Source Rock and Depositional Environment Study of Three Hydrocarbon Fields in Prinos–Kavala Basin (North Aegean)

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Abstract: Cored samples from four wells from Prinos, Prinos North and Epsilon fields have been analyzed using geochemical methods. The results show that the depositional environment was hyper-saline, strongly reducing in all fields, and indicating similar conditions during sedimentation through the basin. This type of environment has preserved the organic matter, and in combination with rapid sedimentation, enabled hydrocarbons generation in the basin.

The analysis of the samples reveals similarities between Epsilon and Prinos fields, while Prinos North field differentiates. Epsilon and Prinos hydrocarbons appear to be immature, non biodegraded, generated from marine organic production in a carbonate source rock, and having migrated into the analyzed sedimentary zones. The rock is characterized as poor source rock with minor hydrocarbon generation potential. On the contrary, Prinos North hydrocarbons appear to be even more immature, non biodegraded, generated in an argillaceous source rock with terrestrial input in organic matter, while in the analyzed zone kerogen type II and III was identified.

Keywords: Organic matter, biomarker, North Greece.

INTRODUCTION

The exploration activity in Prinos-Kavala basin, located in North Aegean Sea (Greece), begun at the early seventy's, when South Kavala Gas field and later on Prinos Oil field were discovered. The confirmed hydrocarbon accumulation in the basin led to further exploration of peripheral structures and revealed new hydrocarbon fields, such as Prinos North and Epsilon, at N and NW of Prinos respectively, as shown in Fig. (**1**).

Earlier geochemical studies regarding Prinos field characterized the source rock as waxy sapropelic oil prone kerogen, formed from aquatic higher plants in a strongly reducing environment. The oil has high aromatic and polar components concentration, while the claystone layers within the reservoir formation of Prinos field were recognized as potential source rocks of the oil [1, 2]. Epsilon oil was also characterized by high aromatic and polar components concentration, while the organic matter appeared immature, non-biodegraded, generated mainly from marine algae in a strongly reducing environment [3].

However, important differences on the quality of hydrocarbons have been noted among reservoirs during exploration tests and production. In order to attribute these discrepancies, the present geochemical study was carried out to characterize the organic matter, identify possible source rocks and recognize the depositional environment in the basin during sedimentation on each field. Therefore, core samples retrieved from one exploration well of Prinos North field, two exploration wells of Epsilon field and one production well of Prinos field were selected and analyzed using Rock-Eval Pyrolysis, Extraction, SARA, Gas chromatography and Gas chromatography – Mass Spectrometry methods.

Geological Setting

Prinos - Kavala basin has been formed during Palaeogene period at the southern margin of the Rhodope Massif, controlled by NE-SW and NW-SE faults, at the area that nowadays is surrounded by Thassos Island and the mainland of NE Greece, as shown in Fig. (**2**).

The development of the basin begun during Miocene, when terrestrial conglomerates, sands, silts and clays, along with a salt layer, deposited in a restricted hyper saline environment. The sedimentation continued with rich in organic matter deposits, clastics and carbonates, overlaid by turbidites that correspond to the hydrocarbon reservoirs. A thick succession of evaporate layers overlaid the turbidites during Messinian age, due to dry climate and isolation of the basin, forming a good trap for hydrocarbons. The sedimentation continued with clastic marine deposits during Pliocene-Pleistocene, and continues to the present time [4]. The rapid sedimentation and subsidence of the basin resulted in a thick sediment section of about 5.8 km at the deepest parts that reached adequate thermal maturity level for hydrocarbon generation. The stratigraphic column and the gamma ray log of each studied well is presented in Fig. (**3**). The sediments deposited above the metamorphic basement (gneisses and marbles) are called the Pre-Evaporitic sequence. The average thickness of this sequence is about 2000 m, the top 350 m of which correspond to Prinos equivalent turbidites. Hydrocarbon accumulation is mainly recorded into these turbidite sediments that represent the oil reservoirs into the basin.

The Evaporitic sequence consists of seven main evaporate layers inter-bedded with clastics, with an average

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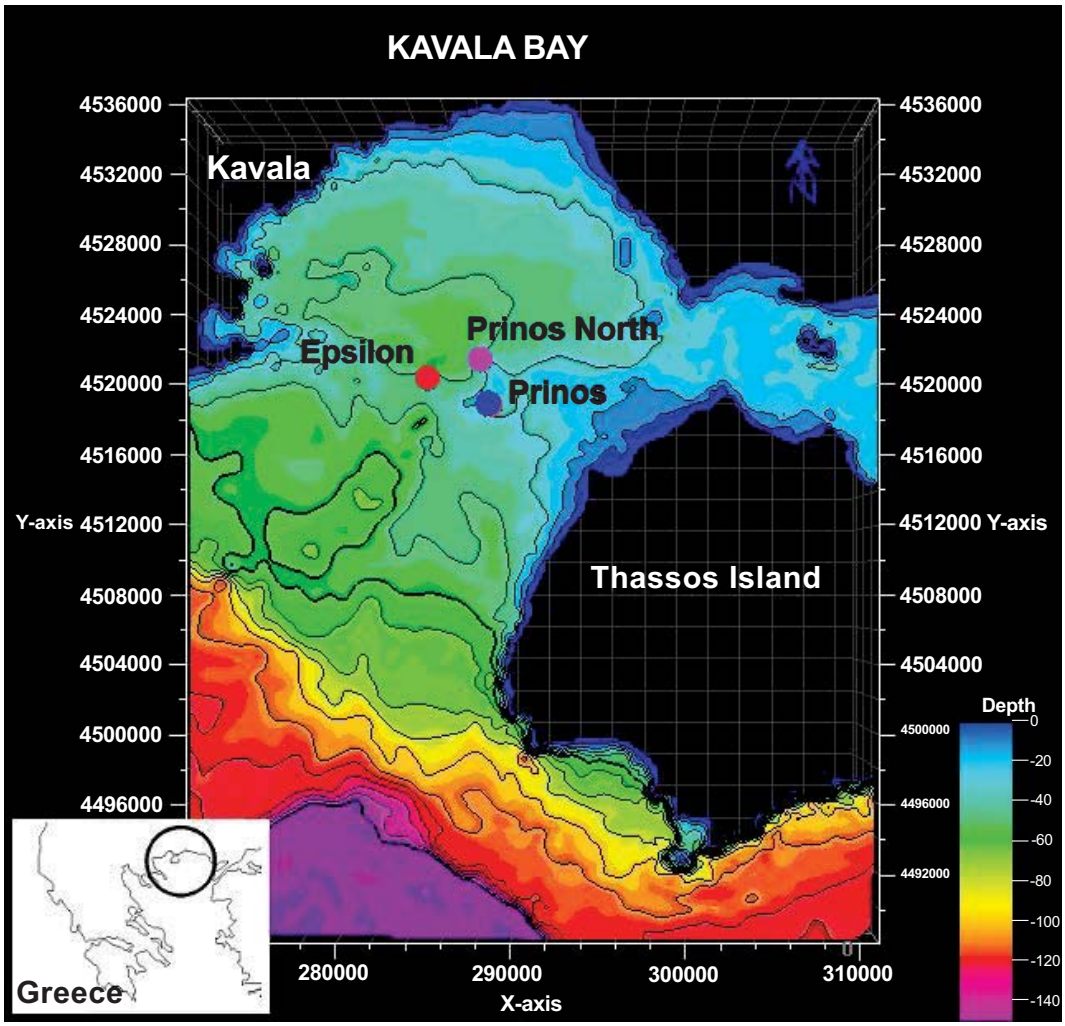

Fig. (1). Kavala Bay Map. Prinos, Prinos North and Epsilon Field are marked at S, N and NW respectively.

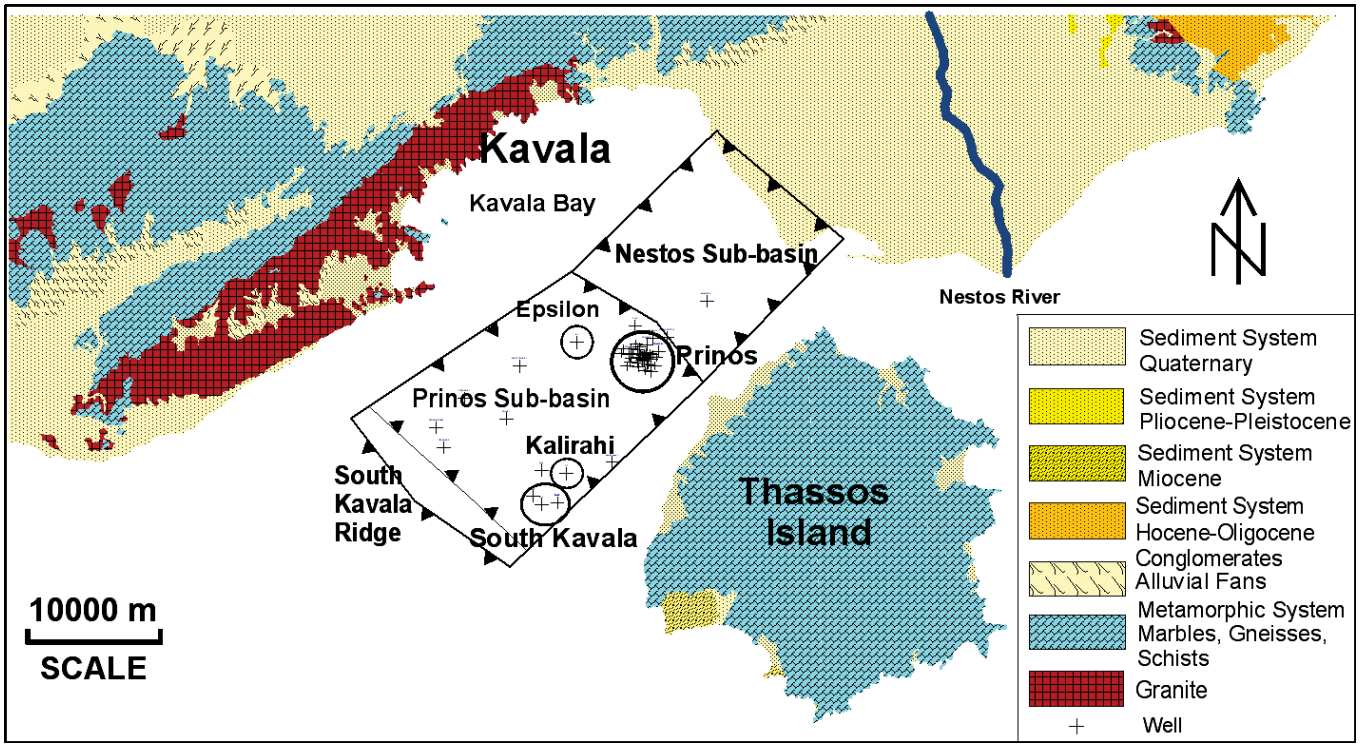

Fig. (2). Prinos – Kavala Basin (improved version published after Kiomourtzi *et al.*, 2007 [3]).

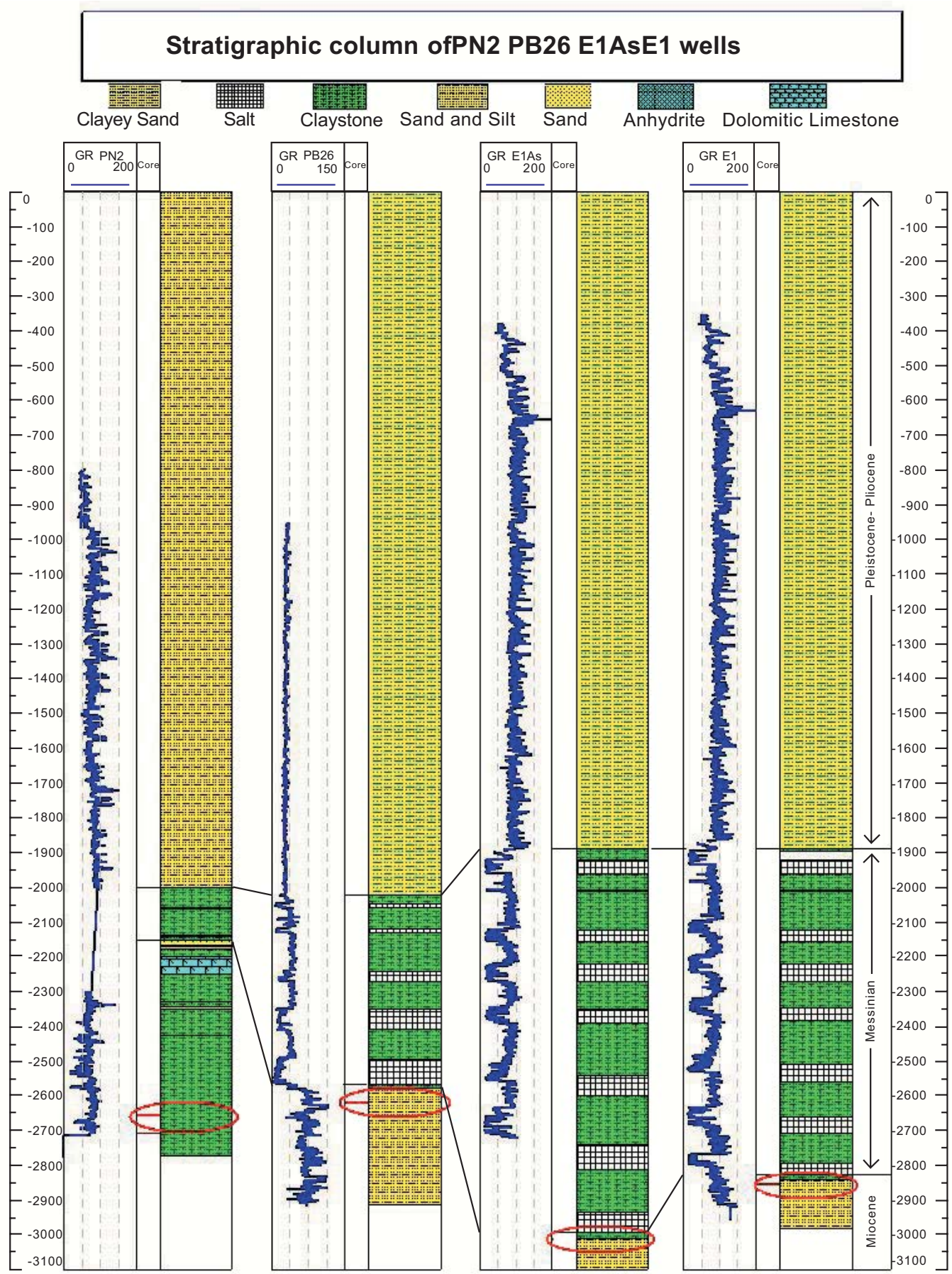

Fig. (3). Stratigraphic column and gamma ray logs (GR) of PN2, PB26, E1As and E1 wells. Depths of core samples are marked on each well.

thickness of 800 m. This sequence, deposited during Upper Miocene (Messinian), overlays the Pre-Evaporitic sequence. The upper, Post-Evaporitic sequence, consisting of sands, silts and clays, deposited from Pliocene-Pleistocene till today. The average thickness of this sequence is 1800m [5-7].

All samples used in this study are retrieved from the Pre-Evaporitic sequence. According to the stratigraphic columns, PN2 well was drilled deeper into zones underlying the reservoir horizons, from which the analyzed samples were selected. The samples of PB26, E1 and E1As wells were selected from the reservoir horizons, also shown in Fig. (**3**).

MATERIALS AND METHODOLOGY

One hundred and four rock samples were retrieved from available cores of four wells in Prinos – Kavala basin, drilled in three separate fields. Specifically, 24 samples were collected from well PN2 (Prinos North field), 26 samples from well PB-26 (Prinos field), 27 samples from well E1As and 27 samples from well E1 (Epsilon field). Detailed sample information is presented in Tables **1-8**.

Core Extraction

Core samples dried at 40°C overnight, were crushed and sieved using a 60 mesh (250μm) sieve. Aliquots (about 100g) were extracted for 24 hrs in a Soxhlet apparatus using chloroform. Concentrated extracts were further treated to remove elemental sulphur, using activated elemental copper. Deasphaltening of the bitumens was performed by using excess of n-pentane (40 volumes).

Group Type Analysis

The obtained maltenes were separated into saturates, aromatics and polar component fractions, using open-column chromatography on silica-alumina mixture (1:3). Saturates were eluted with n-pentane, aromatics with toluene and NSO components with a 60:40 v/v mixture of toluene - methanol.

Gas Chromatography (GC)

The saturated fractions were analyzed by gas chromatography (GC) using a Perkin-Elmer 8700 FID chromatograph with FID detection. A 30 m x 0.32 mm x 0.25 μm column

Table 1. Rock-Eval Pyrolysis – TOC – SARA – GC Data from PN2 Well Samples

Rock-Eval Pyrolysis – TOC Analysis										SARA – GC Analysis								
Well		Depth	Tmax	S1	S2	S3	TOC	HI	OI	Extract	Extract	Sat	Arom	NSO	Pr/Ph	Pr/nC17	Ph/nC18	CPI
Sample		m	°C	mg/g	mg/g	mg/g	%			mg/g (sed)	/TOC	% mass						
PN2	1	2655,0	422	1,4	7,5	1,3	2,0	375	63	4,0	2,0	37,3	16,9	45,7	0,18	3,21	32,05	1,64
	2	2655,2	428	0,7	4,6	1,0	1,8	252	57	3,8	2,1	35,1	16,8	48,1	0,18	3,05	34,48	1,82
	3	2655,3	430	1,0	6,6	1,0	1,8	369	53	3,5	2,0	34,3	16,3	49,4	0,20	3,32	31,54	1,64
	4	2655,5	432	1,0	6,1	1,2	1,7	367	72	3,4	2,1	21,2	11,1	67,7	0,19	3,10	26,70	1,74
	5	2655,7	431	1,1	7,0	0,7	1,7	418	40	3,5	2,1	27,7	19,8	52,5	0,15	3,23	28,86	1,60
	6	2655,9	425	0,3	1,3	0,6	1,5	91	40	1,6	1,1	30,0	16,9	53,1	0,17	3,53	33,36	1,64
	7	2656,0	426	0,9	4,0	0,6	1,0	380	58	2,4	2,3	34,0	17,6	48,4	0,16	3,40	33,47	1,59
	8	2656,1	422	0,6	3,0	0,8	1,1	280	70	1,9	1,8	33,2	16,6	50,2	0,20	3,17	31,11	1,54
	9	2706,7	420	0,3	2,1	0,7	1,2	174	54	1,5	1,3	33,9	18,8	47,3	0,31	2,34	11,97	1,90
	10	2707,0	433	0,4	2,8	0,9	1,0	266	89	1,5	1,4	46,8	24,8	28,4	0,34	2,24	9,87	1,93
	11	2707,3	427	0,4	3,3	0,8	1,2	273	66	1,9	1,6	43,9	24,4	31,7	0,35	2,33	11,18	1,92
	12	2707,5	421	0,4	2,9	0,7	1,3	221	56	1,8	1,4	32,9	18,0	49,1	0,35	2,65	13,42	1,88
	13	2707,6	419	0,5	3,3	0,9	1,2	280	74	1,6	1,4	33,3	19,4	47,3	0,34	2,22	9,20	1,79
	14	2708,0	424	0,3	3,0	0,5	1,1	266	47	1,4	1,2	33,1	19,1	47,8	0,33	2,25	10,22	1,83
	15	2708,2	423	0,4	2,7	1,1	1,4	197	80	2,1	1,5	32,4	18,5	49,1	0,31	2,64	15,67	1,82
	16	2708,4	420	0,1	1,1	0,7	0,6	189	117	0,7	1,2	28,1	16,5	55,4	0,31	2,05	9,87	1,85
	17	2708,7	423	0,6	4,1	0,8	1,3	318	63	2,0	1,5	30,0	19,3	50,7	0,27	2,26	12,13	1,95
	18	2708,8	424	0,5	2,9	1,1	1,5	196	75	2,0	1,4	33,8	19,0	47,2	0,27	2,51	16,97	1,87
	19	2709,0	417	0,7	3,8	1,2	1,3	296	95	1,8	1,4	36,3	17,9	45,8	0,25	2,18	12,96	1,76
	20	2709,2	418	0,7	4,7	1,8	1,5	319	120	2,1	1,4	40,8	13,1	46,1	0,27	2,11	13,75	1,96
	21	2709,4	416	0,7	3,8	1,0	1,2	315	83	1,7	1,4	35,4	19,8	44,8	0,27	2,05	11,12	1,72
	22	2709,6	417	0,7	3,5	0,8	1,2	294	71	1,9	1,6	34,0	22,7	43,4	0,28	2,20	9,76	1,60
	23	2709,8	431	0,8	4,1	0,9	1,3	310	65	2,3	1,8	37,7	16,7	45,6	0,25	2,41	11,67	1,56
	24	2710,0	419	0,8	4,5	1,4	1,3	338	106	2,9	2,2	35,2	15,7	49,1	0,24	2,28	10,19	1,56

Table 2. Rock-Eval Pyrolysis – TOC – SARA – GC Data from PB26 Well Samples

Rock-Eval Pyrolysis – TOC Analysis										SARA – GC Analysis								
Well		Depth	Tmax	S1	S2	S3	TOC	HI	OI	Extract	Extract	Sat	Arom	NSO	Pr/Ph	Pr/nC17	Ph/nC18	CPI
Sample		m	°C	mg/g	mg/g	mg/g	%			mg/g (sed)	/TOC	% mass						
PB26	2A	2618,0	398	5,2	1,0	0,6	0,9	117	66	10,1	11,3	41,3	43,4	15,3	0,13	0,48	1,58	0,78
	2B	2618,1	399	3,7	0,8	0,5	0,7	110	77	9,7	14,1	49,5	33,9	16,6	0,16	0,50	1,67	0,76
	2PA	2619,6	406	10,7	2,2	0,2	1,8	123	13	11,1	6,2	60,1	27,8	12,2	0,24	0,54	1,77	0,70
	2PB	2619,8	404	11,2	2,3	0,3	1,6	145	18	16,2	10,4	52,9	34,2	13,0	0,18	0,56	1,80	0,72
	2PG	2620,0	405	10,3	2,0	0,2	1,5	139	16	14,0	9,5	50,8	33,8	15,4	0,18	0,61	1,93	0,76
	2PD	2620,2	412	8,8	1,8	0,3	1,4	128	22	13,8	10,0	49,7	36,6	13,7	0,19	0,59	1,82	0,75
	2PE	2620,4	428	1,3	1,5	0,2	1,5	104	16	5,8	4,0	46,8	36,6	16,6	0,17	0,49	1,77	0,77
	2PST	2620,6	400	8,4	2,0	0,3	1,8	111	15	11,8	6,5	50,1	33,3	16,6	0,17	0,66	2,03	0,63
	3PA	2620,6	411	7,4	1,8	0,2	1,7	101	12	13,0	7,5	50,8	34,3	14,9	0,17	0,58	1,89	0,72
	1B	2620,7	418	1,5	0,4	0,9	0,8	51	105	11,1	13,7	45,6	39,9	14,5	0,19	0,59	1,81	0,80
	3PB	2620,8	379	1,4	0,6	0,3	0,7	95	40	4,1	6,2	49,2	34,6	16,2	0,19	0,57	1,73	0,86
	1A	2620,9	402	5,0	1,1	0,6	1,0	109	57	11,9	12,4	34,5	56,9	8,7	0,21	0,54	1,76	0,79
	3PG	2621,0	412	6,4	1,3	0,2	1,1	117	17	6,1	5,6	52,3	32,4	15,4	0,17	0,53	1,73	0,75
	3PD	2621,2	409	8,4	1,9	0,2	1,4	142	15	7,2	5,3	51,7	32,2	16,1	0,17	0,57	1,81	0,73
	1G	2621,3	413	3,2	0,6	0,3	0,6	107	58	8,9	16,2	37,6	43,2	19,2	0,17	0,58	1,84	0,78
	3PE	2621,6	406	8,4	2,0	0,2	1,3	159	18	8,9	7,0	49,8	33,5	16,7	0,16	0,61	1,99	0,73
	4PA	2621,6	417	4,8	1,6	0,2	1,1	146	20	11,3	10,7	51,2	35,1	13,7	0,19	0,64	2,02	0,73
	4PB	2621,9	431	1,2	0,5	0,4	0,6	84	64	2,3	4,2	57,6	33,3	9,1	0,10	0,37	1,79	0,85
	4PG	2621,9	405	3,9	0,8	0,2	1,0	82	15	9,1	8,9	51,5	33,5	15,0	0,20	0,62	1,95	0,77
	4PD	2622,0	416	1,1	1,1	0,5	1,0	107	44	4,0	3,9	37,8	43,8	18,5	0,21	0,58	1,61	0,84
	4PE	2622,1	420	13,5	3,6	0,2	2,3	158	10	18,5	8,0	51,3	34,6	14,1	0,20	0,63	1,95	0,78
	4PST	2622,4	408	1,2	0,6	0,2	0,8	82	22	4,2	5,4	49,1	40,6	10,3	0,18	0,62	1,83	0,73
	4PZ	2622,6	410	1,2	0,5	0,1	0,8	69	17	4,4	5,6	37,4	33,4	29,2	0,19	0,61	1,91	0,86
	6PA	2623,6	381	1,0	0,6	0,2	0,5	124	34	6,0	12,1	48,0	37,8	14,2	0,23	0,73	1,99	0,73
	6PB	2623,9	389	1,0	0,6	0,2	0,4	169	54	6,9	19,6	48,3	38,5	13,2	0,21	0,70	1,93	0,78
	6PD	2624,2	380	1,5	0,5	0,2	0,8	58	27	4,8	6,2	49,5	35,8	14,7	0,20	0,76	2,38	0,81

(SPB-5 from Supelco) was used with helium as carrier gas. The oven temperature was programmed from 60^0C to 300^0C at a rate of 6^0C/min. The samples (1 μl) were injected dissolved in n-hexane (1/150) in a split-split less mode. Injector and detector temperatures were set at 250^0C and 300^0C respectively. GC data were acquired and processed using the Millenium 32 software (Waters Corporation).

Gas Chromatography – Mass Spectrometry (GC-MS)

The GC-MS analysis of the saturates was carried out using a Fisson MD-800 system. A DB-5MS, 30 m x 0.32 mm x 0.25 μm column (J&W Scientific) was used, with a 5m deactivated precolumnconnected to an on-column injector. The GC oven temperature was programmed from 60^0C to 120^0C at a rate of 30^0C/min following by a ramp rate of 4^0C/min to 300^0C and a 30min isotherm. The MS was operated at 70 eV ionization voltage, with the interface and source temperatures set at 300^0C and 250^0C respectively in full-scan (50-500 m/z). The hopanes and steranes biomarkers were determined from the m/z 191, 217 and 218 mass fragmentograms based on the retention times of standard components as well as on their mass spectra.

Rock-Eval Pyrolysis – Total Organic Carbon (TOC)

The Rock-Eval Pyrolysis of the core samples was carried out on a Delsi RE2 system. TOC content was determined in a LECO Carbon Analyzer, using rock acquits previously treated with 2N HCl to remove carbonates.

RESULTS

The analytical results and the respective calculated geochemical indices obtained from the Rock-Eval Pyrolysis, TOC determination, extract fractionation and the GC analysis of the saturates, are presented in Tables **1-4**. Additionally,

Table 3. Rock-Eval Pyrolysis – TOC – SARA – GC Data from E1As Well Samples

		Rock-Eval Pyrolysis – TOC Analysis								SARA – GC Analysis								
Well		Depth	Tmax	S1	S2	S3	TOC	HI	OI	Extract	Extract	Sat	Arom	NSO	Pr/Ph	Pr/nC17	Ph/nC18	CPI
Sample		m	°C	mg/g	mg/g	mg/g	%			mg/g (sed)	/TOC	% mass						
E1As	53	3008,0	374	1,0	1,0	0,2	0,3	317	55	1,7	5,1	52,8	33,1	14,0	0,3	0,79	2,38	0,79
	36	3008,3	386	0,9	0,6	0,2	0,5	130	33	2,8	6,2	61,9	25,9	12,2	0,3	0,49	1,56	0,77
	44	3009,0	422	1,0	1,4	0,5	0,6	248	87	2,9	5,3	53,0	33,8	13,2	0,3	0,73	2,43	0,86
	16	3009,1	378	0,9	0,5	0,2	0,5	109	33			42,7	38,5	14,7	0,3	0,65	1,66	0,80
	33	3009,2	389	0,6	0,5	0,3	0,4	136	75	1,5	4,2	54,9	30,2	14,8	0,2	1,13	5,05	0,81
	42	3009,9	428	1,1	1,0	0,3	0,5	208	60	4,5	8,9	54,7	32,9	12,4	0,3	0,82	2,59	0,75
	39	3010,0	377	0,9	0,4	0,0	0,5	79	2	2,8	5,3	59,1	25,4	15,5	0,2	1,41	5,23	0,66
	41	3010,1	378	1,6	0,9	0,1	0,2	369	56	4,0	17,2	72,6	20,1	7,3	0,2	1,58	4,71	0,84
	17	3010,4	369	10,1	1,4	0,2	0,9	159	21			52,7	37,9	9,2	0,3	0,72	1,79	0,82
	50	3010,5	390	9,3	1,5	0,1	0,7	232	20	15,6	24,1	69,8	23,5	6,8	0,2	0,71	1,86	0,81
	37	3010,6	402	6,1	1,0	0,1	0,5	213	11	10,8	22,8	72,2	19,7	8,1	0,2	0,67	1,78	0,81
	49	3010,9	404	4,4	1,0	0,1	0,7	138	18	8,1	11,3	74,7	18,8	6,5	0,3	0,74	1,79	0,84
	51	3011,2	406	8,3	1,7	0,1	0,3	495	38	10,1	29,5	66,9	24,0	9,1	0,2	0,69	1,81	0,81
	11	3011,5	405	10,7	2,2	0,2	1,0	218	24			67,0	23,6	8,0	0,3	0,59	1,51	0,76
	47	3011,9	410	7,9	1,5	0,2	0,8	183	26	13,4	16,1	74,4	20,2	5,4	0,3	0,80	1,74	0,80
	12	3011,9	420	6,7	1,5	0,2	0,9	178	22		0,0	48,6	38,4	10,9	0,3	0,73	1,81	0,78
	45	3012,0	357	1,9	1,1	0,3	0,9	115	35	7,6	8,2	70,1	23,2	6,6	0,3	1,25	3,54	0,77
	32	3012,2	393	1,2	0,8	0,2	0,6	128	38	3,4	5,5	67,7	25,2	7,1	0,2	1,61	4,65	0,76
	43	3012,2	345	2,7	1,1	0,3	0,7	150	34	7,3	9,8	71,6	21,8	6,6	0,2	1,24	3,54	0,78
	40	3012,6	359	4,0	1,4	0,5	0,7	199	65	8,6	12,0	68,0	22,7	9,4	0,2	1,12	2,91	0,79
	13	3012,7	434	5,2	1,1	0,2	0,6	175	30			46,9	38,4	11,4	0,3	0,74	1,87	0,75
	34	3013,0	405	1,2	0,8	0,3	0,9	85	37	6,0	6,7	63,9	27,9	8,2	0,3	1,51	4,28	0,72
	14	3013,3	364	2,3	0,6	0,1	0,5	115	23			30,9	50,9	14,0	0,3	0,42	1,29	0,90
	35	3013,5	375	2,7	0,9	0,1	0,6	147	17	6,6	10,4	66,5	26,2	7,3	0,2	1,88	4,68	0,81
	52	3013,6	366	2,8	1,7	0,8	0,3	537	261	6,2	19,6	64,1	25,6	10,3	0,3	1,19	3,16	0,81
	15	3013,8	374	1,1	0,5	0,1	1,2	39	8			53,1	36,8	8,5	0,4	0,62	1,66	0,77
	46	3013,9	352	1,7	0,9	0,4	0,7	131	61	5,3	7,6	68,9	22,9	8,2	0,3	1,04	3,09	0,70

the hopanes and steranes biomarker indices, derived from the GC-MS analysis of the saturate fraction, are shown in Tables **5-8**.

Rock-Eval Pyrolysis – TOC Content

The core samples under study, showed TOC values ranging from about 0.2-2.3 wt %, with an average of 0.95 wt %, although most values are between 0.5-1.5 wt %. The determined, using the Rock-Eval pyrolysis, S1, S2, S3 values vary widely within the samples retrieved from different wells as well as within samples from the same formation. All PN2 well samples and several samples from Epsilon and Prinos formations showed low S1 values (<2 mg/g). These samples were considered as being relatively free from migrated oil contamination. Especially for Prinos North formation, it should be noticed that low S1 values correspond to S2 values ranging from 1-8 mg/g. On the contrary samples from the remaining wells, exhibited S2 values lower than 2 mg/g, while their S1 values vary between 0.5-12 mg/g. A similar intercorrelation exists between S1 and S3 values. Therefore, it can be concluded that PN2 core samples might be related to a source rock, while the remaining samples are contaminated with migrated oil. This statement is in agreement with the measured Tmax values, which are high for PN2 well samples (>416°C), while most of the remaining samples showed lower values. The calculated results of Hydrogen and Oxygen indices from the Roc-Eval pyrolysis are shown Fig. (**4**). According to the Van Krevelen classification, the organic matter can be characterized as intermediate II and III type.

Table 4. Rock-Eval Pyrolysis – TOC – SARA – GC Data from E1 Well Samples

Rock-Eval Pyrolysis – TOC Analysis										SARA – GC Analysis								
Well		Depth	Tmax	S1	S2	S3	TOC	HI	OI	Extract	Extract	Sat	Arom	NSO	Pr/Ph	Pr/nC17	Ph/nC18	CPI
Sample		m	°C	mg/g	mg/g	mg/g	%			mg/g (sed)	/TOC	% mass						
E1	1	2850,0	397	4,3	1,1	0,2	0,7	155	32	9,5	13,8	62,9	27,6	9,5	0,2	0,83	2,15	0,78
	2	2850,1	396	5,8	1,2	0,1	0,9	127	5	12,5	13,4	64,6	24,5	10,9	0,2	0,70	1,94	0,77
	46	2850,1	391	2,7	0,6	0,3	0,5	106	53	5,8	11,0	63,4	29,1	7,4	0,2	0,79	2,26	0,74
	3	2850,4	393	6,4	1,4	0,1	1,2	117	4	13,0	11,0	64,7	25,7	9,6	0,2	0,70	1,99	0,78
	4	2850,5	394	7,2	1,4	0,1	1,0	138	5	14,3	14,6	70,1	21,1	8,8	0,2	0,71	1,93	0,75
	5	2850,6	394	5,4	1,1	0,2	0,9	125	17	12,0	13,7	66,7	21,3	12,0	0,2	0,80	2,10	0,74
	6	2850,9	395	4,3	1,2	0,1	0,9	127	9	10,9	11,7	67,7	22,3	10,0	0,2	0,77	2,05	0,76
	7	2851,0	399	5,9	1,3	0,2	0,9	137	22	12,9	14,0	66,3	22,4	11,3	0,2	0,74	1,94	0,75
	45	2851,1	397	4,0	0,8	0,3	0,7	110	42	8,2	11,8	62,3	29,9	7,8	0,2	0,75	2,19	0,76
	8	2851,1	372	0,6	0,2	0,1	0,3	96	36	1,3	5,3	65,3	16,5	18,2	0,2	0,83	2,24	0,69
	9	2851,3	389	1,8	0,5	0,1	0,5	102	31	4,8	10,7	74,5	25,5	0,0	0,2	0,83	2,17	0,74
	10	2851,5	386	4,7	0,7	0,2	0,9	83	18	9,9	11,2	69,1	21,2	9,7	0,2	0,77	2,05	0,76
	12	2851,9	388	2,1	0,4	0,1	0,5	83	21	5,2	10,0	74,0	17,2	8,8	0,2	0,79	2,06	0,77
	13	2852,0	388	1,0	0,4	0,1	1,0	44	9	4,7	4,8	73,9	14,1	12,0	0,2	0,69	1,92	0,61
	14	2852,1	375	2,4	0,7	0,2	0,8	86	23	7,3	9,3	69,0	22,0	9,0	0,2	0,79	2,17	0,73
	41	2852,2	393	2,8	0,9	0,2	0,8	107	22	6,5	7,9	66,5	23,7	9,8	0,2	0,77	2,11	0,69
	15	2852,4	393	5,2	1,3	0,2	0,8	158	25	10,6	13,2	74,8	15,5	9,7	0,2	0,76	2,03	0,75
	16	2852,5	393	4,1	1,0	0,2	0,9	118	26	9,6	11,3	71,6	19,7	8,7	0,2	0,79	2,20	0,81
	42	2852,6	389	2,9	0,8	0,3	0,7	109	45	6,4	9,2	61,5	28,6	9,8	0,2	0,72	1,89	0,75
	17	2852,6	393	3,7	0,9	0,2	0,7	135	32	8,4	12,7	71,0	20,1	8,9	0,2	0,82	2,26	0,75
	18	2853,0	397	5,6	1,2	0,2	1,1	104	21	8,1	7,1	68,3	21,2	10,5	0,2	0,77	2,13	0,74
	44	2853,1	401	3,6	0,7	0,3	0,6	130	44	6,8	11,9	60,3	30,4	9,3	0,2	0,73	2,07	0,76
	48	2853,7	392	6,2	1,1	0,3	1,0	106	30	13,0	13,2	64,6	27,5	7,9	0,2	0,76	2,03	0,73
	49	2854,7	431	2,8	1,3	0,2	1,2	111	21	7,5	6,5	61,0	28,8	10,2	0,2	0,77	2,23	0,77
	43	2855,2	399	6,3	1,5	0,5	1,1	141	43	11,1	10,5	58,7	30,9	10,4	0,2	0,73	2,11	0,74
	47	2856,0	397	3,2	0,9	0,3	0,8	108	39	8,8	11,1	63,9	28,6	7,5	0,2	0,79	2,27	0,75
	50	2857,2	435	0,7	0,2	0,2	0,4	58	45	1,9	4,8	55,3	27,6	17,1	0,2	0,97	2,60	0,76

Extraction and Group Type Analysis

The extract yields of rock samples from PB26, E1As and E1 wells exhibit high values, varying widely, while samples from PN2 well show a relative constant low extractable organic matter content. The ratio of the extract yields to the respective TOC values for PN2 well samples shows low and relative constant values (2-3 mg/TOC %). On the contrary, the same ratio for the rest samples varies significantly (5-30 mg/TOC %), with most of the samples exhibiting high values. This observation is in agreement with the previously reported conclusion from Rock-Eval analysis, indicating that PN2 well core samples may be associated partially, at least, with a source rock, while the samples from the other wells are contaminated, in a different degree, with the reservoir oil.

Significant bulk compositional differences may also be observed between PN2 well sample extracts and those from Epsilon and Prinos fields. PN2 well extracts show higher concentration of NSO components and lower concentration of saturates. This difference can be attributed to a different maturation level, as well as to the already reported presence of migrated oil in the rock samples. An obvious compositional similarity can be noticed between Epsilon and Prinos fields (wells E1, E1As and PB26) in terms of group-type content. Finally, the composition of the core extracts does not vary in a systematic way with their depth, indicating a non-homogeneous distribution of the organic matter in the sediments.

Gas Chromatography

Indicative gas chromatograms of the saturate fraction are presented in Fig. (**5**). Normal alkanes distributions from Epsilon and Prinos fields samples show a clear even to odd predominance, with the phytane being the component exhib-

Table 5. GC - MS Data from PN2 Well Samples

GC-MS Analysis																								
Well		Hopanes						Homohopane Index					22S/22S+22R index					Steranes						
Sample		Ts/	Ts/	C29/	Olean	Gam	Mor/	C31	C32	C33	C34	C35	C31	C32	C33	C34	C35	C27	C28	C29	Dia/	S/	bb/	C21/
		Tm	(Ts+Tm)	C30			Hop														nor	(S+R)	(aa+bb)	C29
PN2	1	0,40	0,30	0,40	0,30	0,10	0,10	58	18	12	7	6	0,5	0,4	0,5	0,4	0,5	17	17	66	0,10	0,30	0,40	0,00
	2	0,40	0,30	0,40	0,30	0,10	0,10	51	19	12	9	9	0,5	0,4	0,5	0,5	0,5	17	17	66	0,20	0,30	0,40	0,00
	3	0,50	0,30	0,60	0,30	0,10	0,20	50	19	13	11	7	0,6	0,6	0,4	0,5	0,2	11	13	76	0,00	0,20	0,40	0,00
	4	0,30	0,20	0,30	0,30	0,20	0,10	44	19	13	9	14	0,4	0,4	0,5	0,5	0,5	19	15	66	0,20	0,20	0,40	0,00
	5	0,60	0,40	0,50	0,30	0,10	0,20	53	20	14	13	0	0,6	0,5	0,5	0,5		12	15	72	0,00	0,20	0,40	0,00
	6	0,40	0,30	0,40	0,30	0,10	0,20	43	15	13	14	15	0,5	0,4	0,5	0,4	0,5	16	16	69	0,00	0,30	0,40	0,00
	7	0,30	0,20	0,40	0,40	0,10	0,20	49	19	13	10	9	0,5	0,5	0,4	0,4	0,4	14	14	72	0,10	0,20	0,40	0,00
	8	0,50	0,30	0,60	0,50	0,10	0,30	53	16	12	9	9	0,5	0,5	0,4	0,5	0,5	16	16	68	0,10	0,20	0,40	0,00
	9	0,40	0,30	0,30	0,30	0,10	0,20	53	19	15	8	5	0,4	0,5	0,4	0,4	0,4	22	19	59	0,20	0,20	0,40	0,00
	10	0,50	0,30	0,10	0,30	0,10	0,10	55	18	15	8	5	0,5	0,4	0,5	0,4	0,4	23	20	56	0,20	0,20	0,40	0,00
	11	0,60	0,40	0,40	0,30	0,10	0,20	55	18	13	8	6	0,6	0,4	0,5	0,5	0,5	25	22	53	0,10	0,30	0,40	0,00
	12	0,50	0,30	0,60	0,40	0,10	0,30	56	17	13	9	6	0,5	0,6	0,4	0,5	0,4	20	17	62	0,10	0,20	0,40	0,00
	13	0,50	0,30	0,60	0,40	0,10	0,30	54	17	14	9	6	0,6	0,5	0,5	0,5	0,5	21	18	62	0,20	0,20	0,40	0,00
	14	0,50	0,30	0,30	0,30	0,10	0,10	53	18	15	8	6	0,5	0,4	0,5	0,4	0,5	23	20	57	0,10	0,20	0,40	0,00
	15	0,40	0,30	0,40	0,30	0,10	0,20	49	19	16	9	6	0,4	0,4	0,4	0,4	0,5	22	18	60	0,20	0,20	0,40	0,00
	16	0,50	0,40	0,60	0,40	0,10	0,30	48	19	14	10	9	0,6	0,5	0,5	0,5	0,5	24	21	55	0,10	0,20	0,30	0,00
	17	0,30	0,20	0,40	0,40	0,10	0,20	50	19	15	10	6	0,4	0,5	0,4	0,4	0,4	20	17	63	0,10	0,20	0,40	0,00
	18	0,40	0,30	0,50	0,50	0,10	0,30	51	18	14	10	7	0,5	0,5	0,4	0,5	0,4	18	18	63	0,20	0,20	0,40	0,00
	19	0,60	0,40	0,60	0,40	0,10	0,30	52	18	14	10	7	0,6	0,5	0,4	0,5	0,5	21	21	59	0,10	0,20	0,40	0,00
	20	0,40	0,30	0,70	0,50	0,10	0,30	54	17	13	9	6	0,5	0,5	0,4	0,5	0,5	19	18	63	0,10	0,20	0,40	0,00
	21	0,30	0,20	0,30	0,40	0,10	0,20	47	20	15	11	7	0,4	0,5	0,4	0,4	0,4	17	18	64	0,10	0,20	0,40	0,00
	22	0,30	0,20	0,30	0,40	0,10	0,20	48	21	15	10	6	0,4	0,4	0,4	0,5	0,5	18	19	63	0,10	0,20	0,40	0,00
	23	0,30	0,20	0,40	0,40	0,10	0,20	49	20	14	11	7	0,5	0,5	0,4	0,4	0,4	18	18	64	0,10	0,20	0,40	0,00
	24	0,50	0,30	0,60	0,40	0,10	0,30	49	17	13	12	9	0,6	0,6	0,4	0,5	0,5	20	20	60	0,10	0,20	0,40	0,00

iting the highest concentration. The even predominance of n-alkanes has previously been reported for Prinos [2], and Epsilon reservoirs [3], and was attributed to marine organic matter input [8]. On the contrary, Prinos North field samples show a clear odd to even predominance of n-alkanes, with the phytane being again the component with the highest concentration. The odd predominance of n-alkanes can be attributed to a higher plant, terrestrial organic input. Using the n-alkanes profile, it is possible to classify the samples of each well into distinguishable groups, indicating the existence of different facies within the formation (or the source rock), containing slightly modified organic matter.

The absence of any noticeable characteristic "hump" of the unresolved complex mixture (UCM) in the gas chromatograms of all samples indicates that the organic matter in the studied fields has not been altered by biodegradation.

The Carbon Preference Index (CPI) is less than 1.0 in Epsilon and Prinos fields samples, and higher than 1.5 in Prinos North field, indicating a carbonate type source rock for the first group and an argillaceous one for the latter [9]. Epsilon and Prinos fields extracts show higher maturity level compared to the respective Prinos North field, as Pr/C17 and Ph/C18 ratios indicate. The average values of Pr/C17 index of Epsilon and Prinos fields are 0,99 and 0,60 respectively, while Prinos North field shows a higher average value of 2,61. Similarly, the average values of Ph/C18 index of Epsilon and Prinos fields are 2,42 and 1,89 respectively, while Prinos North field shows a remarkable high average value of 18,40.

The depositional environment appears to be hyper-saline, strongly reducing in all fields, based on Pr/Ph and Odd-Even Predominance ratios (OEP) [8]. Pr/Ph values less than one, as in the current study, indicate anoxic deposition conditions,

Table 6. GC - MS Data from PB26 Well Samples

GC-MS analysis																									
Well		**Hopanes**						**Homohopane Index**					**22S/22S+22R Index**					**Steranes**						
Sample		**Ts/**	**Ts/**	**C29/**	**Olean**	**Gam**	**Mor/**	**C31**	**C32**	**C33**	**C34**	**C35**	**C31**	**C32**	**C33**	**C34**	**C35**	**C27**	**C28**	**C29**	**Dia/**	**S/**	**bb/**	**C21/**
		Tm	**(Ts+Tm)**	**C30**			**Hop**														**nor**	**(S+R)**	**(aa+bb)**	**C29**
PB26	2A	0,20	0,20	1,00	0,20	1,10	0,10	25	19	14	10	33	0,6	0,6	0,6	0,6	0,6	35	29	36	0,20	0,50	0,50	0,60
	2B	0,10	0,10	1,00	0,20	1,10	0,10	27	18	12	10	33	0,6	0,6	0,6	0,6	0,6	36	27	37	0,20	0,50	0,60	0,40
	2PA	0,20	0,20	0,90	0,10	1,00	0,10	25	17	14	11	33	0,6	0,5	0,6	0,5	0,6	33	27	39	0,20	0,50	0,60	0,50
	2PB	0,20	0,10	0,80	0,10	1,00	0,10	28	17	13	10	32	0,5	0,6	0,6	0,5	0,6	34	27	39	0,20	0,50	0,60	0,50
	2PG	0,20	0,10	0,80	0,10	1,10	0,10	31	21	15	13	21	0,5	0,6	0,6	0,5	1,0	33	27	40	0,20	0,50	0,60	0,40
	2PD	0,20	0,20	1,40	0,10	1,20	0,10	25	15	12	12	37	0,7	0,6	0,7	0,6	0,7	34	27	39	0,10	0,50	0,50	0,30
	2PE	0,30	0,20	1,10	0,10	0,90	0,10	23	13	13	10	41	0,6	0,5	0,7	0,6	0,7	35	28	37	0,10	0,50	0,50	0,40
	2PST	0,10	0,10	1,00	0,10	1,70	0,10	26	16	11	11	37	0,6	0,7	0,5	0,6	0,6	33	26	41	0,10	0,50	0,60	0,30
	3PA	0,20	0,20	1,00	0,10	1,00	0,10	24	15	13	10	37	0,6	0,5	0,6	0,6	0,6	34	28	38	0,10	0,50	0,60	0,40
	1B	0,20	0,20	1,00	0,10	1,00	0,10	24	15	13	10	37	0,6	0,5	0,6	0,6	0,6	33	29	38	0,20	0,50	0,60	0,40
	3PB	0,30	0,20	1,00	0,10	0,80	0,10	26	15	12	10	37	0,6	0,5	0,6	0,6	0,6	33	29	38	0,10	0,50	0,60	0,50
	1A	0,30	0,20	1,00	0,10	0,80	0,10	26	15	12	10	37	0,6	0,5	0,6	0,6	0,6	36	28	36	0,20	0,50	0,60	0,50
	3PG	0,20	0,20	1,10	0,10	0,80	0,10	27	15	12	10	36	0,6	0,5	0,7	0,6	0,6	33	29	38	0,10	0,50	0,60	0,40
	3PD	0,20	0,20	0,80	0,10	1,00	0,00	25	16	14	11	34	0,6	0,5	0,6	0,5	0,6	32	27	40	0,20	0,50	0,60	0,40
	1G	0,20	0,20	0,80	0,10	1,00	0,00	25	16	14	11	34	0,6	0,5	0,6	0,5	0,6	35	28	37	0,20	0,50	0,50	0,50
	3PE	0,10	0,10	1,10	0,10	1,70	0,10	26	16	11	10	36	0,6	0,7	0,5	0,6	0,6	33	26	41	0,10	0,50	0,50	0,20
	4PA	0,20	0,20	1,10	0,10	0,90	0,10	27	15	13	11	34	0,6	0,5	0,6	0,6	0,6	34	29	37	0,10	0,50	0,60	0,50
	4PB	0,20	0,20	0,70	0,10	1,00	0,10	24	17	12	11	36	0,5	0,6	0,6	0,6	0,6	33	26	41	0,10	0,50	0,60	0,40
	4PG	0,10	0,10	1,40	0,10	1,90	0,10	25	15	12	11	37	0,6	0,7	0,6	0,6	0,6	34	27	40	0,10	0,50	0,50	0,30
	4PD	0,90	0,50	1,10	0,10	1,20	0,10	24	14	13	11	38	0,6	0,7	0,5	0,6	0,6	30	28	41	0,20	0,50	0,50	0,30
	4PE	0,10	0,10	1,10	0,10	1,60	0,10	26	16	11	11	36	0,6	0,7	0,5	0,6	0,6	33	26	41	0,10	0,50	0,60	0,30
	4PST	0,20	0,10	1,30	0,10	1,90	0,10	26	14	12	11	37	0,6	0,7	0,5	0,6	0,6	34	26	41	0,10	0,50	0,50	0,30
	4PZ	0,20	0,10	1,10	0,10	1,70	0,10	27	16	11	11	35	0,6	0,7	0,5	0,6	0,6	33	26	41	0,10	0,50	0,50	0,30
	6PA	0,50	0,30	0,70	0,10	0,80	0,10	21	12	14	12	41	0,5	0,6	0,6	0,5	0,6	30	26	44	0,20	0,40	0,60	0,30
	6PB	0,60	0,40	0,70	0,10	0,80	0,10	21	14	14	10	42	0,5	0,6	0,6	0,5	0,5	30	26	44	0,20	0,50	0,60	0,40
	6PD	0,20	0,20	0,80	0,10	1,20	0,00	25	16	14	11	33	0,5	0,5	0,6	0,5	0,6	36	24	40	0,20	0,50	0,50	0,20

particularly in oils exhibiting high sulfur content. All the extracts show Pr/Ph values of the same magnitude (average values of 0.23, 0.19 and 0.26 of Epsilon, Prinos and Prinos North) indicating similar conditions in the depositional environment within the basin.

Concluding, from the gas chromatographic analysis of the saturates, it can be noticed that Epsilon and Prinos fields exhibit pronounced compositional similarities. The observed differences in Prinos North field compared to the other two formations can be attributed to a different organic matter input and possibly to a lower thermal maturity level.

Gas Chromatography – Mass Spectrometry

Selected m/z 191 and m/z 217 fragmentograms of samples from each one of the studied wells are presented in Fig. (**6**). The interpretation of the main biomarkers indices, presented in Tables **5-8**, can be summarized as follows:

Oleanane, a characteristic biomarker for organic matter derived from higher plants, was identified in all samples under study. The respective oleanane index, although varies between samples, shows distinguishable high values in PN2 well samples. This fact can be interpreted as an indication of a more pronounced contribution of terrestrial organic matter in this field, compared to Prinos and Epsilon fields. Gammacerane, a characteristic biomarker of anoxic hypersaline environments, was also identified in the studied samples. The calculated gammacerane index distinguishes samples into two separated groups. Prinos and Epsilon fields samples show high values, while Prinos North field samples exhibit remarkable lower values. This finding can be interpreted as an indication of a strong reducing environment in the former

Table 7. GC - MS Data from E1As Well Samples

GC-MS Analysis																									
Well		Hopanes						Homohopane Index					22S/22S+22R index					Steranes						
Sample		Ts/	Ts/	C29/	Olean	Gam	Mor/	C31	C32	C33	C34	C35	C31	C32	C33	C34	C35	C27	C28	C29	Dia/	S/	bb/	C21/
		Tm	(Ts+Tm)	C30			Hop														nor	(S+R)	(aa+bb)	C29
E1As	53	2,90	0,70	0,60	0,20	0,90	0,10	19	16	13	12	41	0,6	0,5	0,7	0,6	0,6	33	29	38	0,20	0,50	0,60	0,20
	36	2,60	0,70	0,60	0,20	0,90	0,10	19	16	12	13	40	0,6	0,6	0,6	0,6	0,6	34	29	37	0,30	0,50	0,50	0,30
	44	1,40	0,60	1,10	0,10	1,50	0,10	23	18	11	12	37	0,6	0,7	0,5	0,6	0,6	37	26	37	0,20	0,50	0,50	0,30
	16	0,00	0,00	0,90	0,20	1,10	0,10	28	20	14	10	28	0,6	0,6	0,6	0,6	0,6	37	24	39	0,20	0,50	0,50	0,40
	33	0,80	0,50	1,10	0,20	1,90	0,10	15	14	11	13	46	0,6	0,6	0,6	0,7	0,7	28	27	45	0,20	0,50	0,50	0,10
	42	1,30	0,60	0,60	0,20	1,50	0,10	21	17	14	11	38	0,5	0,5	0,6	0,5	0,6	34	26	40	0,40	0,50	0,60	0,20
	39	0,20	0,20	0,60	0,30	1,00	0,10	23	21	13	11	32	0,5	0,6	0,5	0,6	0,6	34	24	42	0,40	0,50	0,60	0,20
	41	0,30	0,20	0,60	0,20	1,00	0,10	24	21	13	11	32	0,5	0,6	0,5	0,6	0,6	35	24	41	0,40	0,50	0,60	0,30
	17	0,00	0,00	1,00	0,20	1,00	0,10	29	22	12	11	27	0,6	0,6	0,6	0,6	0,6	38	24	38	0,40	0,50	0,50	0,60
	50	0,40	0,30	1,20	0,20	0,80	0,10	28	19	13	10	31	0,7	0,6	0,7	0,7	0,7	36	27	37	0,30	0,50	0,50	0,40
	37	0,60	0,40	1,00	0,30	1,30	0,10	22	16	12	13	38	0,6	0,7	0,5	0,6	0,7	27	24	49	0,20	0,50	0,50	0,10
	49	0,40	0,30	0,90	0,20	0,70	0,10	27	18	12	10	33	0,6	0,5	0,7	0,5	0,6	35	27	38	0,20	0,60	0,60	0,40
	51	0,20	0,20	0,90	0,30	1,20	0,10	27	21	12	11	28	0,5	0,6	0,5	0,6	0,6	34	24	41	0,30	0,50	0,50	0,40
	11	0,00	0,00	0,80	0,20	2,50	0,10	20	11	10	9	50	0,6	0,6	0,5	0,6	0,6	37	23	40	0,40	0,50	0,50	0,20
	47	0,30	0,20	0,60	0,20	1,00	0,10	24	21	12	10	32	0,5	0,6	0,5	0,6	0,6	37	25	39	0,40	0,50	0,60	0,50
	12	0,00	0,00	1,00	0,20	0,90	0,10	32	23	13	9	24	0,6	0,6	0,6	0,6	0,6	38	24	38	0,40	0,50	0,50	0,50
	45	0,60	0,40	0,90	0,20	1,30	0,10	22	16	13	10	39	0,7	0,6	0,7	0,7	0,6	36	26	38	0,30	0,50	0,50	0,20
	32	0,50	0,30	0,70	0,30	1,60	0,10	18	15	10	12	45	0,5	0,7	0,5	0,7	0,6	27	24	49	0,30	0,40	0,50	0,10
	43	0,80	0,50	0,20	0,30	1,00	0,20	22	18	16	15	28	0,4	0,6	0,5	0,5	0,5	29	27	45	0,40	0,50	0,50	0,10
	40	0,20	0,20	0,90	0,30	1,40	0,10	25	19	11	11	33	0,5	0,6	0,5	0,6	0,6	34	24	42	0,30	0,50	0,60	0,30
	13	0,00	0,00	1,00	0,20	1,10	0,10	27	20	13	10	29	0,6	0,6	0,6	0,6	0,6	34	24	42	0,40	0,50	0,50	0,40
	34	0,00	0,00	0,90	0,30	1,70	0,20	19	13	13	10	45	0,5	0,5	0,7	0,6	0,5	29	24	47	0,30	0,50	0,40	0,00
	14	0,00	0,00	0,60	0,20	1,40	0,10	22	20	11	12	35	0,6	0,6	0,6	0,6	0,6	35	25	40	0,20	0,50	0,50	0,20
	35	0,40	0,30	0,70	0,30	1,20	0,10	21	16	11	12	40	0,5	0,6	0,5	0,7	0,6	28	24	48	0,30	0,40	0,50	0,10
	52	0,60	0,40	1,00	0,20	1,90	0,10	21	16	13	10	40	0,7	0,6	0,6	0,6	0,7	37	25	37	0,30	0,50	0,50	0,20
	15	0,00	0,00	0,80	0,20	1,40	0,10	24	18	14	10	33	0,6	0,6	0,6	0,6	0,6	37	22	41	0,50	0,50	0,60	0,30
	46	0,00	0,00	0,50	0,20	2,50	0,10	15	16	12	11	45	0,5	0,6	0,5	0,6	0,6	36	24	40	0,50	0,50	0,60	0,20

fields and a different source environment for the latter. The distribution of the C31-C35 hopanes also confirms this fact, with Prinos North samples showing high C31 and low C35 homohopanes concentration.

The presence of moretane and the values of the calculated moretane index, which is considered characteristic of the thermal maturity, also classify the samples into two separate groups. Prinos North field samples may be considered as less mature, according to their high moretane index values, compared to Epsilon and Prinos fields samples.

Concluding, from the biomarker analysis, it can be noticed that the organic matter of Epsilon and Prinos fields is mainly of marine origin, while terrestrial input is significant for the Prinos North field. Additionally, the depositional environment in all cases is reducing, although in a different level. It should be underlined that these findings from biomarker analysis are in agreement with the analogous conclusions presented earlier, based on the gas chromatographic analysis.

DISCUSSION

The analyzed rock samples of three fields, Prinos, Prinos North and Epsilon, present similar characteristics regarding the depositional environment during sedimentation. In all cases hypersaline, strongly reducing conditions were identified, favoring organic matter preservation, as indicated by Pr/Ph index as well as OEP ratios (GC analysis). GC-MS analysis also concludes to the same result, based on Gammacerane and C31-C35 Hopane indexes.

Table 8. GC - MS Data from E1 Well Samples

GC-MS Analysis																									
Well		Hopanes						Homohopane Index					22S/22S+22R Index					Steranes						
Sample		Ts/	Ts/	C29/	Olean	Gam	Mor/	C31	C32	C33	C34	C35	C31	C32	C33	C34	C35	C27	C28	C29	Dia/	S/	bb/	C21/
		Tm	(Ts+Tm)	C30			Hop														nor	(S+R)	(aa+bb)	C29
E1	1	0,30	0,30	1,50	0,20	0,80	0,10	24	14	14	13	34	0,6	0,5	0,6	0,6	0,6	28	27	45	0,20	0,40	0,50	0,20
	2	0,30	0,20	1,50	0,20	0,80	0,10	28	15	13	12	33	0,6	0,5	0,6	0,6	0,7	31	26	43	0,20	0,40	0,50	0,40
	46	0,20	0,20	0,70	0,20	1,10	0,10	26	21	12	11	29	0,5	0,6	0,5	0,6	0,6	37	24	40	0,30	0,50	0,60	0,30
	3	0,20	0,20	1,00	0,30	1,30	0,10	27	19	12	13	30	0,5	0,7	0,5	0,6	0,6	35	24	41	0,30	0,50	0,50	0,30
	4	0,40	0,30	1,20	0,20	0,80	0,10	22	14	14	16	33	0,7	0,6	0,6	0,6	0,6	34	27	39	0,20	0,50	0,50	0,30
	5	0,30	0,20	0,90	0,20	0,80	0,10	27	19	13	10	30	0,6	0,5	0,6	0,5	0,6	34	28	38	0,30	0,50	0,60	0,30
	6	0,30	0,20	0,70	0,30	0,90	0,10	24	18	13	12	32	0,5	0,6	0,6	0,6	0,5	34	26	40	0,30	0,50	0,60	0,30
	7	0,20	0,20	0,60	0,20	1,00	0,10	24	18	14	12	31	0,5	0,6	0,5	0,6	0,6	35	24	40	0,30	0,50	0,60	0,30
	45	0,40	0,30	1,10	0,20	0,90	0,10	27	18	12	11	32	0,7	0,6	0,6	0,6	0,6	36	27	37	0,30	0,50	0,50	0,30
	8	0,30	0,20	0,70	0,20	0,90	0,10	26	21	14	10	29	0,6	0,5	0,6	0,5	0,6	34	25	41	0,40	0,50	0,60	0,30
	9	0,20	0,20	1,20	0,30	1,30	0,10	28	18	11	12	30	0,6	0,7	0,5	0,6	0,6	35	24	41	0,30	0,50	0,50	0,20
	10	0,40	0,30	1,20	0,20	0,90	0,10	27	18	13	11	32	0,7	0,6	0,7	0,6	0,6	36	26	38	0,20	0,50	0,50	0,30
	12	0,20	0,20	0,60	0,20	1,10	0,10	24	20	12	11	33	0,5	0,6	0,5	0,6	0,6	36	24	40	0,30	0,50	0,60	0,30
	13	0,90	0,50	0,90	0,20	1,80	0,10	14	15	11	8	51	0,6	0,7	0,6	0,6	0,6	33	25	42	0,20	0,50	0,50	0,10
	14	0,30	0,20	1,30	0,20	1,30	0,10	27	18	11	10	34	0,6	0,7	0,6	0,7	0,7	37	24	39	0,20	0,50	0,50	0,20
	41	0,30	0,20	0,70	0,20	0,80	0,10	24	18	14	9	35	0,6	0,5	0,6	0,6	0,6	36	26	39	0,30	0,50	0,60	0,30
	15	0,40	0,30	1,00	0,20	0,80	0,10	27	18	13	10	33	0,7	0,6	0,6	0,6	0,6	35	26	39	0,20	0,60	0,50	0,30
	16	0,40	0,30	1,10	0,20	0,90	0,10	28	19	12	10	31	0,7	0,6	0,6	0,7	0,6	36	25	39	0,20	0,50	0,50	0,30
	42	0,40	0,30	1,10	0,20	1,00	0,10	26	17	12	11	33	0,7	0,6	0,6	0,6	0,6	36	26	38	0,20	0,50	0,50	0,30
	17	0,40	0,30	1,10	0,20	1,10	0,10	27	18	12	10	32	0,6	0,7	0,6	0,7	0,6	36	25	39	0,20	0,50	0,50	0,30
	18	0,20	0,20	1,00	0,20	1,30	0,10	27	19	11	12	32	0,5	0,6	0,5	0,6	0,6	35	23	42	0,30	0,50	0,50	0,30
	44	0,20	0,20	1,00	0,30	1,20	0,10	28	20	12	11	28	0,6	0,6	0,5	0,6	0,6	35	24	41	0,20	0,50	0,60	0,20
	48	0,30	0,20	1,00	0,20	0,90	0,10	26	17	13	13	31	0,7	0,6	0,6	0,6	0,6	36	27	37	0,30	0,50	0,50	0,40
	49	0,30	0,20	0,90	0,20	0,70	0,10	29	18	14	10	29	0,6	0,5	0,6	0,6	0,6	36	27	37	0,30	0,50	0,50	0,40
	43	0,20	0,20	1,10	0,30	1,30	0,10	28	19	11	11	30	0,6	0,7	0,5	0,6	0,6	35	24	41	0,20	0,50	0,50	0,20
	47	0,20	0,20	1,20	0,30	1,40	0,10	28	19	11	12	29	0,6	0,7	0,5	0,6	0,6	36	24	40	0,20	0,50	0,50	0,20
	50	0,30	0,20	0,60	0,20	1,00	0,10	25	21	13	11	29	0,5	0,6	0,5	0,6	0,6	35	24	41	0,30	0,50	0,60	0,20

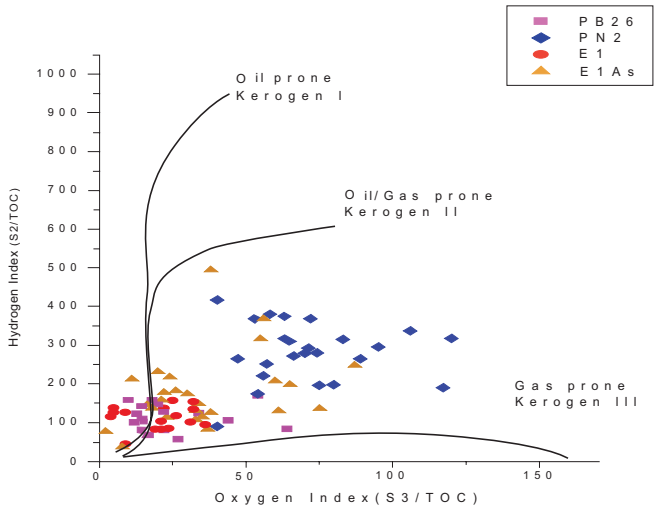

Fig. (4). Core samples plotted on the Van Krevelen diagram.

In addition, the organic matter shows similarities among the three fields, not being altered by biodegradation, as indicated by the gas chromatograms of the saturated fraction (GC analysis). All analyzed sediments appear to be rich in organic matter, as shown by TOC values, but immature as indicated by low Tmax values (Rock-Eval Pyrolysis). Also, organic matter of different quality appears to be present in all fields, as indicated by normal alkane distribution. Moreover, a rather non-homogeneous distribution of the organic matter in all sediments is implied, since no correlation can be observed between the extracts composition and samples retrieved depth.

However, the organic matter type differentiates between Prinos North field and Prinos, Epsilon fields regarding its composition. Low polar components, low aromatic and high saturated fraction of Epsilon and Prinos fields, against high polar components, low aromatic and saturate concentrations of Prinos North field extracts imply different maturation level, assigning more immature oils for the latter (SARA analysis). Pr/C17 and Ph/C18 ratios also indicate more mature oils in Prinos and Epsilon compared to Prinos Notrh field (GC analysis). GC-MS analysis also concludes to the same result, based on Moretane and S/S+R Sterane indexes.

Differences on normal alkane distribution among fields are also observed. Epsilon and Prinos fields samples show a clear predominance of even to odd carbon number n-alkanes, which is attributed to marine organic production. In contrast, Prinos North field samples show a clear predominance of odd to even carbon number n-alkanes, attributing to higher plant, terrestrial organic input on organic matter production (GC analysis).

Rock-Eval Pyrolysis results indicate higher thermal maturity level for rock samples of Prinos North field compared to Prinos and Epsilon, as indicated by Tmax values. Additionally, hydrocarbon migration is identified in Prinos and Epsilon fields, while in Prinos North field, kerogen of type II and III is indicated (Rock-Eval Pyrolysis). Migrant hydrocarbons in Prinos and Epsilon fields are also supported by the fact that high extracted hydrocarbons ratios do not match with the low S2 concentration measured during Rock-Eval Pyrolysis.

Prinos and Epsilon source rocks appear to be carbonate rocks, contrary to Prinos North hydrocarbons that are generated from argillaceous source rock, as indicated by the CPI index (GC analysis).

CONCLUSIONS

Consequently, it is evaluated that hydrocarbons from Prinos and Epsilon fields have been generated in deeper stratigraphic horizons that obtained higher thermal maturity, and migrated into the reservoirs, where the analyzed samples were retrieved, once no significant hydrocarbons could be generated from the poor source rock analyzed, at the present thermal maturity level. The organic matter identified is attributed to hydrocarbons accumulation and no kerogen could be recognized due to the presence of migrant oils. On the other hand, Prinos North field hydrocarbons are not contaminated with migrant oils. Although the identified kerogen appears to have generated minor hydrocarbons so far, it is considered as a good potential source rock for future hydrocarbon generation. The above conclusions are also supported by the fact that Prinos and Epsilon samples are retrieved from the reservoir horizons, whist Prinos North samples are retrieved from zones deposited below the reservoirs.

Finally, it should be emphasized that source rock samples from deeper stratigraphic horizons were not analyzed due to unavailability. Though, Prinos North field samples, retrieved from zones underlying the reservoirs, show obvious differences regarding source rock types and thermal maturity level. Further investigation of different fields within Prinos - Kavala basin continues, to reveal changes on organic matter input, thermal maturation level and organic matter source rocks, which also influence the quality and quantity of generated hydrocarbons and finally control recoverable hydrocarbons reserves.

Ultimately, Prinos - Kavala fields samples are supplementary studied using sedimentological methods to investigate the depositional environments into the basin, as well as the sediments origin and source rocks. Thin sections are also examined under microscope to identify the sediments mineral composition and diagenesis level that control the reservoirs characteristics. The conjunction of geochemical and geological analysis results will guide to the understanding of the Palaeogeographic development of Prinos - Kavala basin and hydrocarbon generation, migration paths and traps. These findings are key factors in exploration and development of new hydrocarbon potential structures into Prinos – Kavala basin, as well as future hydrocarbon exploration of similar sedimentary basins in North Aegean Sea.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Kavala Oil S. A. Company, and especially Mr. C. Papaconstantinou, for making the cores available and permitting the publication of this study. The authors also wish to acknowledge the General Secretariat for Research and Technology of the Ministry of Development and the European Office of Regional Development of the European Commission for financing this project.

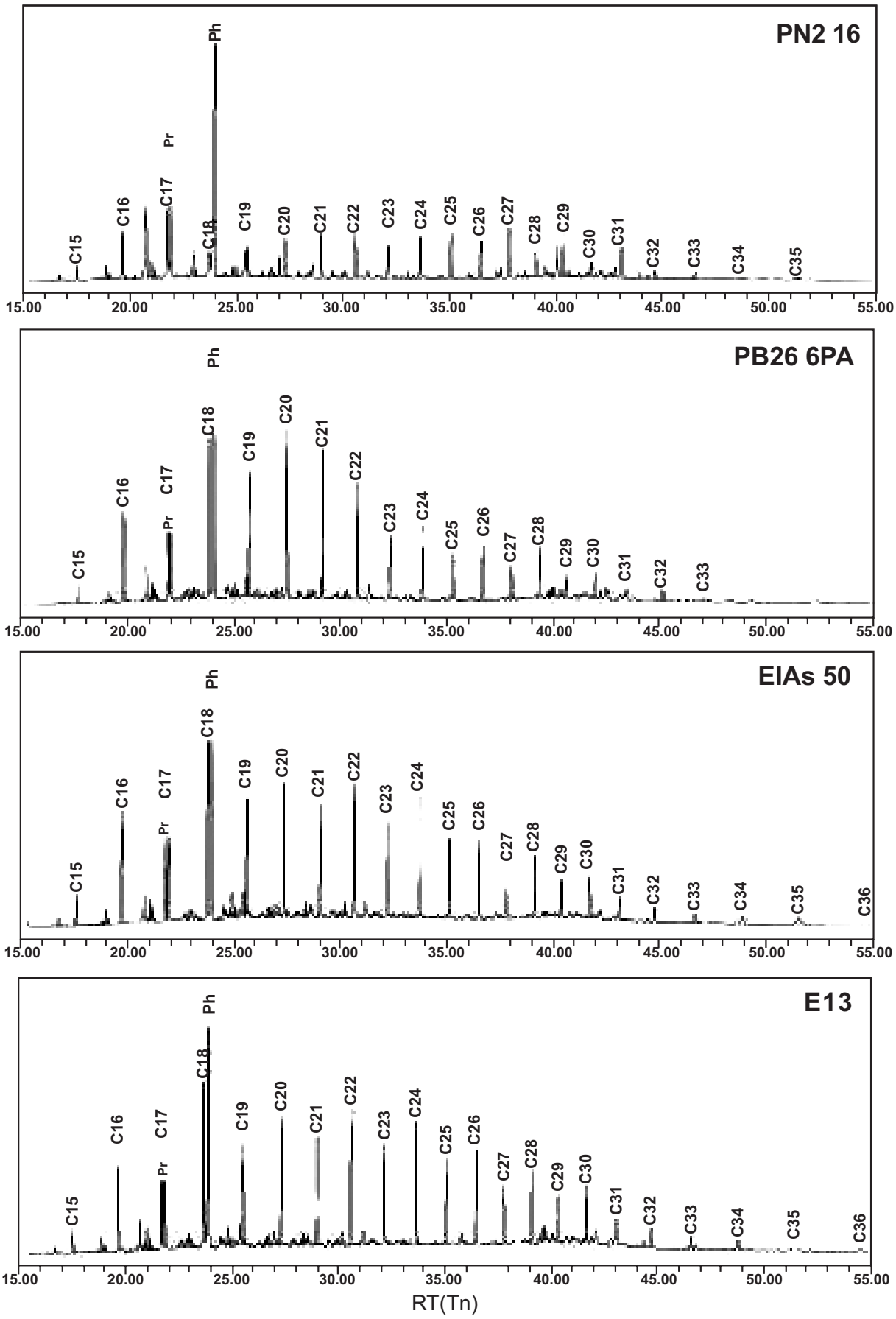

Fig. (5). Selected gas chromatograms of the saturated fractions.

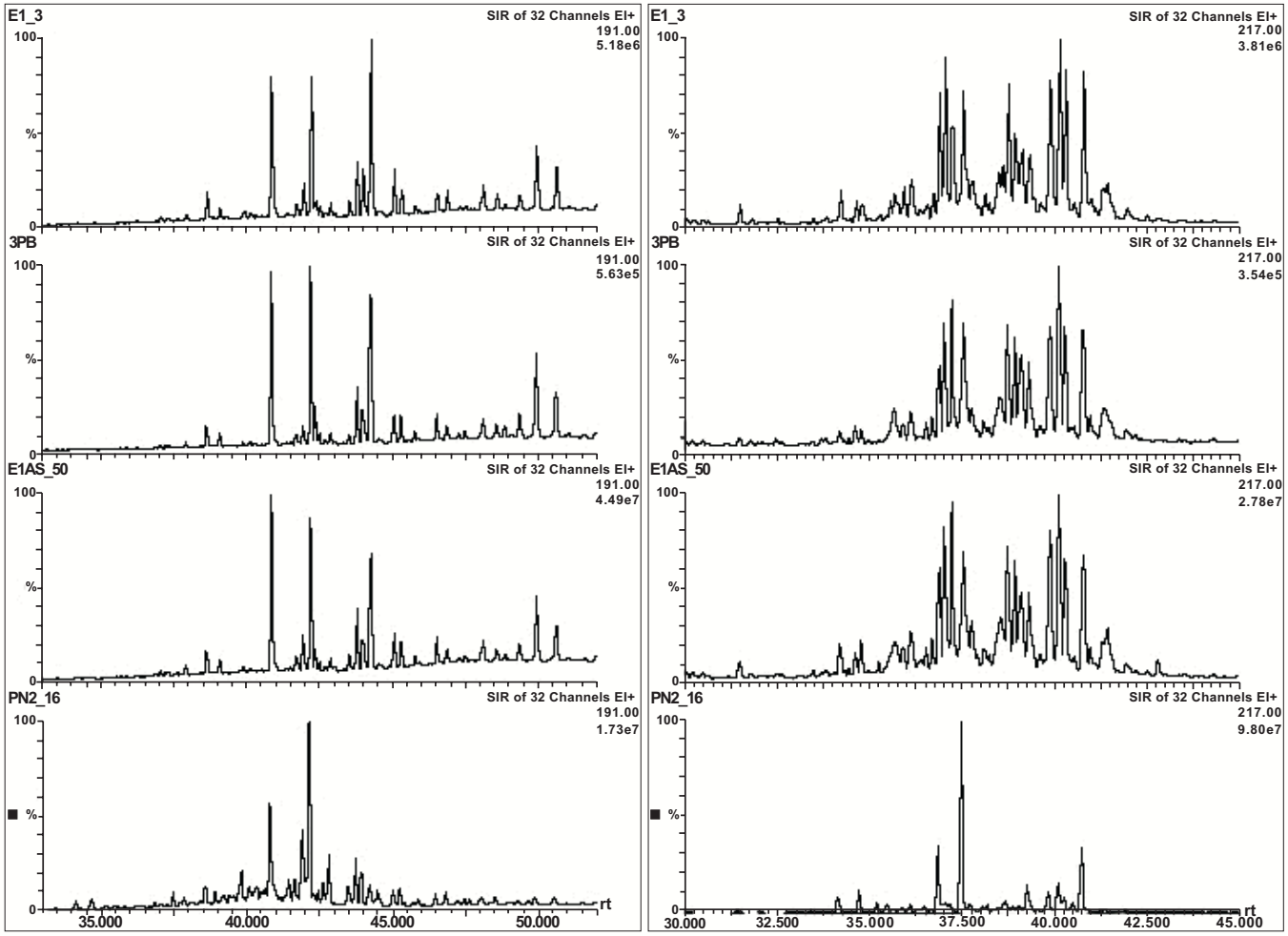

Fig. (6). Indicative m/z 191 and m/z 217 fragmentograms.

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Received: March 31, 2008 Revised: April 9, 2008 Accepted: April 10, 2008