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Full Length Research Paper

Organic facies of the Beydağları carbonate platform (Mesozoic), Western Taurus, Antalya, Turkey

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Mesozoic carbonates are widespread in the Antalya region of south-west Turkey and have been studied in the outcrop. Mesozoic units include a Jurrasic/Cretaceous sequence that comprises, from bottom to top, the following stratigraphic sequence: Beydağları Formation (Jurrasic-Cretaceous) and Çiğdemtepe Formation (Senonian). Detailed data from thick Mesozoic carbonates (Beydağları and Çiğdemtepe Formations) made it possible to construct an organic facies framework using different zonations. Organic matter is composed predominantly of amorphous material, with a minor contribution of allochthonous terrestrial material. Kerogen in the deposite is primarily type II/III, as indicated by organic petrographic observations and Rock-Eval data. Total organic carbon content (TOC) of this deposit is less than 0.5% in different zonations of the Beydağları and Çiğdemtepe Formations. Tmax values vary between 332 and 535°C, confirming the increase in maturation trends indicated by Rock-Eval data. Both organic petrographic and geochemical maturation parameters place the Mesozoic carbonates of the western Taurides (Antalya-SW Turkey) region within C-CD organic facies. According to this, the different types of kerogen observed fall dominantly in the C facies, with a poor capacity for liquid hydrocarbon generation. When seen in Mesozoic Beydağları carbonates, the organic matter is highly oxidized.

Key words: Western Taurus, organic facies, source rock, Mesozoic.

INTRODUCTION

The western Taurus region of SW Turkey including the study area is part of northern margin of Gondwana Plate (Beydoun, 1991). The region has three main sequences: Autochthon Beydağları units in central, the Antalya nappes in the east and the Lycian Nappes (Elmalı Nappes) in the west (Figure 1). Tectonic history of the Western Taurus Belt has been characterized by several periods of rift-related subsidence, compressional uplift and erosion (Poisson et al., 1983). As documented clearly in Marcoux (1978), Argyriadis et al. (1980), Güvenç et al. (1994) and Demirel et al. (2001), the Western Taurus region was initiated as a cratonic basin developed by the rifting of the Late Permian and early Triassic break up of the autochthonous Taurus units. The Beydağları units, then, were formed as a carbonate platform, which has deepened partly and dismembered during significant compressional tectonism that occured throughout the Upper Cretaceous and the Lower Miocene. The emplacement of the Antalya Nappes occured in Maastrichtian in the north and in Danian in the south (Şenel, 1983), while the emplacement of the Lycian Nappes developed after the Lower Miocene in the western part of study area (Günay and Bölükbaşı, 1980).

Autochthon Beydağları units include a Jurrasic/Cretaceous sequence that comprises, from bottom to top, the following stratigraphic sequence: Beydağları Formation (Middle-Upper Jurrasic-Cretaceous) and Çiğdemtepe Formation (Senonian) (Figures 2 and 3).

Beydağları Formation is the oldest units of Beydağları autochthonous which consist of neritic biomicrite

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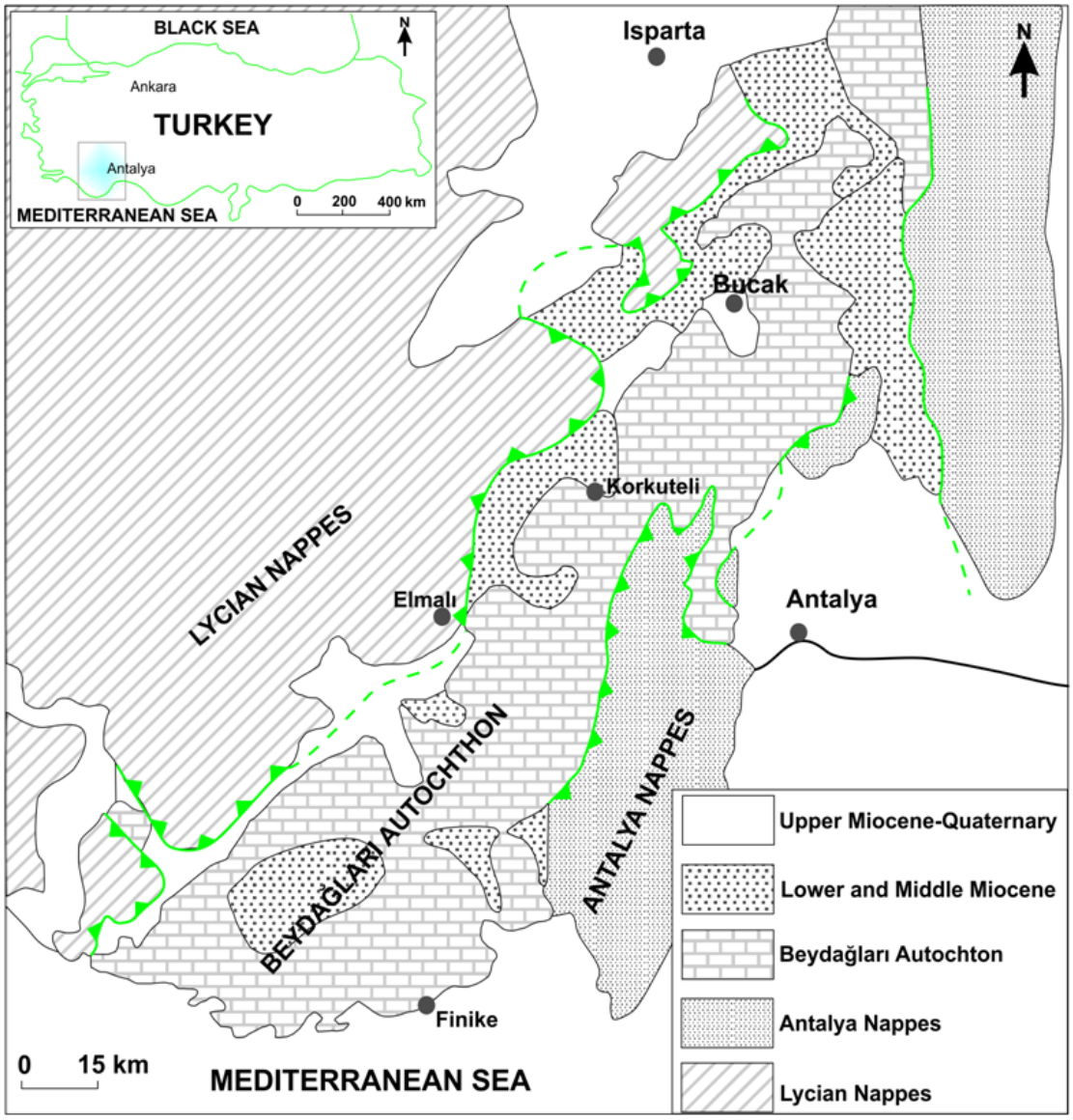

Figure 1. Map showing the main tectonic belts of the Western Taurus and location of the study area.

limestone. The highest level of the Mesozoic carbonate sediments of Çiğdemtepe Formation is represented by intramicritic limestone. Previous studies of this region have defined and described the rock units, sedimentary associations, stratigraphy, tectonics and petroleum geology. General geological investigations and reports have been presented by Özgül (1976), Poisson (1977), Gutnic et al. (1979), Hayward (1984), Akay et al. (1985), Görmüş, and Hançer (1997), Flecker et al. (1998, 2005), Robertson (2000), Sarı and Özer (2002) and Poisson et al. (2003), who studied the sedimentological character and tectonics of the study area and environments. Petroleum-geological studies have also been carried out; significant ones include the works of Altunsoy (1999), Demirel et al. (2001, 2002), Özçelik et al. (2005) and Özçelik et al. (2009).

In this study, we described organic-facies characteristics of the Middle-Upper Jurassic (Beydağları Formation) and the Senonian (Çiğdemtepe Formation) sediments of the Beydağları carbonate unit in the Western Taurus, using the organic facies classification of Jones (1987). In order to determine the amounts, types and maturation of organic matter in these strata, outcrop samples of carbonates were collected.

MATERIALS AND METHODS

The Middle-Upper Jurrasic Beydağları and Senonian Çiğdemtepe Formations (Antalya region) have been investigated with respect to their organic-facies characteristics. About 220 outcrop samples

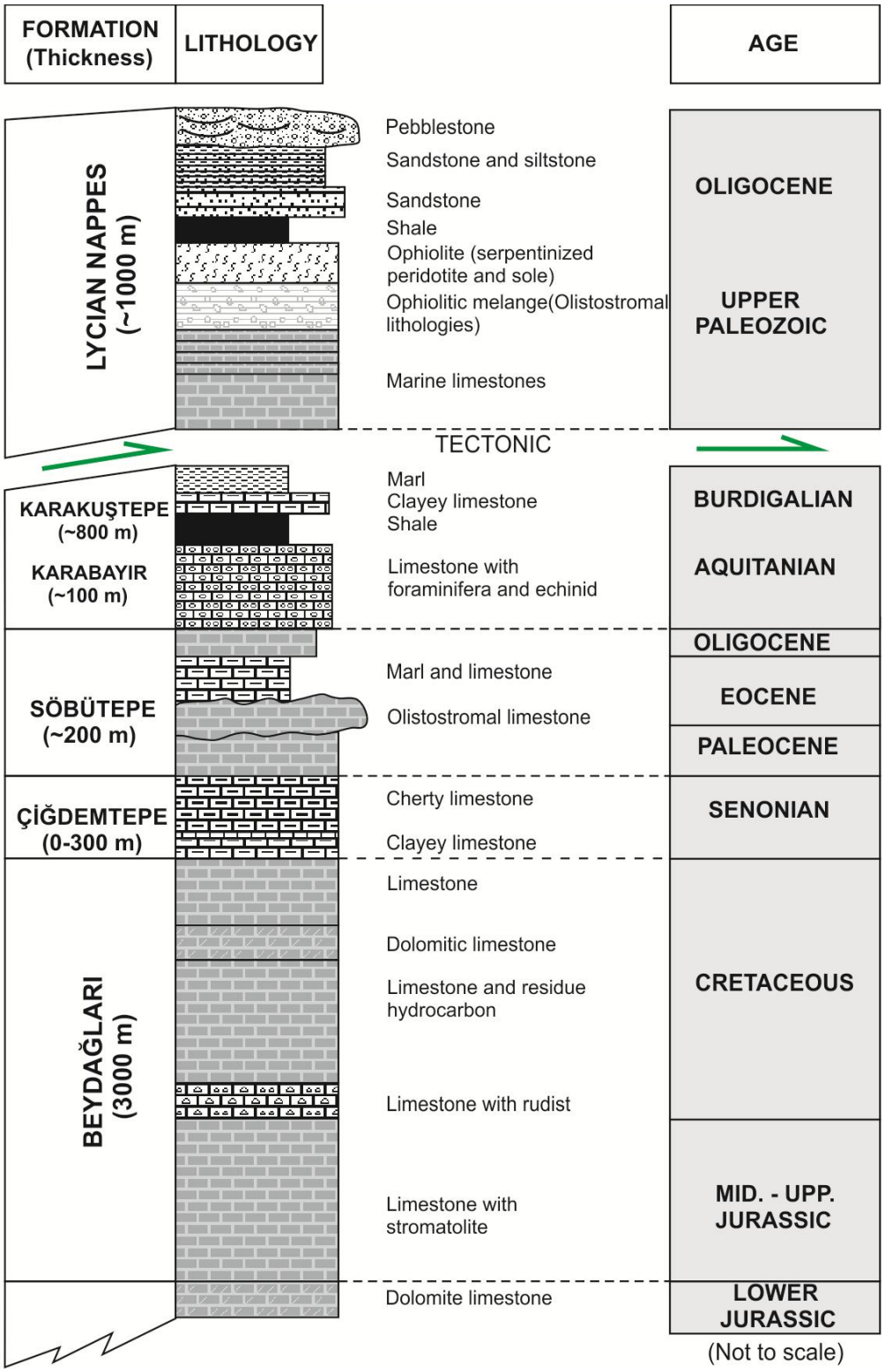

Figure 2. Generalized tectono-stratigraphic section of the investigated area.

were collected from surface stations.

Selected samples, representing the Jurassic-Cretacous sequence, were obtained from limestone and dolomitic limestone units in 19 stratigraphic sections (Figure 4). For analysis, the selection of samples was based primarily upon changes in colour, type of lithology and other sedimentary characteristics. In order to

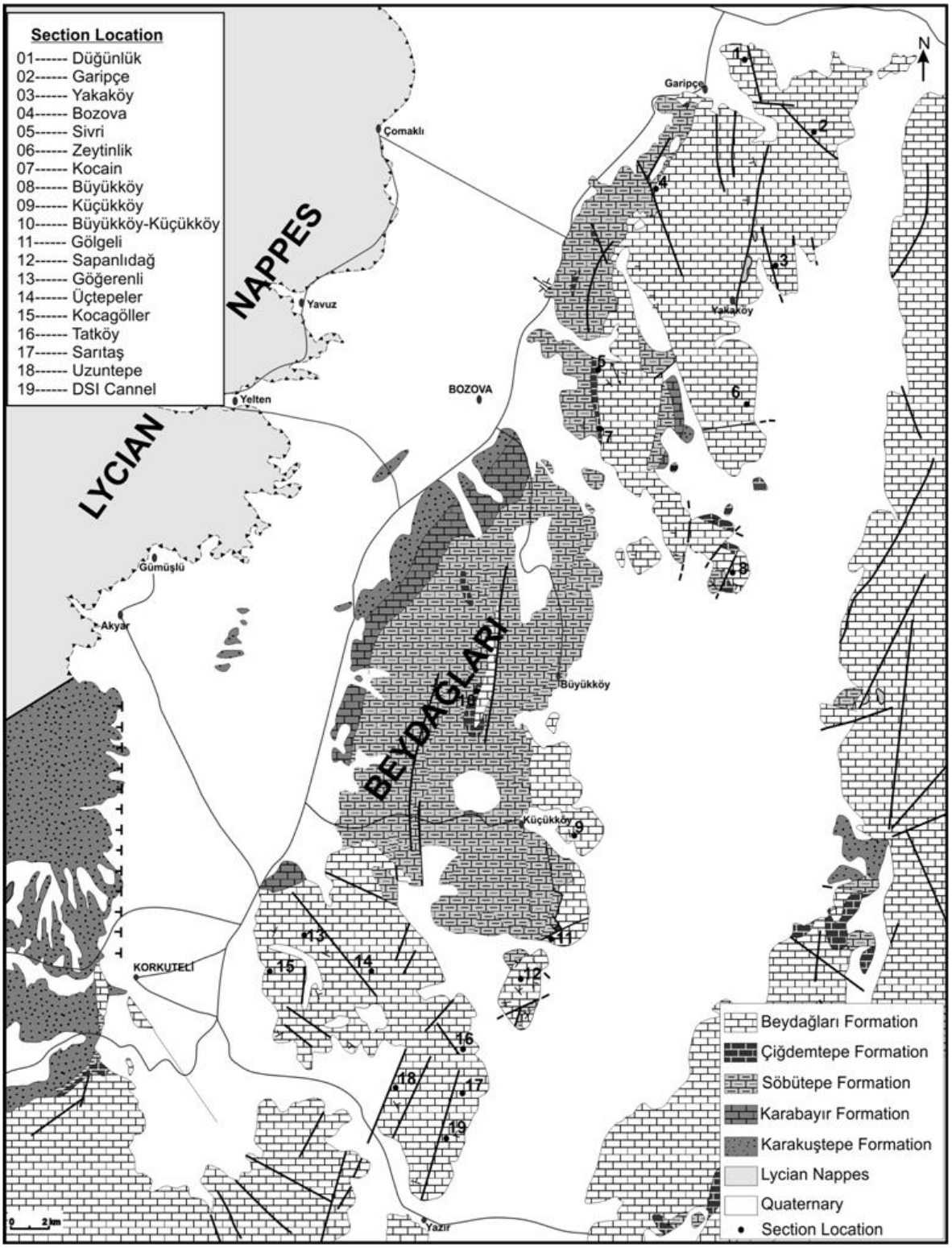

Figure 3. Simplified geological map of the investigated area and section locations.

determine the nature of the organic matter, a number of organic-petrographic and geochemical analyses were made upon kerogen isolated from the outcrop samples.

Total organic carbon (TOC) and Rock–Eval pyrolysis analysis were undertaken in the Turkish Petroleum Research Centre (Ankara, Turkey). Other microscopic studies were carried out in the

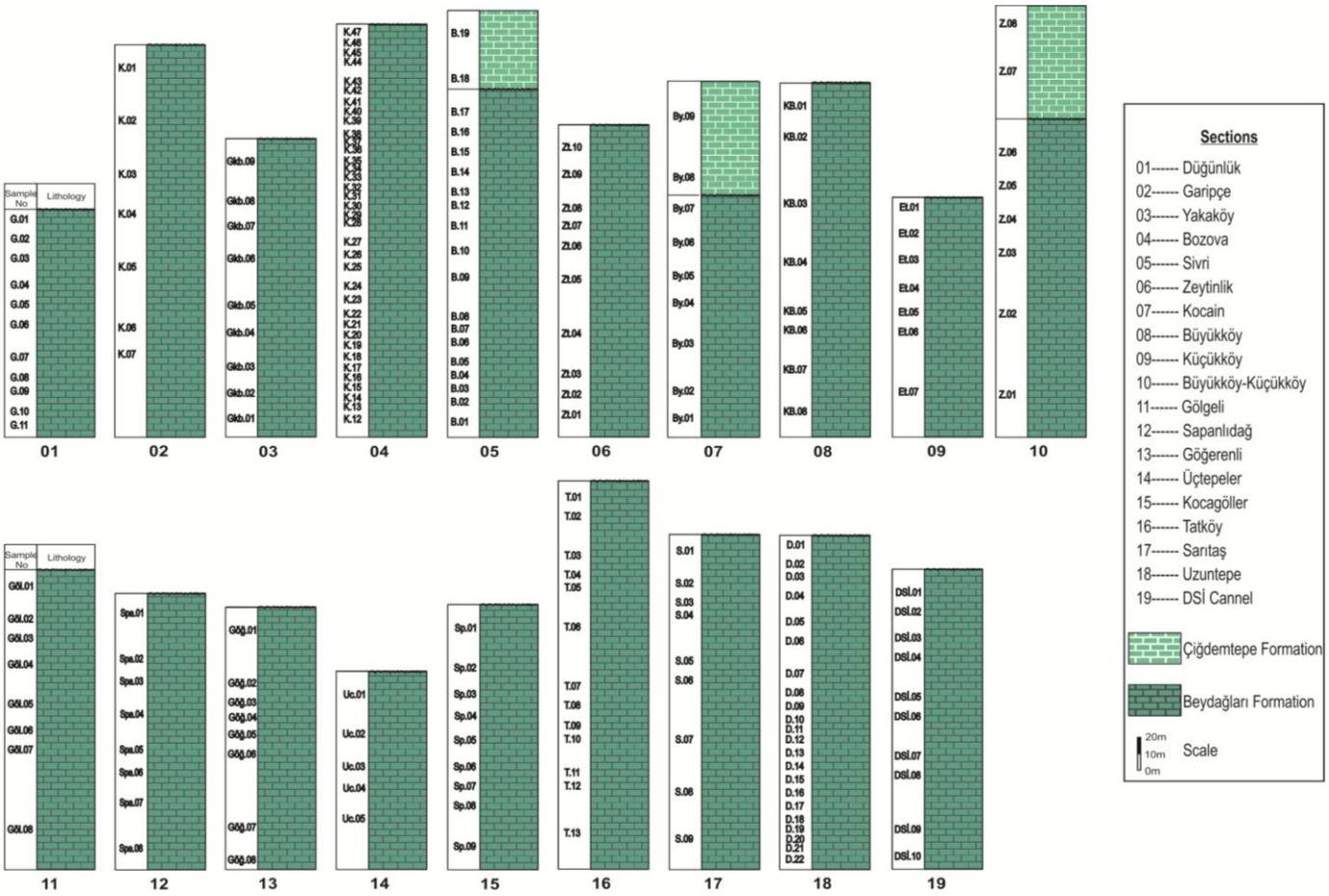

Figure 4. Sample distribution of the Beydağları and Çiğdemtepe Formations in the investigated stratigraphic sections.

laboratories of Akdeniz University (Antalya, Turkey). Rock-Eval pyrolysis provides information on the quantity and type of organic matter in a sedimentary rock, in addition to the level of organic maturation (Espitalie´ et al., 1985). Samples from each interval were pulverized, and about 100 mg from each sample was analyzed using a Rock-Eval/TOC analyser (RE-2, Institut Français du Pe´trole Standard) following techniques outlined by Espitalie´ et al. (1985). Thus, S1, S2, S3 and Tmax values were obtained. Parameter S1 is a measure of the amount of hydrocarbon liberated at 300°C. Peak S2 is the amount of hydrocarbon released during temperature-programmed pyrolysis (300° - 600°C). TOC is determined by oxidizing the pyrolysis residue in a second oven (600°C in air). The hydrogen index (HI) is the normalized S2 value (S2/TOC), expressed as mg HC/gTOC. The oxygen index (OI) is the normalized S3 value (S3/TOC), expressed in mg CO2/gTOC. The production index (PI) shows the level of thermal maturation. The S2/S3 values indicate the type of organic matter for low to moderately mature samples (Leckie et al. 1988).

Kerogen was isolated from the rock matrix using standard palynological preparation procedures. All samples were first decontaminated and crushed to about 2.0 mm. Carbonates were removed with 40% cold HF. After decantation, organic residue was sieved at 10 mm and a portion of the retained material was strew-mounted on glass slides. Organic-petrographic analysis were undertaken using transmitted-light microscopes in the Research Group Laboratories of the Turkish Petroleum Corporation. Maceral analysis was performed under incident and blue light excitation and by point counting transects (100 points/sample).

RESULTS

Table 1 illustrates the values of total organic carbon, Rock-Eval pyrolysis for the Beydağları and Çiğdemtepe samples. Total organic carbon values were measured on 19 samples (Table 1). The obtained data shows that the total organic carbon values are between 0.05 and 0.22%, with an average of about 0.09%. For the Beydağları Formation, the total organic carbon values range from 0.05 to 022%, with an average of 0.09%. The total organic carbon contents of the outcrop samples indicated that the Beydağları and Çiğdemtepe Formations have insufficient organic matter to be hydrocarbon source rocks.

In the Beydağları sediments, hydrogen index ranges from 100 to 611 mgHC/gTOC, with an average of about 180.4 mgHC/gTOC. PI ranges from 0.02 to 0.14, with an average of 0.09, and Tmax ranges from 332° to 535°C, with an average of 456°C. Organic-geochemical measurements of the samples were plotted on a

Table 1. Total organic carbon and Rock Eval pyrolysis results of study area.

Formation	Sample No	TOC	S1	S2	S3	S2/S3	Tmax	HI	OI	PI	PY S1+S2	RC (%)	PC (%)
Çiğdemtepe	B.19	0.1	0.01	0.06	0.34	0.18	470	60	340	0.08	0.07	0.08	0.02
	Z.07	0.06	0.01	0.05	0.32	0.16	457	83	533	0.09	0.06	0.04	0.02
	By.08	0.06	0.01	0.1	0.36	0.28	441	167	600	0.1	0.11	0.04	0.02
Beydağları	DSİ.08	0.07	0.01	0.09	0.45	0.2	465	129	643	0.1	0.1	0.05	0.02
	Du.21	0.18	0.02	1.1	0.53	2.08	447	611	294	0.02	1.12	0.07	0.11
	Et.06	0.07	0.01	0.09	0.38	0.24	435	129	453	0.1	0.1	0.05	0.02
	G.01	0.09	0.02	0.16	0.49	0.33	427	178	544	0.11	0.18	0.06	0.03
	Göğ.03	0.08	0.01	0.08	0.37	0.22	459	100	462	0.1	0.09	0.06	0.02
	Göl.05	0.07	0.01	0.08	0.33	0.24	472	114	471	0.1	0.09	0.05	0.02
	K.05	0.12	0.02	0.24	0.58	0.41	432	200	483	0.08	0.26	0.08	0.04
	K.37	0.16	0.02	0.43	0.62	0.70	535	269	388	0.05	0.45	0.1	0.06
	KB.05	0.07	0.01	0.08	0.36	0.22	436	114	514	0.1	0.09	0.05	0.02
	S.07	0.07	0.01	0.08	0.37	0.22	456	114	529	0.1	0.09	0.05	0.02
	Sp.06	0.07	0.01	0.08	0.33	0.24	464	114	471	0.11	0.09	0.05	0.02
	Spa.07	0.16	0.03	0.31	0.71	0.44	334	194	444	0.09	0.34	0.11	0.05
	T.07	0.22	0.03	0.5	0.8	0.63	332	227	364	0.06	0.53	0.13	0.09
	Uc.03	0.07	0.01	0.09	0.48	0.19	340	129	686	0.1	0.1	0.04	0.03
	B.13	0.09	0.01	0.13	0.43	0.30	444	144	478	0.08	0.14	0.06	0.03
	Zt.04	0.05	0.01	0.06	0.32	0.19	471	120	640	0.14	0.07	0.03	0.02

TOC; Total Organic carbon (wt %). S1; Free Hydrocarbons in rock (mg HC\g rock). S2; Hydrocarbon generated from the thermal breakdown of kerogen (mg HC/ g rock). S3; CO_2 value (mg CO_2\g rock). Tmax; Maximum temperature (°C). HI; Hydrogen Index (mg HC/ g TOC). OI; Oxygen Index (mg CO_2\g TOC). PI; Production Index (mg HC\g TOC). S2\S3; Hydrocarbon Type Index. S1+S2; Potential Yield (mg HC\g TOC). RC; Residual Organic Carbon. PC; Pyrolysable Organic Carbon.

hydrogen index–Tmax diagram (Figure 5); the results indicate that the samples contain dominantly type II/III kerogen. In the Çiğdemtepe sediments, hydrogen index ranges from 60 to 167 mg HC/gTOC, with an average around 103 mg HC/gTOC. PI ranges from 0.08 to 0.10, with an average of 0.09, and Tmax ranges from 441 to 470°C, with an average of 456°C. Tmax and production index show that the organic matter in the samples is immature to mature (Figure 6).

In the study area, no vitrinite was found and no reflectance was measured in as much as the Beydağları Autochthon generally consists of carbonate units. On the basis of microscope observations, we have determined that the kerogens are dominated by marine (amorphous) organic matter (ranging from 40 to 90%) and a little terrestrial organic matter (ranging from 5 to 40%; Table 2), in the Beydağları Formation. In the Çiğdemtepe Formation, kerogens are dominated by amorphous organic matter (70 to 80%) with lesser terrestrial (herbaceous, woody and coaly) organic matter (5 to 30%; Table 2).

DISCUSSION

The concept of organic facies is based primarly on hydrogen richness and secondarily on optical characteristics of organic matter in the sediments. It originates from coal petrographers, who recognized that different coal macerals, or types of organic matter that commonly occur in a special composition or grouping with unique chemical and physical properties that determine their industrial importance (Stach et al, 1982; Mann and Stein, 1997). In general, the succession of organic facies types D, CD, C, BC, B, AB, and A describes a decreasing oxygen content of the quantitative and qualitative preservation of the organic matter and, therefore, the petroleum source rock potential (Jones,1987). This classification system is used in the present study. Organic facies A shows the highest degree of preservation, whereas organic facies D has the lowest. Organic facies A is relatively rare, well laminated, organic rich, and usually is observed in lakes with persistent bottom-water anoxia. In the latter facies, recognizable terrestrial organic matter input is negligible. However, the origin of the high quality organic matter, except where it consists of discrete algae, is essentially unknown. Organic facies AB is laminated and rich in organic material. It is volumetrically more important than organic facies A. The organic matter is composed almost entirely of algae and bacteria. Carbonate source rocks occasionally reflect organic facies AB as well as shale

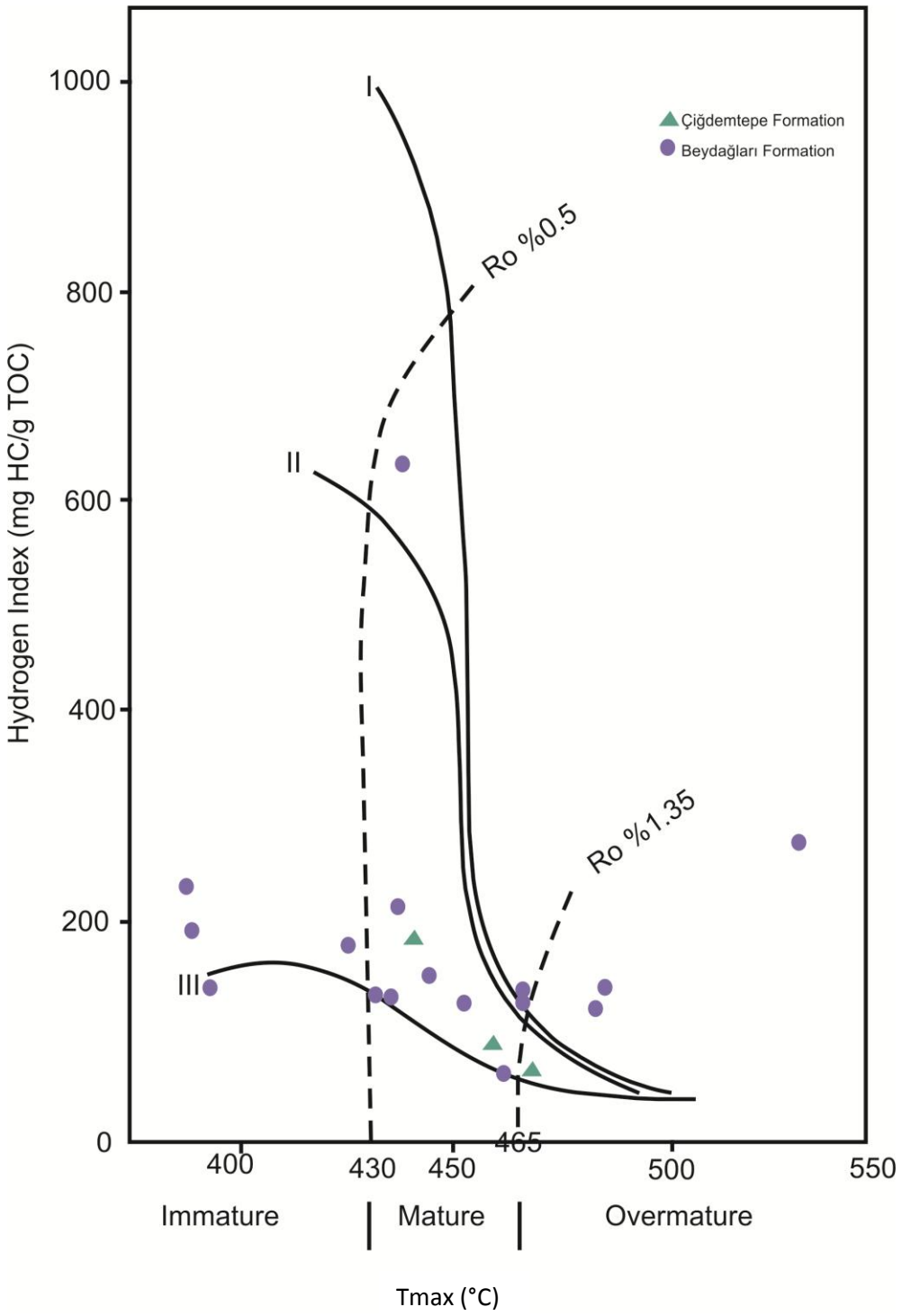

Figure 5. Classification of the kerogen types by using Hydrogen Index vs. T_{max} (°C) diagram.

source rocks deposited under a well-developed, persistent, anoxic water column. Organic facies B is volumetrically the most important of the oil-prone source rocks and is the source of the majority of the world's oil fields. This facies is laminated and well bedded, and usually contains a higher percentage of terrestrial and resudial organic matter than organic facies AB, but often the two facies have different values of total ogranic carbon. The B facies often is found in transgressive marine shales deposited in relatively shallow water, and it

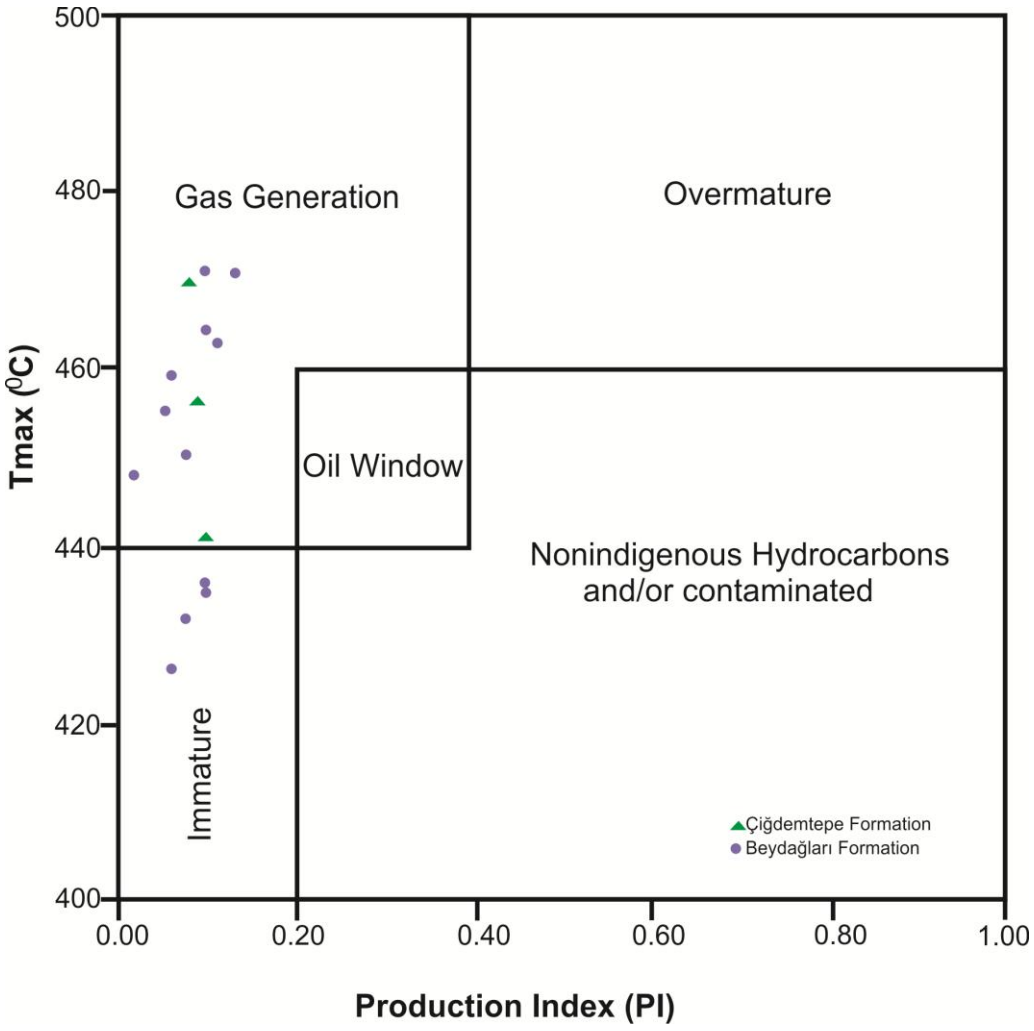

Figure 6. T_{max} (^{o}C)-PI diagram of the investigated samples.

is likely to be interbedded with less oil-prone facies because of fluctuations in bottom-water anoxia. Organic facies BC often is deposited under an anoxic water column in a fine–grained system of siliceous clastics, where rapid deposition creates anoxia in the sediments soon after deposition. The organic materials usually are a mixture of partially biodegraded terrestrial and algal material. Organic facies C is the “gas-prone” facies of modern literature. The organic matter is dominated by terrestrial debris in various stages of oxidization. Large volumes of organic facies C were deposited on the Tertiary and Mesozoic shelves and slopes of continental margins. Most coal deposits are found in this facies. Volumetrically, organic facies CD is deposited mostly as a massive unit containing moderately to well-oxidized terrestrial organic matter and substantial amount of residual organic matter. It also occurs in carbonate sequences where the algal organic matter has been highly oxidized. Organic facies D is essentially nongenerative; the organic matter is either highly oxidized or redeposited residual organic matter. Oxidization can occur in innumerable depositional environments, ranging from deep ocean to terrestrial (Jones,1987).

According to the classification scheme proposed by Jones (1987), two different organic facies types (C and CD) were recognized in the Beydağları Unit (Table 3). The Beydağları unit is a calcareous petroleum source rock with poor potential for gas. Most of the geochemical parameters of the Beydağları unit in the study area display a relatively wide range. However, the geochemical variations are sufficient to differentiate several organic facies.

Beydağları formation

Organic facies type C and CD (Jones, 1987) were identified in the Beydağları Formation (Table 3). The main composition in the organic matter of Beydağları

Table 2. Organic Matter Types within the investigated units.

Formation	Sample No	Amorphous	Woody	Herbaceous	Coaly
Çiğdemtepe	B.19	80	15	5	-
	Z.07	75	10	10	5
	By.08	70	-	30	-
Beydağları	Dsi.08	70	10	20	-
	Du.21	40	20	40	-
	Et.06	80	-	20	-
	G.01	65	10	25	-
	Göğ.03	60	10	30	-
	Göl.05	75	5	15	5
	K.05	75	15	10	-
	K.37	50	-	50	-
	Kb.05	40	-	60	-
	S.07	40	10	40	10
	Sp.06	85	-	15	-
	Spa.07	55	10	35	-
	T.07	70	10	15	5
	Uc.03	90	10	-	-
	B.13	85	10	5	-
	Zt.04	80	5	15	-

Table 3. Organic Facies distribution of the investigated units.

Formation	Sample No	Jones (1987)
Çiğdemtepe	B.19	C-CD
	Z.07	C-CD
	By.08	C
Beydağları	DSİ.08	C
	Du.21	B
	Et.06	C
	G.01	C
	Göğ.03	C-CD
	Göl.05	C-CD
	K.05	C
	K.37	BC
	KB.05	C-CD
	S.07	C-CD
	Sp.06	C-CD
	Spa.07	C
	T.07	C
	Uc.03	C
	B.13	C
	Zt.04	C-CD

Formation sediments are amorphous (66%), with minor portions of planty (24%), woody (9%), and coaly (1%) in the investigation area. The organic faces C is related to the dolomicrite and biomicrite lithofacies. This facies is

characterized by average values of HI around 200 mg HC/g TOC (equivalent to Type II Kerogene), TOC around 0.09%, and an average of S2 of 0.30 mg HC/g of rock. An organic facies CD, associated with the dolomicrite lithofacies, displays values of HI around 125 (equivalent to Type II/III Kerogene) and TOC around 0.09%. S2 varies between 0.06 and 0.13 mg HC/g of rock (Table 1).

Çiğdemtepe Formation

The geochemical parameters of the formation exhibit C and CD organic facies (Table 3). The main composition of organic matter in Çiğdemtepe Formation sediments are amorphous (75%), with minor portion of planty (15%), woody (8%), and coaly (2%). Organic facies C is associated with the biomicrite lithofacies. This facies is composed of organic matter with average values of HI around 160 (equivalent to Type II/III Kerogene), TOC around 0.07, and S2 between 0.05 and 0.10. An organic facies CD associated with the biomicrite lithofacies, display values of HI around 80 (Equivalent to Type III Kerogene), TOC around 0.19, and S2 around 0.23 (Table 1).

In the Mesozoic Beydağları Unit, geochemical and microscope data display a decreasing content of marine organic matter. These formations are related to organic facies C and CD. Based on the data presented in Jones (1987), we determined that the residual organic matter of the organic facies CD is usually deposited where enough oxygen remains available in the pore spaces to oxidize all but the most resistant organic matter by aerobic bacteria and bottom-dwelling fauna. The low TOC, low HI values, and widely Tmax values, especially in Beydağları Autochthon, indicate oxic decomposition and reworking processes in this unit.

Conclusions

Several conclusions can be drawn from this study concerning the organic facies classification of the Beydağları Autochthon (Beydağları and Çiğdemtepe formations) and its level of thermal maturation. These sediments are characterised by low amounts of organic matter with an important marine component. During Mesozoic time, TOC decreased and limestone components became dominant. In the dolomite and limestone, the organic matter can be classified as type II/III kerogen, and these sediments indicate catagenesis stage. Kerogens from the limestones are dominated by amorphous organic matter. Organic matter in these sediments is not sufficiently mature for hydrocarbon occurence, and the sediments can be plotted in organic facies C and CD. Organic geochemical and petrographic data indicate that, considering the amount, type, and level of maturation of this unit, the Mesozoic sediments should have served as a poor hydrocarbon source rock.

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