (1993*a*) and Özçelik & Yetiş (1994) in the Adana Basin. In addition, it has been described by Toker (1985) in the Antalya region, by Toker & Yıldız (1991) and Şafak (1993*b*) in the Antakya Basin, Misis-Andırın area by Gökçen, Gökçen & Kelling (1991) (Fig. 3).

3.a.2. Praeorbulina glomerosa curva *Zone*

Category. Interval zone.

Age. Late Burdigalian.

Author. Jenkins (1966).

Definition. Interval from first occurrence of *Praeorbulina glomerosa curva* to first occurrence of *Orbulina suturalis*.

Correlation and interpretation. *Praeorbulina glomerosa curva* Zone is identified within the Kaplankaya, Cingöz and Güvenç formations by Nazik & Gürbüz (1992), Şafak (1993*a*), Özçelik & Yetiş (1994), and Gürbüz, Nazik & Cronin (1998) in the Adana Basin.

In addition, this zone has been defined in the Antalya-Mut and Adana basins by Bizon *et al*. (1974), in the Antalya region by Toker (1985) and Şafak & Subaşı (1998), in the Mut Basin by Şafak & Gökçen (1991), and in the Antakya Basin by Toker & Yıldız (1991) and Şafak (1993*b*).

3.b. Langhian

The Langhian was introduced by Pareto (1865) in the Langhe, north of Seva, northern Italy. The base of N9 is characterized by the *Orbulina* datum. The Langhian includes Zone N9–10 of Blow (1969). In the study area this stage is characterized by the *Orbulina suturalis* Zone in the Cingöz and Güvenç formations.

3.b.1. Orbulina suturalis *Zone*

Category. Interval zone.

Age. Langhian.

Author. Jenkins (1966).

Definition. Interval from first occurrence of zonal marker to first occurrence of *Globorotalia mayeri*.

Correlation and interpretation. The *Orbulina suturalis* Zone is represented within the Cingöz and Güvenç formations (Nazik & Gürbüz, 1992; Şafak, 1993*a*; Özçelik & Yetiş, 1994; Gürbüz, Nazik & Cronin, 1998) in the Adana Basin.

In other Turkish basins the *Orbulina suturalis* Zone has also been identified in the Antalya region by Toker (1985), in the Mut Basin by Şafak & Gökçen (1991), in the Antakya Basin by Toker & Yıldız (1991), and Şafak (1993*b*). In addition, the *Globorotalia fohsi peripheroronda* Zone is described within the Güvenç Formation by Nazik & Toker (1986) and was identified within the Misis–Andırın sequence by Gökçen, Gökçen & Kelling (1991) in the mid-Langhian.

3.c. Serravallian

The Serravallian was defined by Pareto in 1865 for outcrops near Serraval Scrivia (Alessandria, Italy). Cita & Premoli-Silva (1968) proposed three biozones for Serravallian: the *Globorotalia mayeri* Zone, the *Globorotalia mayeri–Globorotalia praemenardii* Zone and the *Globorotalia mayeri–Globorotalia lenguensis* Zone.

In the Adana Basin the Serravallian is defined by the range of *Globorotalia mayeri* (Cushman & Ellisor) in the Cingöz and Güvenç formations. This zone is correlated Zone 11–14 of Blow (1969).

3.c.1. Globorotalia mayeri *Zone*

Category. Taxon range zone.

Age. Serravallian.

Author. Jenkins (1960).

Definition. Range of *Globorotalia mayeri*.

Correlation and interpretation. It is identified within the uppermost level of the Cingöz and Güvenç formations (Nazik & Gürbüz, 1992; Özçelik & Yetiş, 1994) in the Adana Basin. This zone is described in the Antalya-Mut and Adana basins by Bizon *et al*. (1974), in the Antalya region by Toker (1985), in the Mut Basin by Şafak & Gökçen (1991), and in the Misis–Andırın area by Gökçen, Gökçen & Kelling (1991).

3.d. Tortonian

Gianotti (1953) described and designated the type section along the Rio Mazzapiedi–Rio Castellania valley, east Tortona. The Tortonian stage is characterized by a part of Zone 15 to a part of Zone N17 (Cita & Blow, 1969).

In the study area the base of Tortonian stage has been defined by the appearance of *Hipparion* sp. teeth. In addition, in the lowermost unit of the Kuzgun Formation the Tortonian is characterized by *Globigerinoides extremus*, *Globorotalia acostaensis*, *Carinocythereis carinata*, *Cyamocytheridea dertonensis*, *Cytheridea acuminata acuminata* (Gürbüz, Gökçen & Gökçen, 1985). In Yenice village (southwest Adana Basin) the upper part of this stage is represented by *Globorotalia suterae* (Öğrünç, Gürbüz & Nazik, 2000).

3.e. Messinian

Colalongo *et al*. (1979) proposed the Falconara section in Sicily as the Tortonian/Messinian boundary stratotype by the first appearance of *Globorotalia conomiozea*. However, in Messinian units of the Adana Basin this species is not identified by researchers.

Iaccarino & Salvatorini (1982) gave the name 'non-distinctive zone' to the interval poorly or not characterized by planktonic foraminifera and other fossils (Bolli, Saunders & Perch-Nielsen, 1985). Up to now, researchers have not identified planktonic foraminiferal genera and species in the Adana Basin Messinian deposits. During this time, the Adana Basin was affected by a salinity crisis characterized by an evaporite sequence and there were no biological events observed in deposits (Nazik *et al*. 1997; Öğrünç, Gürbüz & Nazik, 2000).

3.f. Pliocene

The Pliocene is represented by Zone N18 to N21 of Blow (1969). The Early Pliocene is defined by *Sphaeroidinellopsis* Acme Zone of Cita (1973, 1975).

The beginning of Pliocene units of the Adana Basin is characterized by small planktonic foraminifera levels shown first open marine conditions after the Late Miocene salinity crisis. In the southwest of the Adana Basin the Early Pliocene is represented by *Sphaeroidinellopsis* (Öğrünç, Gürbüz & Nazik, 2000).

3.f.1. Sphaeroidinellopsis Acme *Zone*

Category. Epibole (Peak zone).

Age. Basal Pliocene.

Author. Cita (1973, 1975).

Definition. This zone is characterized by peak abundance of *Sphaeroidinellopsis*.

Correlation and interpretation. In the *Sphaeroidinellopsis* Zone, *Orbulina*, *Globigerina* and *Globigerinoides* are common. Öğrünç, Gürbüz & Nazik (2000) and Nazik *et al.* (1997) found *Sphaeroidinellopsis seminulina* (Schwager) and *S. dehiscens* (Parker & Jones) within fine-grained units of Pliocene in the Adana Basin. Since this genus is abundant in this level deposited after the salinity crisis, *Sphaeroidinellopsis* Acme Zone is suggested in this study.

4. Discussion and conclusion

As a result of previous studies and this study, the biostratigraphic, chronostratigraphic and ecostratigraphic relationships of the Neogene sequence in the Adana Basin are given below.

The Kaplankaya Formation has been interpreted as a beginning unit of transgression in the Adana Basin. Pelecypoda, Gastropoda, benthic and planktonic Foraminiferida and Ostracoda are observed in this formation, which consists of gravelly sandstone, sandstone and sandy–silty–clayey limestone deposited in shallow marine conditions. Two planktonic biozones (*Globigerinoides trilobus* and *Praeorbulina glomerosa curva*) are identified within the Kaplankaya Formation (Fig. 2). *Praeorbulina glomerosa curva* Zone is also described in the Cingöz and Güvenç formations. Lateral and vertical facies changes of these formations have been reported by Schmidt (1961), Görür (1979), Yetiş (1988), U. C. Ünlügenç (unpub. Ph.D. thesis, Univ. Keel, 1993) and Yetiş *et al*. (1995). In addition, lateral facies changes and occur within the same biozone.

Kaplankaya Formation shallow marine (slope deposits), Karaisalı Formation (reefal carbonate), Cingöz (submarine fans) and Güvenç formations (shale) in deep marine environment are formed during the Late Burdigalian, contain the *Globigerinoides trilobus* and *Praeorbulina glomerosa curva* zones. There is no detailed palaeontological study of foraminiferal biozonation in the Karaisalı Formation that is of use for this study. However, foraminiferal biozones (*Praeorbulina glomerosa curva* and *Orbulina suturalis* zones) have been used which derive from studies carried out on the Kaplankaya, Cingöz and Güvenç formations; these have lateral and vertical transitional contacts with the Karaisalı Formation. Lateral and vertical facies changed at the end of the Burdigalian in the Adana Basin. At this time, deposition of the Kaplankaya Formation ended, and the Cingöz and Güvenç formations formed in deep marine environments during the Langhian, represented by the *Orbulina suturalis* Zone. During the same time interval, the Karaisalı Formation was deposited in a shallow marine environment. From base to top the Kaplankaya–Cingöz–Güvenç sequence has a high planktonic foraminiferal diversity. The uppermost part of the Cingöz formation has lateral and vertical transitional boundaries with the Güvenç Formation. The *Globorotalia mayeri* Zone is identified

AGE		MY	LOW LATITUDES ZONES Bolli & Saunders (1985)	ZONES Blow (1969)	MEDITERRANEAN Iaccarino (1985) ZONES	MEDITERRANEAN Iaccarino (1985) SUBZONES	SOUTHERN MID-LATITUDES ZONES Jenkins (1985)	CENTRAL PARATETHYS ZONES Rögl (1985)	SOUTHERN ANATOLIAN BASINS: ANTAKYA BASIN Toker & Yıldız (1991) Şafak (1993b)	SOUTHERN ANATOLIAN BASINS: MİSİS-ANDIRIN AREA Gökçen, Gökçen & Kelling (1991)	SOUTHERN ANATOLIAN BASINS: ANTALYA BASIN Toker (1985) Şafak & Subaşı (1998)	SOUTHERN ANATOLIAN BASINS: MUT BASIN Şafak & Gökçen (1991)	PRESENT STUDY
PLIOCENE	L		Globorotalia tosaensis tosaensis	N21	G.inflata		G.inflata						
	M	2.4	Globorotalia miocenica	N20	G.aemiliana G. puncticulata								
	E	3.2	Globorotalia margaritae	N19 N18	G.puncticulata.- G.margaritae G.margaritae Sphaeroidinellopsis seminulina s.l.		G.puncticulata						Sphaeroidinellopsis Acme Zone
MIOCENE	L	5.1	Globorotalia humerosa	N17	Non-distinctive Zone G.conomiozea		G.conomiozea						Non-distinctive Zone
			Globorotalia acostaensis	N16	Globigerinoides obliquus extremus	Globorotalia suterae	G. miotumida						First occurrence Globorotalia suterae
						Globigerinoides obliquus extremus/ G. bulloideus							?
					Globorotalia acostaensis								
		11.3	Globorotalia menardii	N15	Globorotalia menardii			Globorotalia menardii					
	M		Globorotalia mayeri	N14	Globorotalia siakensis	Globorotalia siakensis/ Globigerinoides obliquus obliquus	Globorotalia mayeri			_ _ _ _ _ _ _ _ _ _ _ G.extremus- G.ruber	Globorotalia mayeri	Globorotalia mayeri	Globorotalia mayeri
			Globigerinoides ruber	N13		Globigerinoides subquadratus		Globorotalia mayeri		G.menardii			
			Globorotalia fohsi robusta	N12		Globoquadrina altispira altispira				G.mayeri			
			Globorotalia fohsi lobata	N11									
			Globorotalia fohsi fohsi	N10	Orbulina suturalis/ G.peripheroronda	G. praemenardii- G. peripheroronda	O. suturalis	O. suturalis	O. suturalis	_ _? _ _ _ ? _ _ _? G.fohsi periphororonda	O. suturalis	O. suturalis	O. suturalis
			Globorotalia fohsi pheripheroronda	N9		O. universa O. suturalis		Praeorbulina glomerosa		G.altispira-G.druryi			
	E	14.4	Praeorbulina glomerosa	N8	Praeorbulina glomerosa		Praeorbulina glomerosa curva	G. trilobus	Praeorbulina glomerosa curva	Praeorbulina glomerosa	Praeorbulina glomerosa curva	Praeorbulina glomerosa curva	Praeorbulina glomerosa curva
			Globigerinatella insueta	N7	Globigerinoides trilobus		G. trilobus		G. trilobus	G.sicanus- G.trilobus	G. trilobus	G. trilobus	G. trilobus
			Catapsydrax stainforthi	N6	G. dehiscens dehiscens- Catapsydrax dissimilis	G. altiaperturus							
			Catapsydrax dissimilis	N5									
			Globigerinoides primordius	N4		G. dehiscens dehiscens				G.altiaperturus- G.subquadratus			
		24.6											

Figure 3. Correlation between Neogene standard zone, low latitudes, Mediterranean, southern mid-latitudes, Central Paratethys, Southern Anatolian Basins and present study zonal shemes.

within the uppermost parts of the Cingöz Formation and also the Güvenç Formation.

Generally, the Güvenç Formation consists of siltstone, mudstone and claystone, although its upper parts contain alternations of fine-grained sandstone and siltstone-mudstone. These levels are deposited in deep marine to shallow marine conditions and have a low planktonic foraminiferal diversity.

There is no clear evidence of an angular unconformity observed between the Güvenç Formation and the overlying Kuzgun Formation in the field. However, U. C. Ünlügenç (unpub. Ph.D. thesis, Univ. Keel, 1993) and Williams *et al*. (1995) pointed out a slight angular unconformity between these two units. Lithological and palaeontological differences in the Kuzgun Formation also support this idea. Shallow marine-lagoon sandstones including *Ostrea* shells intercalated with fluvio-deltaic sediments were deposited on the Güvenç Formation to the north of the Seyhan Dam where local uplifting occurred in the eastern sector of the Adana Basin (U. C. Ünlügenç, unpub. Ph.D. thesis, Univ. Keel, 1993; Williams *et al*. 1995). Tortonian age *Globigerinoides extremus*, *Globoratia acostaensis*, *Orbulina universa*, *Ammonia beccarii*, *Cytheridea acuminata acuminata, Cytheretta semiornata* and *Carinocythereis carinata* were determined within the sandstones (Gürbüz, Gökçen & Gökçen, 1985) and *Hipparion* sp. teeth were found in fluvio-deltaic sediments (Yetiş, 1988; U. C. Ünlügenç, unpub. Ph.D. thesis, Univ. Keel, 1993). Following these units, some ostracoda forms such as *Cyprideis torosa*, *Schneidrella dromas*, *Loxoconcha rhomboidea*, *Loxoconcha cristatissima*, *Loxoconcha subovata* characterizing a lagoon environment were determined in the tuffite zone (Nazik, 2001). Kuzgun Formation deposits are represented by shallow marine sediments resting on the basement units at the west of the basin to the north of Tarsus. Some fossil forms such as *Cytheridea acuminata acuminata*, *Cytheridea acuminata neapolitana*, *Cyamocytheridea dertonensis*, *Keijella hodgii*, *Keijella dolobrata*, *Tenedocythere prava*, *Tenedocythere mediterranea and Loculicytheretta pavonia* representative of Tortonian age were determined in these sediments (Öğrünç & Nazik, 1998; Nazik, 2001); some others of the Late Tortonian period such as *Globorotalia suterae* from the north of Yenice village, southwest of Adana Basin, were also determined (Öğrünç, Gürbüz & Nazik, 2000).

In this study, 'Non-distinctive zone' is suggested to describe the Adana Basin deposits characterized by an evaporite sequence of the Handere Formation in the Messinian. The beginning of the Pliocene units in the Adana Basin is characterized by small planktonic foraminifera (species of *Globigerina*, *Orbulina*, *Globigerinoides*) levels showing the first open marine conditions seen after the Late Miocene evaporites. *Sphaeroidinellopsis* Acme Zone has been suggested and used in this study within fine-grained marine units of same formation deposited after salinity crisis in the Adana Basin. This zone is Early Pliocene.

In the present study, the planktonic foraminiferal zones defined from the Adana Basin are correlated with the standard zones of Blow (1969), the low and southern mid-latitudes, Mediterranean, Central Paratethys and Southern Anatolian Basins (Fig. 3). The planktonic assemblages in the Adana Basin in the Burdigalian and Langhian showed similarities with those regions. The closing of the Tethys to the east, the rotation of Spain towards to the North African continent during the end of the Middle Miocene, and the Latest Miocene salinity crisis affected the planktonic foraminiferal assemblages and other fauna and floras (Iaccarino, 1985). Furthermore, at that time the planktonic foraminiferal assemblages and zones were different from those regions because of differences in Mediterranean sea-level changes, tectonic control, salinity crisis and so forth.

Acknowledgements. I would like to express my thanks to the reviewers for their valuable reviews and their input on improvements to the manuscript. I also thank Dr Phillip Bassant for his helpful comments and for correcting the English of the manuscript.

References

BIZON, G. & BIZON, J. J. 1972. *Atlas de principaux foraminifères planctoniques du bassin méditerranéen, Oligocéne à Quaternaire*. Editions Technip, Paris, 316 pp.

BIZON, G., BIZON, J. J., FEINBERG, H. & ÖZTÜMER, E. 1974. Antalya, Mut, Adana Havzalari Tersiyer biyostratigrafisi ve mikropaleontoloji yenilikleri. *Türkiye İkinci Petrol Kongresi Tebliğleri*, 217–28. Ankara (in Turkish).

BLOW, W. H. 1969. Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. *Proceedings, First International Conference on Planktonic Microfossils, Geneva* **1**, 199–442.

BOLLI, H. M. & SAUNDERS, J. B. 1985. Oligocene to Holocene low latitude planktic foraminifera. In *Plankton Stratigraphy* (eds H. M. Bolli, J. B. Saunders and K. Perch-Nielsen), pp. 155–262. Cambridge: Cambridge University Press.

BOLLI, H. M., SAUNDERS, J. B. & PERCH-NIELSEN, K. 1985. *Plankton stratigraphy*. Cambridge University Press, 328 pp.

CITA, M. B. 1973. Pliocene biostratigraphy and chronostratigraphy. *Initial Report Deep Sea Drilling Project* **13**, 1349–79.

CITA, M. B. 1975. Studi sul Pliocene e sugli strati di passaggio dal Miocene al Pliocene. VIII. Planktonic foraminiferal biozonation of the Mediterranean Pliocene deep sea record. A revision. *Rivista Italiana di Paleontologia e Stratigrafia* **81**, 527–44.

CITA, M. B. & BLOW, W. H. 1969. The Biostratigraphy of the Langhian, Serravallian and Tortonian stages in the Type-Sections in Italy. *Rivista Italiana di Paleontologia e Stratigrafia* **75**, 549–603.

CITA, M. B. & PREMOLI SILVA, I. 1968. Evolution of the planktonic foraminiferal assemblages in the stratigraphical interval between the type-Langhian and the type-Tortonian and biozonation of the Miocene of Piedmont. *Giornale Geologia* **35**, pp. 1–27.

COLALONGO, M. L., DI GRANDE, A., D'ONOFRIO, S., GIANNELLI, L., IACCARINO, S., MAZZEI, R., ROMEO, M. & SALVATORINI, G. 1979. Stratigraphy of Late Miocene Italian sections straddling the Tortonian Messinian boundary. *Bollettino della Società Paleontologica Italiana* **18**, 258–302.

CRONIN, B. T., GÜRBÜZ, K., HURST, A. & SATUR, N. 2000. Characterization of a carbonate deep-water slope in the marginal part of a submarine fan system. *Sedimentology* **47**, 801–4.

DEPERET, M. 1892. Note sur la classification et le parellélisme du systéme Miocene. *Compte Rendu Société Géologique de France* **13**, 145–56.

GIANOTTI, A. 1953. Microfaune della serie tortoniana del Rio Mazzapedie-Castellania (tortona-Alessandria). *Rivista Italiana di Paleontologia e Stratigrafia Memorie* **6**, 167–308.

GÖKÇEN, N., GÖKÇEN, S. L. & KELLING, G. 1991. Microfaunal biostratigraphy of Cenozoic sequences from the Misis-Andırın area, Southern Turkey. *Stratigraphy Newsletters* **24**, 111–35.

GÖKÇEN, S. L., KELLING, G., GÖKÇEN, N. & FLOYD, P. 1988. Sedimentology of Late Cenozoic collisional sequence: the Misis Complex, Adana, Southern Turkey. *Sedimentary Geology* **59**, 205–35.

GÖRÜR, N. 1979. Karaisalı kireçtaşının sedimantolojisi. *Türkiye Jeoloji Kurumu Bülteni* **22**, 227–35 (in Turkish).

GÖRÜR, N. 1982. Adana havzası'nın petrol potansiyelinin değerlendirilmesinde yeni bir görüş. *Türkiye 6. Petrol Kongresi*, 73–80 (in Turkish).

GÖRÜR, N. 1985. Depositional history of Miocene sediments of the NW flank of the Adana Basin. *The Sixth Colloquium on the Geology of the Aegean Region*, 185–208 (in Turkish).

GÜRBÜZ, K. 1999. Regional implications of structural and eustatic controls in the evolution of submarine fans: an example from the Miocene Adana Basin, southern Turkey. *Geological Magazine* **136**, 311–19.

GÜRBÜZ, K. & GÖKÇEN, S. L. 1985. Provenance and sedimentology of the Late Tertiary foreland deposits of the Northern Adana Basin-Turkey. *International Symposium on Foreland Basins*, Fribourg, Switzerland, 66.

GÜRBÜZ, K., GÖKÇEN, N. & GÖKÇEN, S. L. 1985. Some stratigraphical remarks on the Upper Neogene sequence of the northern Adana Basin-Southern Turkey. *8th Congress of the Regional Committee on Mediterranean Neogene Stratigraphy*, Budapest, 238–40.

GÜRBÜZ, K. & KELLING, G. 1991. Evolution of Miocene Submarine Fans, Northern Adana Basin, Turkey. *EUG VI Strasbourg, 24–28 March, Terra Abstracts*, 342.

GÜRBÜZ, K. & KELLING, G. 1993. Provenance of Miocene Submarine Fans in the northern Adana Basin: a test of Discriminant Function Analysis. *Geological Journal* **28**, 277–95.

GÜRBÜZ, K., NAZIK, A. & CRONIN, B. T. 1998. Eğner-Akören (Aladağ-Adana/Türkiye) civarında yüzeylenen basen kenarı ve kıta yokuşu çökellerinin sedimantolojisi ve paleontolojisi. *Firat Üniversitesi, Jeoloji Mühendisliği Eğitiminin 20. yılı Sempozyumu Bildirileri*, 45–61 (in Turkish).

IACCARINO, S. 1985. Mediterranean Miocene and Pliocene planktic foraminifera. In *Plankton Stratigraphy* (eds H. M. Bolli, J. B. Saunders and K. Perch-Nielsen), pp. 283–314. Cambridge: Cambridge University Press.

IACCARINO, S. & SALVATORINI, G. 1982. A framework of planktonic foraminiferal biostratigraphy for Early Miocene to Late Pliocene Mediterranean area. *Paleontologia e Stratigrafia ed Evoluzione* **2**, 115–25.

JENKINS, D. G. 1960. Planktonik foraminifera from the Lakes Entrance oil shaft, Victoria, Australia. *Micropaleontology* **6**, 345–71.

JENKINS, D. G. 1966. Standard Cenozoic stratigraphical scheme. *Nature* **211**, 178.

JENKINS, D. G. 1985. Southern mid-latitude Paleocene to Holocene planktic foraminifera. In *Plankton Stratigraphy* (eds H. M. Bolli, J. B. Saunders and K. Perch-Nielsen), pp. 263–82. Cambridge: Cambridge University Press.

NAZIK, A. 2001. Effect of Tortonian tuffaceous level on ostracod distribution in Adana Basin (southern Turkey). *14th International Symposium on Ostracoda*. Shizuoka, Programs and Abstracts, 29.

NAZIK, A. & GÜRBÜZ, K. 1992. Karaisali–Çatalan–Eğner Yöresinin (KB-Adana) Alt-Orta Miyosen İstifinin Planktonik Foraminifer Biyostratigrafisi. *Türkiye Jeoloji Bülteni* **35**(1), 67–80 (in Turkish).

NAZIK, A. & TOKER, V. 1986. Karaisalı yoresi Orta Miyosen istifinin foraminifer biyostatigrafisi. *Maden Tetkik ve Arama Enstitüsü Dergisi* **103/104**, 139–50 (in Turkish).

NAZIK, A., TOKER, V., ŞENOL, M. & ÖĞRÜNÇ, G. 1997. Tarsus yöresi (Adana Baseni) Üst Tersiyer-Kuvaterner istifinin mikropaleontolojik (planktik foraminifer, nannoplankton ve ostrakod) incelemesi. *Çukurova Üniversitesi Jeoloji Mühendisliği Eğitiminin 20. Yılı Sempozyumu*, Bildiri Özleri, Adana, 251 (in Turkish).

ÖĞRÜNÇ, G., GÜRBÜZ, K. & NAZIK, A. 2000. Adana Baseni Üst Miyosen-Pliyosen istifinde "Messiniyen tuzluluk Krizine" ait bulgular. *Yerbilimleri, Hacettepe Üniversitesi Yerbilimleri Uygulama ve Araştırma Merkezi Bülteni* **22**, 183–92.

ÖĞRÜNÇ, G. & NAZIK, A. 1998. Yenice (Tarsus) kuzeyi (Adana Havzasi) Üst Miyosen-Pliyosen istifinin ostrakod faunasi. *Türkiye Jeoloji Bülteni* **41**(1), 63–84 (in Turkish).

ÖZÇELİK, N. & YETIŞ, C. 1994. Adana baseni Tersiyer istifi Güvenç formasyonunun planktik foraminifer biyostratigrafisi. *Yerbilimleri/Geosound* **25**, 21–30 (in Turkish).

ÖZER, B., DUVAL, B., COURRIER, P. & LETOUZEY, J. 1974. Antalya–Mut–Adana Neojen Havzalari Jeolojisi. *Turkiye II. Petrol Kongresi, Ankara*, 57–84 (in Turkish).

PARETO, L. 1865. Note sur les subdivisions que l'on pourrait établir dans les terrains tertiaires de l'Apennin septentrional. *Bulletin de Société Géologique de France* **22**, 210–77.

RÖGL, F. 1985. Late Oligocene and Miocene planktic foraminifera of the Central Paratethys. In *Plankton Stratigraphy* (eds H. M. Bolli, J. B. Saunders and K. Perch-Nielsen), pp. 314–28. Cambridge: Cambridge University Press.

ŞAFAK, Ü. 1993*a*. Işıktepe-Dalakdere (KB Mersin) civarının Miyosen biyostratigrafisi. *Yerbilimleri/Geosound* **22**, 127–49 (in Turkish).

ŞAFAK, Ü. 1993*b*. Antakya Havzası planktonik foraminifer biyostratigrafisi. *Suat Erk Jeoloji Simpozyumu Bildirileri*, 143–56 (in Turkish).

ŞAFAK, Ü. & GÖKÇEN, N. 1991. Planktik foraminifer zonlamasina doğu Akdeniz provensinden bir örnek: Mut havzası Tersiyer istifi. *Türkiye Jeoloji Kurumu Bülteni* **34**(1), 27–37 (in Turkish).

ŞAFAK, Ü. & SUBAŞI, Y. 1998. Beşkonak–Altınkaya (Serik KD'su, Antalya) dolayı Miyosen istifinin mikropaleontolojik ve ortamsal özellikleri. *Yerbilimleri Dergisi/Engineering Faculty Earth Review* **11**, 67–86 (in Turkish).

SATUR, N., HURST, A., CRONIN, B., KELLING, G. & GÜRBÜZ, K. 2000. Sand body geometry in a sand-rich, deep-water clastic system, Miocene Cingöz Formation of southern Turkey. *Marine and Petroleum Geology* **17**, 239–52.

SCHMIDT, G. C. 1961. Stratigraphic Nomenclature for the Adana Region Petroleum Distict, 7. *Petroleum Administration Bulletin* **6**, 47–63. Ankara.

STEININGER, F. F., SENES, J., KLEEMAN, K. & RÖGL, F. 1985. *Neogene Mediterranean Tethys and Paratethys*. Institute of Paleontology, University of Vienna, 356 pp.

TOKER, V. 1985. Korkuteli yöresi Miyosen nannoplankton biyostratigrafisi. *Karadeniz Teknik Üniversitesi Dergisi, Jeoloji* **4**(1–2), 9–21 (in Turkish).

TOKER, V. & YILDIZ, A. 1991. Hatay yöresi Nannoplankton biyostratigrafisi. *Ahmet Acar Jeoloji Sempozyumu*, 199–211 (in Turkish).

ÜNLÜGENÇ, U. C. & DEMİRKOL, C. 1988. Kızıldağ Yayla (Adana) Dolayının Stratigrafisi. *Jeoloji Mühendisliği* **32–33**, 17–25 (in Turkish).

ÜNLÜGENÇ, U. C., KELLING, G. & DEMİRKOL, C. 1991. Aspect of basin evolution in the Neogene Adana Basin, SE Turkey. *International Scientific Congress on Aegean Regions, Proceedings* **1**, 353–70. İzmir.

WILLIAMS, G. D., ÜNLÜGENÇ, U. C., KELLING, G. & DEMİRKOL, C. 1995. Tectonic controls on stratigraphic evolution of the Adana Basin, Turkey. *Journal of the Geological Society, London* **152**, 873–82.

YALÇIN, N. M. & GÖRÜR, N. 1984. Sedimentological evolution of the Adana Basin. *International Symposium on the Geology of the Taurus Belt, Proceedings*, 165–7. Ankara.

YETIŞ, C. 1988. Reorganisation of the Tertiary stratigraphy in the Adana Basin, Southern Turkey. *Stratigraphy Newsletters* **20**(1), 43–58.

YETIŞ, C., DEMİRKOL, C. & KEREY, E. 1985. Adana Baseni ust Miyosen yasli kuzgun formasyonunun fasiyes ve cokelme ortami. *Türkiye Jeoloji Kurumu Bülteni* **29**, 81–96 (in Turkish).

YETIŞ, C., KELLING, G., GÖKÇEN, S. L. & BAROZ, F. 1995. A revised Stratigraphic Framework for Later Cenozoic Sequences in the Northeastern Mediterranean Region. *Geologische Rundshau* **84**, 794–812.