GEOCHEMICAL MEASUREMENT OF THERMAL MATURITY IN NEOPROTEROZOIC AND CAMBRIAN SEDIMENTS, EASTERN OFFICER BASIN

Report for South Australian Department of Mines and Energy

by

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INTRODUCTION

As part of the South Australian Exploration Initiative, a study of the burial history of the sediments comprising the eastern Officer Basin is being undertaken by R. Moussavi-Harami (Department of Geology and Geophysics, University of Adelaide) and D.I. Gravestock (MESA). A logical extension of this work is to model the thermal history of the Ediacaran (Late Neoproterozoic) and Early Cambrian sequences that are host to oil shows and potential source and reservoir rocks (McKirdy, 1993; Kamali *et al.*, 1993; McKirdy *et al.*, 1994). An essential prerequisite of any such thermal modelling exercise is reliable maturity data. Measurement of the present-day maturation levels of the target formations in strategically located drillholes across the basin makes possible determination of the timing of oil and gas generation in relation to trap formation.

Previous studies of the Offficer Basin by McKirdy (1987), McKirdy *et al.* (1987, 1991) and Kamali *et al.* (1993) exploited the capability of triaromatic hydrocarbon distributions (Radke and Welte, 1983; Radke *et al.*, 1984; Radke, 1987) to provide thermal maturity data on pre-Devonian sediments devoid of vitrinite phytoclasts (Summons *et al.*, 1994).

The aim of the present investigation was to augment the existing aromatic maturity database for the Officer Basin (Table 1) by undertaking measurements of methylphenanthrene index (MPI), methylphenanthrene ratio (MPR) and calculated vitrinite reflectance (VR_{calc}) on the triaromatic hydrocarbons extracted from another ten mudstone samples. The samples were selected from drillcore to provide data on specific stratigraphic units and structural provinces, as follows:

Province	*Well*	*Formation*	*No. of Samples*
Tallaringa Trough	Duvall KD-2A	Ouldburra Formation	2
Manya Trough	Marla-9	Mena Mudstone	2
Murnaroo Platform	Murnaroo-1	Karlaya Limestone	2
	Karlaya-1	Dey Dey Mudstone	2
	SMD 5001 (Lake Maurice West)	Dey Dey Mudstone	2

EXPERIMENTAL

The rock samples (lengths of quarter core) were scraped and brushed clean to remove surficial contamination before crushing in a Siebtechnik mill. Powdered rock (~50 g) was extracted in Soxhlet apparatus for 72 hours using an azeotropic solvent mixture (CH_2Cl_2:CH_3OH; 93:7). The extract was fractionated by open column liquid chromatography on activated silica into saturated hydrocarbons, aromatic hydrocarbons and nonhydrocarbons (NSO compounds and asphaltenes).

GC-MS analyses of the aromatic hydrocarbons were undertaken using a Varian 3400 gas chromatograph interfaced with a Finnigan TSQ 70 mass spectrometer. The gas chromatograph was fitted with a 30 m x 0.25 mm i.d. fused silica column (DB-5, 0.25 μm film thickness; J&W Scientific). Helium was used as the carrier gas at an inlet pressure of approximately 10 psi. The temperature program of the oven was as follows: 50°C for 2 min, 50°C to 120°C at 8°C min^{-1}, 120°C to 300°C at 4°C min^{-1} and then held at 300°C for 35 min. Mass spectrometer operating parameters included an ionization voltage of 70 eV, a filament current of 200 μA and a photomultiplier voltage of 1100 V. Aromatic fractions in CH_2Cl_2 were injected on-column. The injector was held at 50°C for 10 seconds then ramped to 300°C at 180°C min^{-1}, and held at 300°C for 5 minutes. The mass spectrometer was programmed (MID mode) to monitor *m/z* 128 (naphthalene), *m/z* 141+142 (methylnaphthalenes), *m/z* 156 (dimethylnaphthalenes), *m/z* 170 (trimethylnaphthalenes), *m/z* 178 (phenanthrene), *m/z* 192 (methylphenanthrenes), *m/z* 206 (dimethylphenanthrenes), *m/z* 219 (retene), m/z 231+245 (triaromatic steranes) and *m/z* 253 (monoaromatic steranes).

RESULTS

Analytical data are summarised and presented herein as follows:

	Table	Figure
Extract yield and composition	2	–
Triaromatic maturity data	3	1–10

Although the alkylnaphthalene distributions of the sediment extacts were recorded, only the nominated maturity parameters based on the relative abundances of phenanthrene and the isomeric methylphenanthrenes are considered in this report.

DISCUSSION

Extract Yield and Composition

The concentration of extractable organic matter (EOM: Table 2) in these mudstones ranges from poor (<500 ppm) to very good (>2000 ppm). The highest yields were obtained from the Ouldburra Formation in Duvall KD-2A (1082–2540 ppm) and the Dey Dey Mudstone in SMD 5001 (1260–1815 ppm). A similarly high yield (1899 ppm) characterises the Dey Dey Mudstone at 2094 metres depth in Karlaya-1, although a second sample from about 250 metres deeper in the same well and formation is almost twenty times leaner (Table 2). The low EOM yield in the latter sample may reflect highly efficient drainage or expulsion of hydrocarbons into an adjacent porous carrier bed during primary migration. This process might also explain the unusually low proportion of hydrocarbons in the residual source rock bitumen (6.2% of EOM: Table 2).

The total hydrocarbon content (saturates + aromatics) of the EOM increases systematically with increasing thermal maturity as follows:

Well	*Formation*	*Hydrocarbons (% EOM)*
SMD 5001	Dey Dey Mudstone	13
Duvall KD-2A	Ouldburra Formation	28
Murnaroo-1	Karlaya Limestone	22–28
Karlaya-1	Dey Dey Mudstone	68
Marla-9	Mena Mudstone	60–73

Aromatic hydrocarbons comprise between 2% (least mature) and 21% (most mature) of the EOM in these mudstones. For all but the least mature samples, the ratio of saturated to aromatic hydrocarbons is reasonably uniform (sat/arom = 0.7–3.3: Table 2).

Thermal Maturity

For each of the targetted structural provinces – Tallaringa Trough, Murnaroo Platform and Manya Trough – the new maturity measurements (Table 3) are broadly congruent with existing data (Table 1). The lack of internal consistency in the VR_{calc} values obtained for the sample pairs from Duvall KD-2A and Karlaya-1 (viz. deeper sample significantly less mature than shallower sample: Table 3) is difficult to explain. It may be due to a mineral or organic matrix effect which inhibited the catagenic methylation of phenanthrene. Such problems are commonly encountered when working with sediments containing non-humic organic matter (Type I or Type II kerogen) (Radke, 1987).

Another feature of the new data set is that, for a given sample, the MPI-derived VR_{calc} is consistently lower than that based on MPR. For most samples the difference between the two VR_{calc} values is slight. The greatest discrepancy (0.17–0.19% VR) is evident in the least mature sample pair (Dey Dey Mudstone from SMD 5001: Table 3). In this case, which of the two parameters, MPI and MPR, provides the most accurate measure of maturation level? The answer seems to be MPI. Lamalginite reflectance data presented by McKirdy *et al.* (1992) (see Table 4) corroborate the MPI-based VR_{calc} value here obtained for the Dey Dey Mudstone in SMD 5001 (Lake Maurice West).

Tallaringa Trough

- In Duvall KD-1 and 2, located on the southern edge of the trough, the *Ouldburra Formation* is early mature (VR_{calc} = 0.58–0.68%).
- Some 65 km to the northwest, in Wilkinson-1, the same formation is somewhat more mature (VR_{calc} = 0.90%) and actively expelling hydrocarbons, as indicated by common oil staining of drillcore from this locality.
- The regional maturation level of this formation appears to increase towards the southwest (*cf.* VR_{calc} = 0.99% in Hughes-2 on the Nullarbor Platform: Table 1).

Murnaroo Platform

- The *Karlaya Limestone* in Murnaroo-1 is mature (VR_{calc} = 0.78–0.82%). The maturity of this unit increases northwards into the Munyarai Trough (VR_{calc} = 1.40% at 2612 metres depth in Munyarai-1).
- The *Dey Dey Mudstone* is early mature in SMD 5001 (418 metres depth, VR_{calc} = 0.57%) and mature in Karlaya-1 (2094–2345 metres depth, VR_{calc} = 0.79–(?)0.86%).

Manya Trough

- Here the *Ouldburra Formation* attains its highest known degree of thermal alteration (VR_{calc} = 1.00–1.68%: late mature to overmature) and therefore is essentially gas-generative.
- The *Observatry Hill Formation* at Byilkaoora-1 is at or just beyond peak maturity (VR_{calc} = 0.99–1.09%) for oil generation from Type I kerogen.
- The *Mena Mudstone* in Marla-9 has a maturity (VR_{calc} = 0.78–0.82%) which seems to be anomalously low with respect to the maturation levels exhibited by younger units in nearby wells (Table 1).

SUMMARY

Ten mudstones analysed in this study provide new maturity data on the Early Cambrian Ouldburra Formation in the Tallaringa Trough (Duvall KD-2A); and the Neoproterozoic Mena Mudstone, Karlaya Limestone and Dey Dey Mudstone on the Murnaroo Platform (SMD 5001, Murnaroo-1, Karlaya-1) and in the Manya Trough (Marla-9).

Calculated vitrinite reflectance values based on the original Radke and Welte (1983) calibration of the methylphenanthrene index (MPI-1) indicate that the sediments in question (VR_{calc} = 0.57–0.83%) all lie within the conventional oil window.

The new results, except perhaps those from Marla-9, are consistent with existing maturity data from the same or adjacent drillholes.

REFERENCES

BOREHAM, C.J., CRICK, I.H. and POWELL, T.G., 1988. Alternative calibration of the Methylphenanthrene Index against vitrinite reflectance: application to maturity measurements on oils and sediments. *Organic Geochemistry*, 12, 289–294.

KAMALI, M.R., LEMON, N.M. and McKIRDY, D.M., 1993. Ouldburra Formation as a potential source and reservoir for petroleum in the Manya Trough, eastern Officer Basin. *In*: ALEXANDER, E.M. and GRAVESTOCK, D.I. (eds), *Central Australian Basins Workshop, Alice Springs, Programme and Abstracts*, pp. 65–66.

McKIRDY, D. M., 1985. Unpublished data on Byilkaoora-1.

McKIRDY, D. M., 1986. Source rock evaluation of Cambrian sediments, Officer Basin, South Australia. *AMDEL Report F6325/86 for South Australian Department of Mines and Energy.* (Duvall KD-2A, Yarlee Lakes-1)

McKIRDY, D. M., 1987. Source rock and petroleum geochemistry of Cambrian basins in South Australia. *In*: GRAVESTOCK, D. I., HIBBURT, J. E., McKIRDY, D. M. and KUANG, K. S. (compilers), *The Setting for Cambrian Oil and Gas in South Australia.* APEA Conference, Surfers Paradise, Poster Display and Extended Abstract.

McKIRDY, D. M., 1993. Oil shows and source rocks of the eastern Officer Basin – a geochemical overview. *In*: ALEXANDER, E.M. and GRAVESTOCK, D.I. (eds), *Central Australian Basins Workshop, Alice Springs, Programme and Abstracts*, pp. 68–70.

McKIRDY, D. M. and KANTSLER, A. J., 1980. Oil geochemistry and assessment of hydrocarbon-source potential of Cambrian and Devonian rocks, Officer Basin, South Australia. *South Australian Department of Mines and Energy Report Book*, 80/10. (Birksgate-1, Byilkaoora-1, Emu-1, Munyarai-1, Murnaroo-1, Wallira West-1, Wilkinson-1)

McKIRDY, D. M. and COX, R. E., 1986. Oil and source rock maturity based on methylphenanthrene index (MPI): a pilot study. *AMDEL Report F6426/86 (Part 2) for South Australian Department of Mines and Energy.* (Byilkaoora-1, Munyarai-1, Wilkinson-1) [SADME Open File Envelope 5530: 68-78]

McKIRDY, D. M. and WATSON, B. L., 1989. Biomarker geochemistry of oil shows in the Late Precambrian Murnaroo Formation, Lake Maurice West-1, Officer Basin, S.A. *AMDEL Report F7224/89 for South Australian Department of Mines and Energy.* (SMD 5001, SMD 5002, Observatory Hill-1)

McKIRDY, D. M., COX, R. E. and O'LEARY, T., 1986. Thermal maturity of Early Palaeozoic potential hydrocarbon source rocks, South Australia. *AMDEL Report F6521/86 (Part 2) for South Australian Department of Mines and Energy.* (Observatory Hill-1) [SADME Open File Envelope 5530: 143-158]

McKIRDY, D. M., COX, R. E., FOSTER, C. B., GORTER, J. D. and MORRIS, D. G., 1987. Biomarker geochemistry of some Early Palaeozoic crude oils: influence of precursor microbiota and source rock environment. *8th International Symposium on Environmental Biogeochemistry, Nancy, France, Abstracts*, p. 53.

McKIRDY, D. M., GRAVESTOCK, D. I. and GATEHOUSE, C. G., 1991. Cambrian petroleum and source rock geochemistry of South Australia. *Australian Society of Exploration Geophysicists and Geological Society of Australia Conference, Sydney, Abstracts*, 30, 63–64.

McKIRDY, D.M., PELL, S.D. and SMYTH, M., 1992. Rodda Beds, eastern Officer Basin: anatomy of a lean Neoproterozoic petroleum source rock. *Geological Society of Australia Abstracts*, 32, 128.

McKIRDY, D.M., MICHAELSEN, B.H. and KAMALI, M.R., 1994. Officer Basin oil shows and source rocks – a geochemical window on the Larapintine petroleum system. *APEA Journal* (in prep.)

MICHAELSEN, B.H., KAMALI, M.R. and McKIRDY, D.M., 1994. Unpublished data on KD-1, Marla-6, 7 and 9.

O'LEARY, T., 1987. Maturity of two Cambrian source rocks. *AMDEL Report F6852/87 for South Australian Department of Mines and Energy.* (Hughes-2)

RADKE, M., 1987. Organic geochemistry of aromatic hydrocarbons. *In*: BROOKS, J. and WELTE, D. (eds), *Advances in Petroleum Geochemistry, Vol. 2.* Academic Press, London, pp. 141–207.

RADKE, M. and WELTE, D.H., 1983. The methylphenanthrene index (MPI): a maturity parameter based on aromatic hydrocarbons. *In*: BJOROY, M. *et al.* (eds), *Advances in Organic Geochemistry 1981.* Wiley, Chichester, pp. 504–512.

SUMMONS, R.E., TAYLOR, D. and BOREHAM, C.J., 1994. Geochemical tools for evaluating petroleum generation in Middle Proterozoic sediments of the McArthur Basin, Northern Territory, Australia. *APEA Journal*, 34(1), 692–706.

ZANG, W. and McKIRDY, D. M., 1993. Microfossils and molecular fossils from the Neoproterozoic Alinya Formation – a possible new source rock in the eastern Officer Basin. *In*: ALEXANDER, E.M. and GRAVESTOCK, D.I. (eds), *Central Australian Basins Workshop, Alice Springs, Programme and Abstracts*, pp. 62–63.

TABLE 1 : Existing aromatic maturity database, Officer Basin

Depth m	Formation	Sample type	MPI	MPR	VR_{calc} % (a)	VR_{calc} % (a')	VR_{calc} % (b)	Reference
Byilkaoora-1								
262.95	Observatory Hill Fm	extract	0.98	1.15	0.99	0.91	1.00	McKirdy and Cox (1986)
285.00	Observatory Hill Fm	extract	1.16	0.87	1.09	1.03	0.88	McKirdy and Cox (1986)
293.17	Observatory Hill Fm	oil	0.38	0.25	0.63	0.49	0.34	McKirdy (1985)
Duvall KD-1								
263.35	Ouldburra Fm	extract	0.38	0.46	0.63	0.49	0.60	Michaelsen *et al.* (1994)
Duvall KD-2A								
298.13	Ouldburra Fm	extract*	0.34	0.38	0.60	0.46	0.52	McKirdy (1986)
Hughes-2								
242.92	Ouldburra Fm	extract	0.99		0.99	0.91		O'Leary (1987)
SMD 5001 (Lake Maurice West)								
534.14	Murnaroo Fm	oil	1.03		1.02	0.94		McKirdy and Watson (1989)
SMD 5002 (Lake Maurice East)								
540.83	Murnaroo Fm	oil	1.40		1.24	1.20		McKirdy and Watson (1989)
Munyarai-1								
633.00	E-M Devonian	extract	1.43	2.78	1.26	1.22	0.98	McKirdy and Cox (1986)
2289.81	~~Leemurra Mdst~~ Tarcana Fm	extract	1.63		1.38	1.36		McKirdy and Cox (1986)
2611.83	Karlaya Lst	extract	1.67		1.40	1.39		McKirdy and Cox (1986)
Observatory Hill-1								
34.14	Observatory Hill Fm	extract	0.90	0.88	0.94	0.85	0.89	McKirdy *et al.* (1986)
155.35	Relief Sandstone	oil	1.32	1.46	1.19	1.15	1.10	McKirdy and Watson (1989)
Wilkinson-1								
333.07	Ouldburra Fm	extract*	0.58	0.64	0.75	0.63	0.75	McKirdy and Cox (1986)
390.08	Ouldburra Fm	extract	0.83	0.45	0.90	0.80	0.60	McKirdy and Cox (1986)
461.87	Ouldburra Fm	extract*	0.52	0.55	0.71	0.58	0.68	McKirdy and Cox (1986)

* Stained by oil

TABLE 1 : Existing aromatic maturity database, Officer Basin (continued)

Depth m	Formation	Sample type	MPI	MPR	VR_{calc} % (a)	VR_{calc} % (a')	VR_{calc} % (b)	Reference
Marla-3								
619.60	Ouldburra Fm	extract	1.00	1.24	1.00	0.92	1.03	Kamali *et al.* (1993)
Marla-6								
416.00	Ouldburra Fm	extract	1.43	1.76	1.26	1.22	1.18	Michaelsen *et al.* (1994)
671.25	Ouldburra Fm	extract	2.13	4.98	1.68	1.71	1.63	Kamali *et al.* (1993)
Marla-7								
392.85	Ouldburra Fm	extract	1.30	1.92	1.18	1.13	1.22	Michaelsen *et al.* (1994)
Marla-9								
234.83	Mena Mudstone	extract	0.68	0.73	0.81	0.70	0.81	Michaelsen *et al.* (1994)
Manya-6								
698.60	Ouldburra Fm	extract	1.11	2.34	1.07	1.00	1.31	Kamali *et al.* (1993)
1279.15	Ouldburra Fm	extract*	0.85	1.33	0.91	0.82	1.06	Kamali *et al.* (1993)
Giles-1								
~~5341.00~~ 1265.5m	Alinya Fm	extract	0.43	1.27	0.66	0.52	1.04	Zang and McKirdy (1993)

1238 - 1266 m

* Stained by oil

KEY TO AROMATIC MATURITY PARAMETERS

Methylphenanthrene index (MPI), methylphenanthrene ratio (MPR) and VR_{calc} are defined by Radke and Welte (1983), Radke *et al.* (1984), Radke (1987) and Boreham *et al.* (1988) as follows:

$$\text{MPI-1} = \frac{1.5\,[\,2\text{-MP} + 3\text{-MP}\,]}{\text{P} + 1\text{-MP} + 9\text{-MP}}$$

$$\text{MPR} = \frac{2\text{-MP}}{1\text{-MP}}$$

VR_{calc} (a) = 0.60 MPI + 0.40 (for VR in the range 0.65–1.35%; r = 0.96)

= – 0.60 MPI + 2.30 (for VR >1.35%)

VR_{calc} (a') = 0.70 MPI + 0.22 (for VR in the range 0.5–1.7%; r = 0.84)

VR_{calc} (b) = 0.99 $\log_{10}$ MPR + 0.94 (for VR in the range 0.4–1.7%; r = 0.84)

where

P	=	phenanthrene*
1-MP	=	1-methylphenanthrene
2-MP	=	2-methylphenanthrene
3-MP	=	3-methylphenanthrene
9-MP	=	9-methylphenanthrene

* *Note* : a response factor of 0.69 was applied to the area of this peak in Figures 1–10 when calculating MPI

TABLE 2 : Extract yield and composition

Well	Depth m	Formation	Sample size g	EOM yield ppm	Saturates % EOM	Aromatics % EOM	NSO's + Asphaltenes % EOM	Sat/Arom
Duvall KD-2A	285.50–285.60	Ouldburra Fm	51.13	2540	13.8	14.1	72.1	0.98
	297.95–298.05	Ouldburra Fm	51.04	1082	11.2	16.7	72.1	0.67
Marla-9	209.72–209.78	Mena Mdst	50.26	780	56.3	17.1	26.6	3.29
	269.87–269.97	Mena Mdst	50.08	494	39.4	21.0	39.6	1.96
Murnaroo-1	183.88–183.90	Karlaya Lst	17.61	912	13.3	9.0	77.7	1.48
	190.91–191.00	Karlaya Lst	52.08	332	16.9	11.5	71.6	1.47
Karlaya-1	2093.67–2093.78	Dey Dey Mdst	49.76	1899	47.1	20.4	32.5	2.30
	2345.09–2345.22	Dey Dey Mdst	48.56	101	3.5	2.7	93.8	1.31
SMD 5001	417.59–417.78	Dey Dey Mdst	50.74	1815	10.9	1.7	87.4	6.58
	418.15–418.25	Dey Dey Mdst	49.77	1260	11.2	nd	nd	nd

TABLE 4 : Lamalginite random reflectance data, Officer Basin

Depth m	Formation	Lamalginite R_O %	Equiv Vitrinite R_O %	Reference
Byilkaoora-1				
200.30	Observatory Hill Fm	0.60	1.0	McKirdy (1985)
SMD 5001 (Lake Maurice West)				
416.90	Dey Dey Mudstone	0.19	0.54	McKirdy *et al.* (1992)
418.10	Dey Dey Mudstone	0.13		McKirdy *et al.* (1992)
431.60	Dey Dey Mudstone	0.21	0.56	McKirdy *et al.* (1992)
Observatory Hill-1				
261.90	Dey Dey Mudstone	0.16	0.52	McKirdy *et al.* (1992)
Munyarai-1				
2289.7	Leemurra Mudstone	1.2	1.3	McKirdy and Kantsler (1980)
2753.4	Dey Dey Mudstone	1.1-1.3		McKirdy and Kantsler (1980)
2897.3	Dey Dey Mudstone	1.3-1.8	1.35-1.8	McKirdy and Kantsler (1980)

Equivalent vitrinite reflectance estimated from alginite maturation scale of Glikson *et al.* (1992), *Org. Geochem.*, 18: 881-897.

TABLE 3 : Aromatic maturity data

Well	Depth m	Formation	Sample type	MPI	MPR	VR_{calc} % (a)	VR_{calc} % (b)
Duvall KD-2A	285.50–285.60	Ouldburra Fm	extract	0.462	0.598	0.68	0.72
	297.95–298.05	Ouldburra Fm	extract	0.296	0.472	0.58	0.62
Marla-9	209.72–209.78	Mena Mdst	extract	0.663	0.898	0.80	0.89
	269.87–269.97	Mena Mdst	extract	0.710	0.944	0.83	0.92
Murnaroo-1	183.88–183.90	Karlaya Lst	extract	0.637	0.847	0.78	0.87
	190.91–191.00	Karlaya Lst	extract	0.699	0.999	0.82	0.94
Karlaya-1	2093.67–2093.78	Dey Dey Mdst	extract	0.655	0.752	0.79	0.82
	2345.09–2345.22	Dey Dey Mdst	extract	0.368	0.898	0.62	0.89
SMD 5001	417.59–417.78	Dey Dey Mdst	extract	0.276	0.627	0.57	0.74
	418.15–418.25	Dey Dey Mdst	extract	0.290	0.823	0.57	0.86

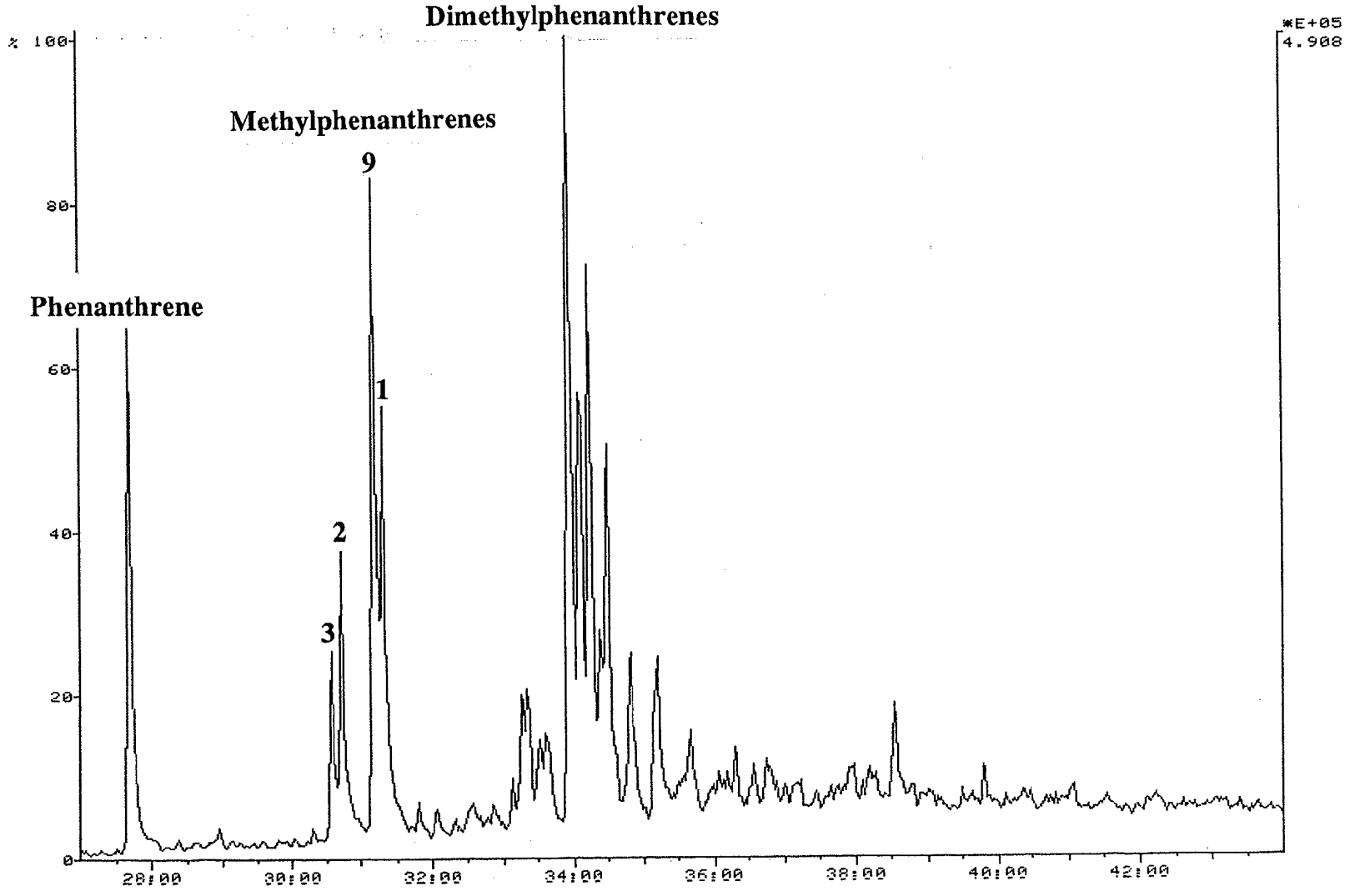
FIGURES 1–10

GC-MS RIC chromatograms of triaromatic hydrocarbons
in selected mudstones from the eastern Officer Basin

Figure	*Well*	*Depth (m)*	*Formation*
1	Duvall KD-2A	285.50–285.60	Ouldburra Fm
2	Duvall KD-2A	297.95–298.05	Ouldburra Fm
3	Marla-9	209.72–209.78	Mena Mdst
4	Marla-9	269.87–269.97	Mena Mdst
5	Murnaroo-1	183.88–183.90	Karlaya Lst
6	Murnaroo-1	190.91–191.00	Karlaya Lst
7	Karlaya-1	2093.67–2093.78	Dey Dey Mdst
8	Karlaya-1	2345.09–2345.22	Dey Dey Mdst
9	SMD 5001	417.59–417.78	Dey Dey Mdst
10	SMD 5001	418.15–418.25	Dey Dey Mdst

CHRO: BMRARO3 ver 1 on UIC 3 1 11-AUG-94 Elapse: 00:03:05.4 1
Samp: KD-2A 285.5m Start : 01:55:02 2686
Comm: DB-5 30m,10psi on-col,ICL=BMAROM,200uA 1100V,S=150 M=60
Mode: EI +03MS LMR UP LR
Oper: MICHAELSEN Inlet :
Peak: 1000.00 mmu Label wndw: 1908 > 2493 Masses: 205 > 253
Area: 0, 4.00 Baseline : 0, 3 Label : 0, 40.00

FIGURE 1



0611

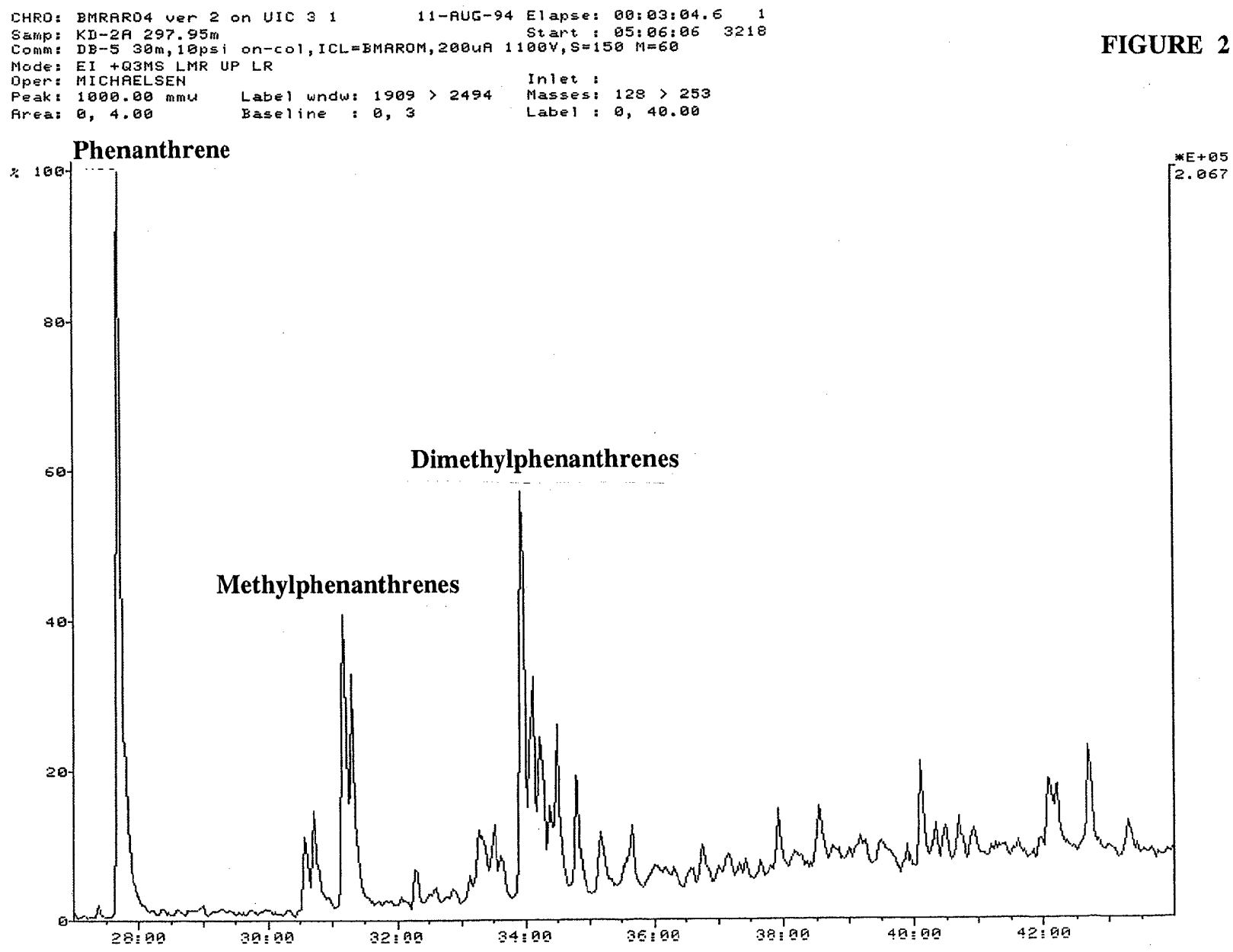
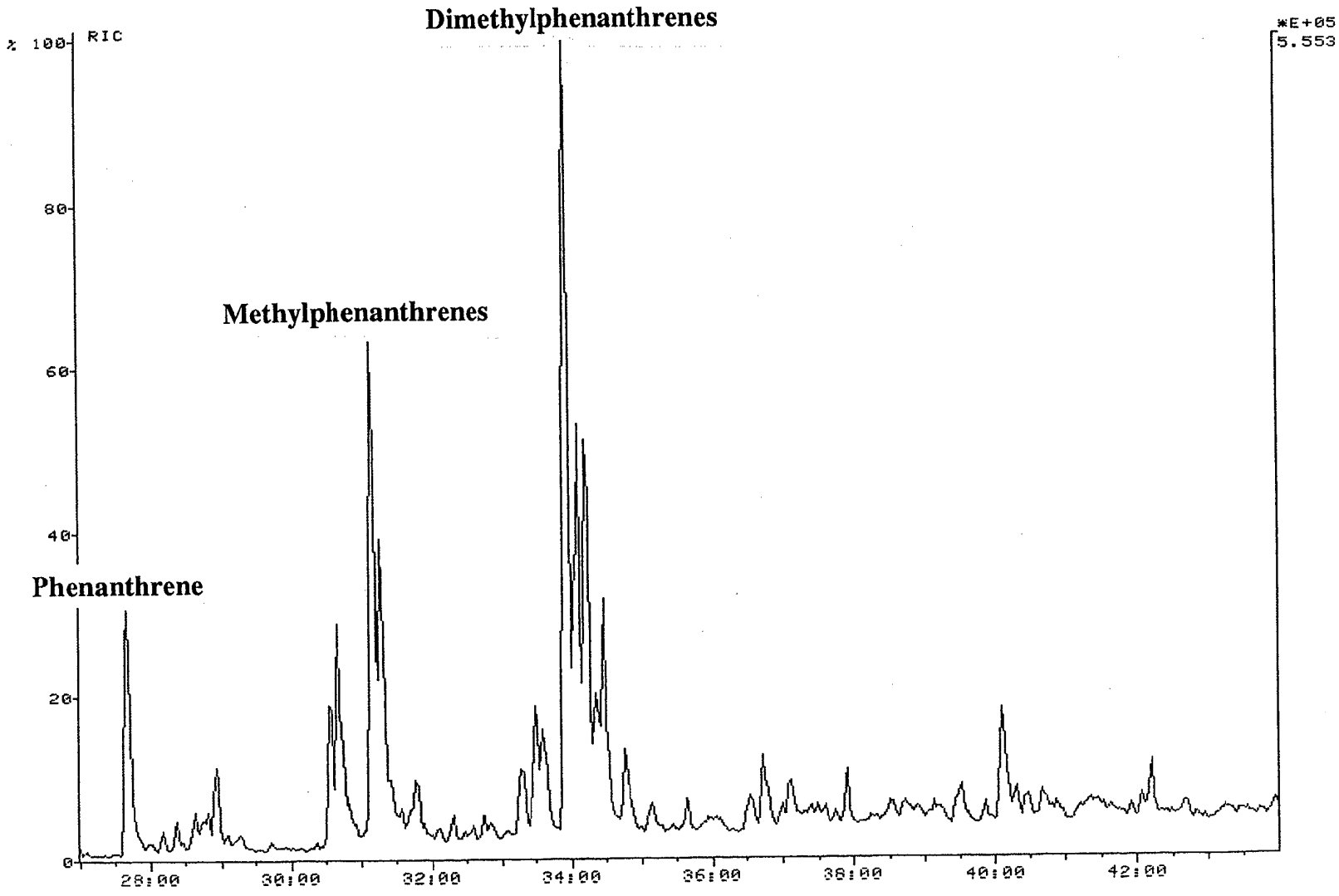

CHRO: BMRAR04 ver 2 on UIC 3 1 11-AUG-94 Elapse: 00:03:04.6 1
Samp: KD-2A 297.95m Start : 05:06:06 3218
Comm: DB-5 30m,10psi on-col,ICL=BMAROM,200uA 1100V,S=150 M=60
Mode: EI +Q3MS LMR UP LR
Oper: MICHAELSEN Inlet :
Peak: 1000.00 mmu Label wndw: 1909 > 2494 Masses: 128 > 253
Area: 0, 4.00 Baseline : 0, 3 Label : 0, 40.00
Phenanthrene
Dimethylphenanthrenes
Methylphenanthrenes
%
100
80
60
40
20
0
*E+05
2.067
28:00
30:00
32:00
34:00
36:00
38:00
40:00
42:00

FIGURE 2

FIGURE 3



0613

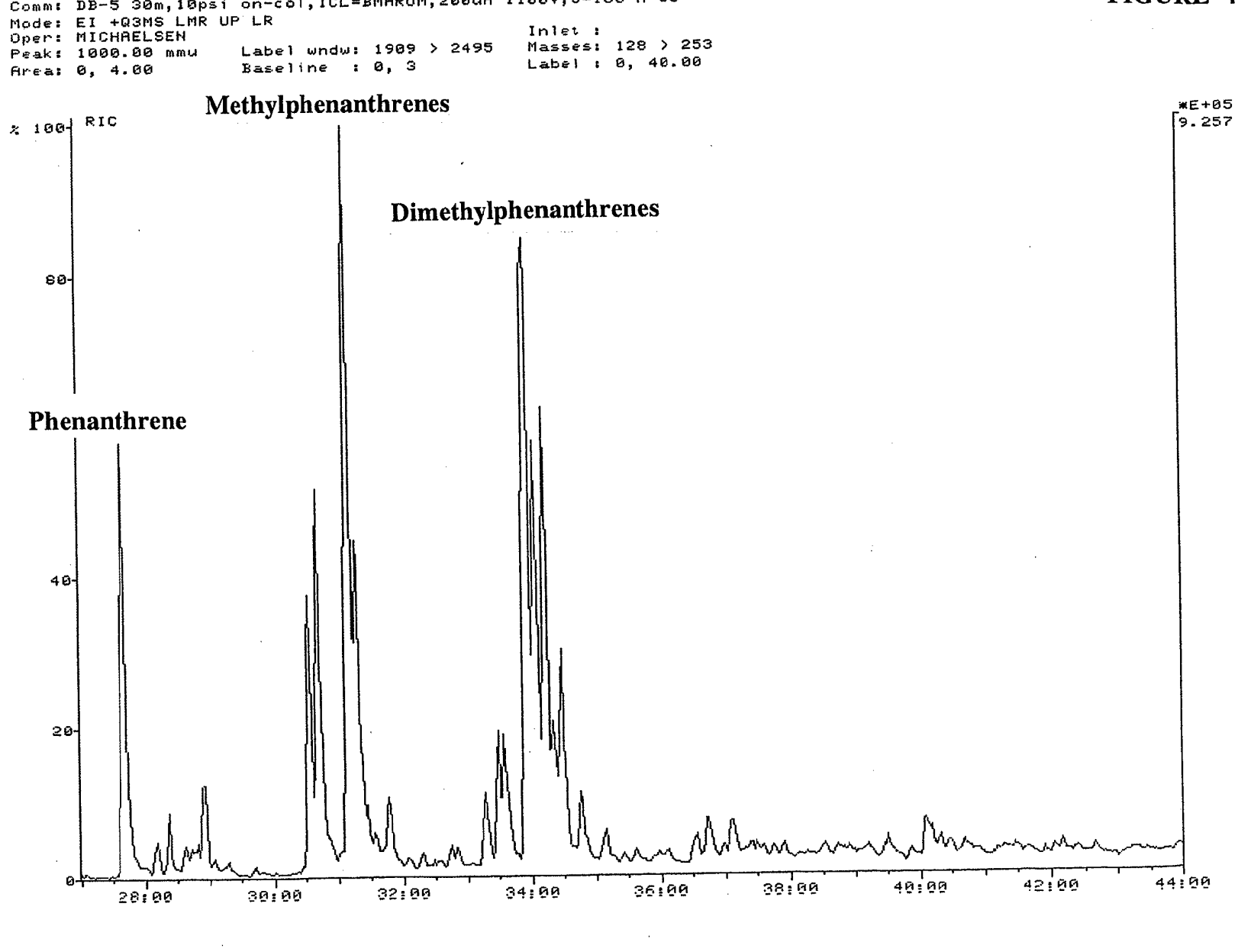
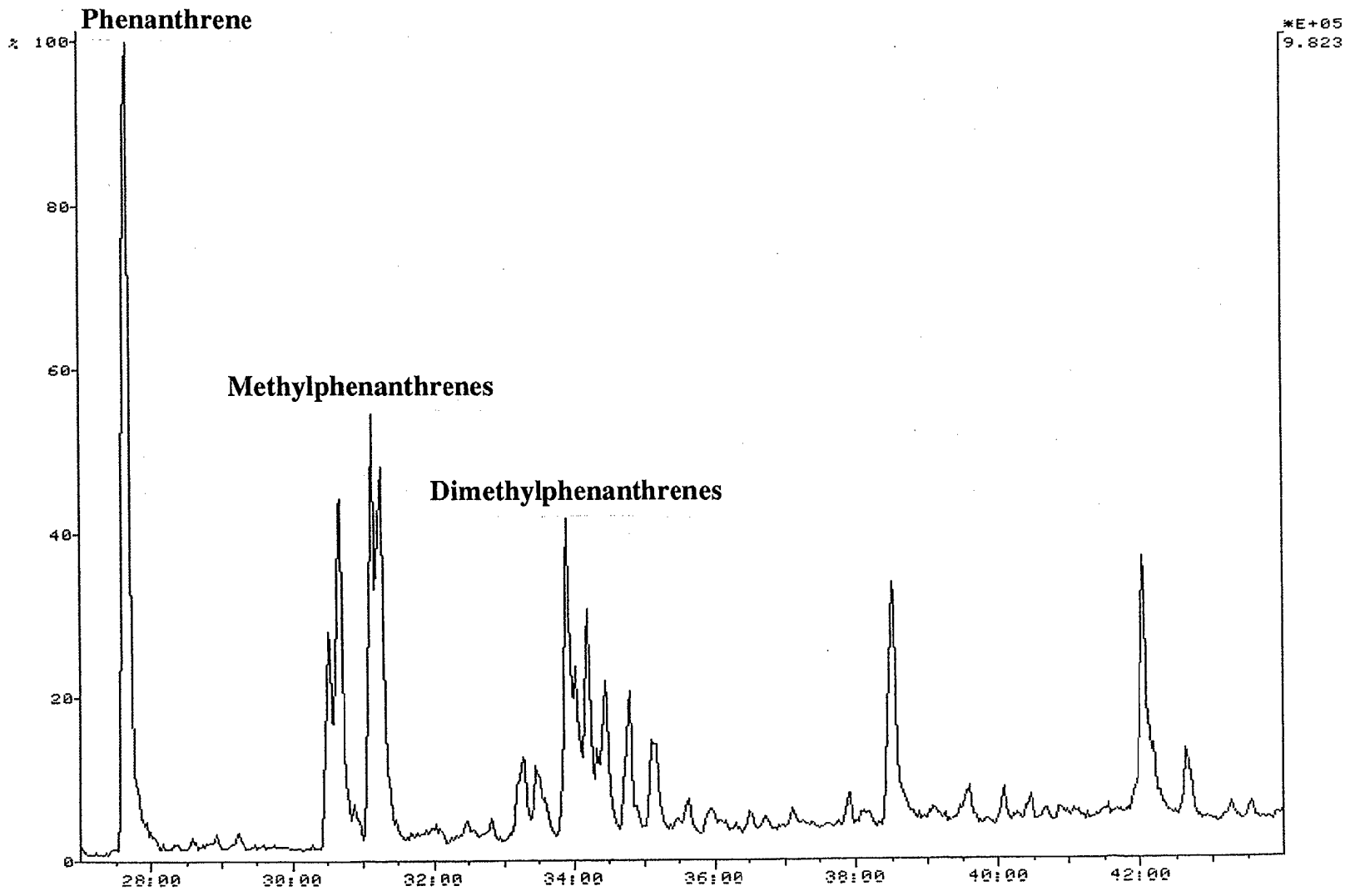

CHRO: BMRARO10 ver 1 on UIC 3 1 10-AUG-94 Elapse: 00:03:04.1 1
Samp: MARLA-9 269.87-269.97m Start : 11:39:25 3219
Comm: DB-5 30m,10psi on-col,ICL=BMAROM,200uA 1100V,S=150 M=60
Mode: EI +Q3MS LMR UP LR
Oper: MICHAELSEN Inlet :
Peak: 1000.00 mmu Label wndw: 1909 > 2495 Masses: 128 > 253
Area: 0, 4.00 Baseline : 0, 3 Label : 0, 40.00
Methylphenanthrenes
Dimethylphenanthrenes
Phenanthrene
% 100
RIC
80
40
20
0
*E+05
9.257
28:00
30:00
32:00
34:00
36:00
38:00
40:00
42:00
44:00

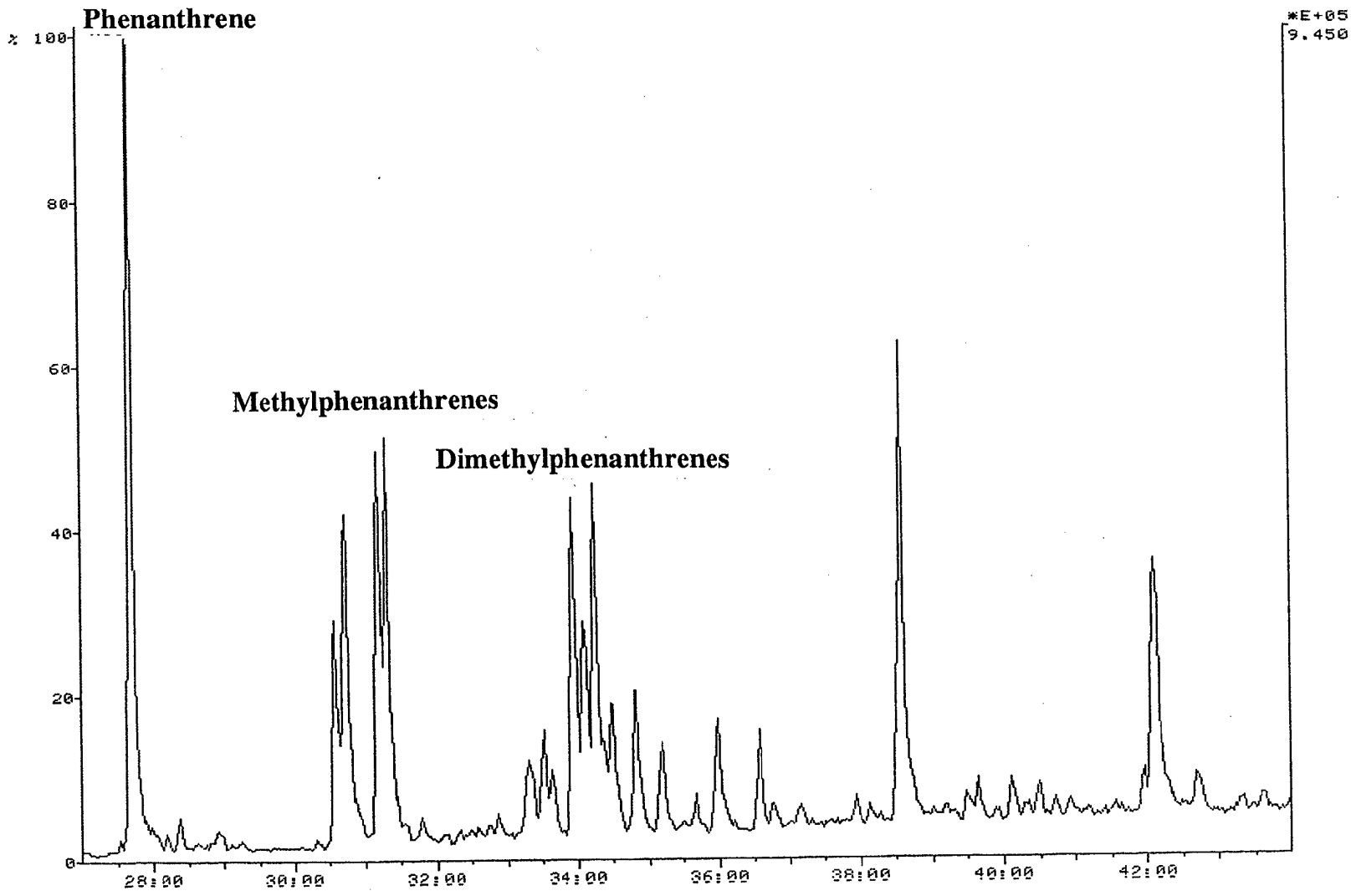
FIGURE 4

FIGURE 5



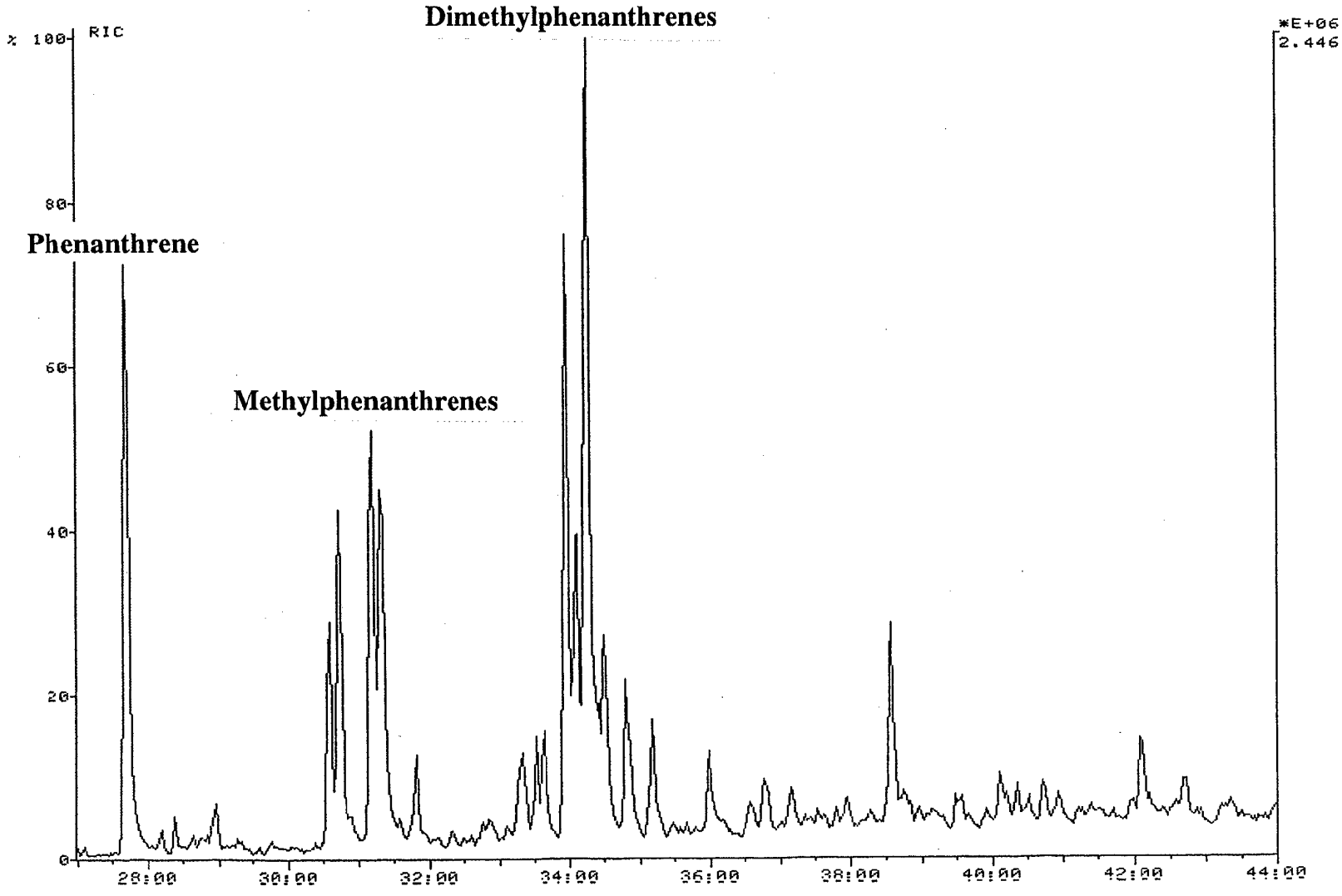
0615

FIGURE 6


CHRO: BMRARO13 ver 1 on UIC 3 1 10-AUG-94 Elapse: 00:03:04.6 1
Samp: MURNARDO-1 190.91-191.00m Start : 05:19:41 3218
Comm: DB-5 30m,10psi on-col,ICL=BMAROM,200uA 1100V,S=150 M=60
Mode: EI +Q3MS LMR UP LR
Oper: MICHAELSEN Inlet :
Peak: 1000.00 mmu Label wndw: 1909 > 2494 Masses: 128 > 253
Area: 0, 4.00 Baseline : 0, 3 Label : 0, 40.00
Phenanthrene
Methylphenanthrenes
Dimethylphenanthrenes
% 100
80
60
40
20
0
*E+05
9.450
28:00
30:00
32:00
34:00
36:00
38:00
40:00
42:00

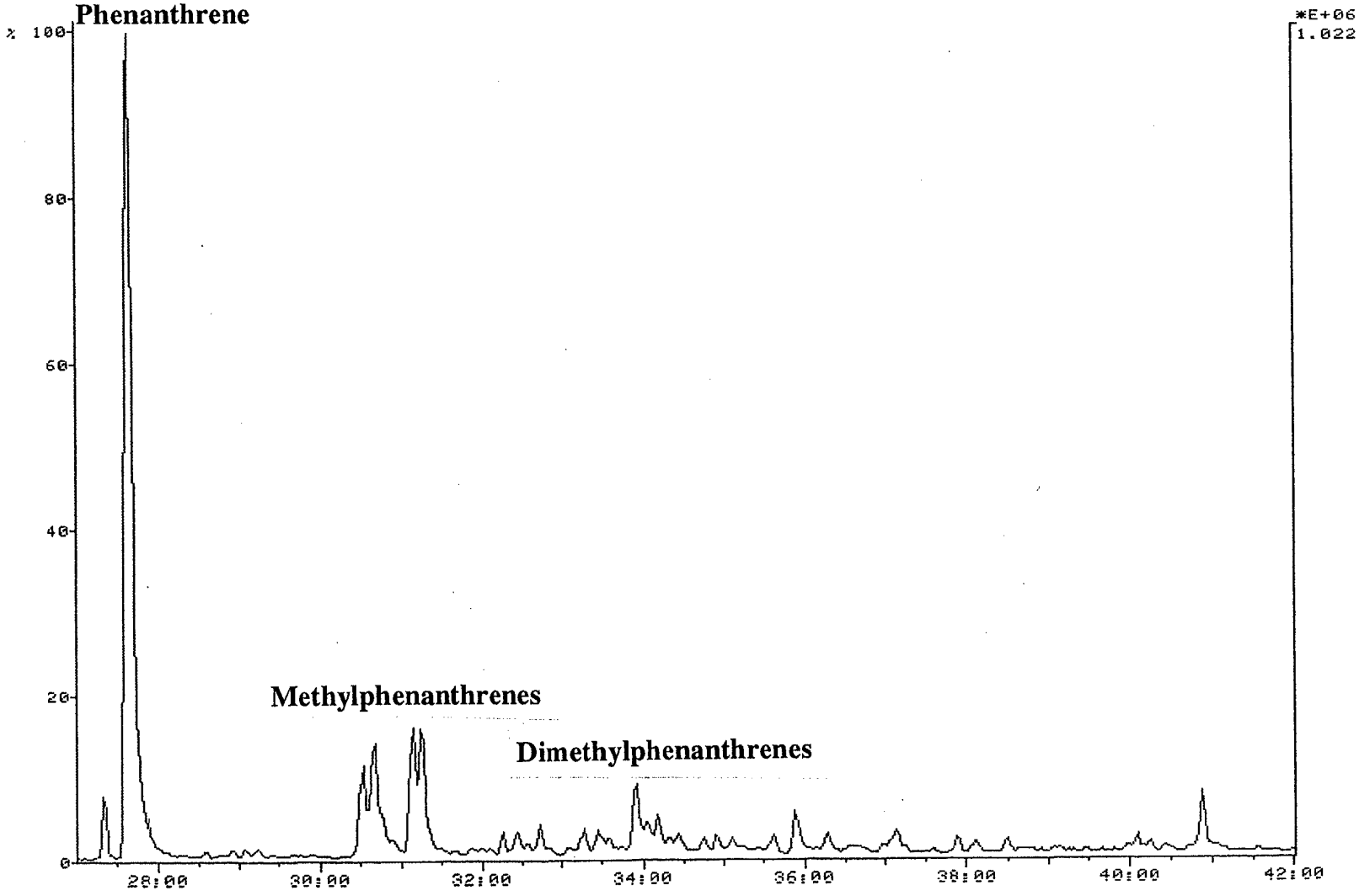
CHRO: BMRARO14 ver 1 on UIC 3 1 11-AUG-94 Elapse: 00:03:05.5 1
Samp: KARLAYA-1 2093.67-2093.78m Start : 00:18:11 3217
Comm: DB-5 30m,10psi on-col,ICL=BMAROM,200uA 1100V,S=150 M=60
Mode: EI +Q3MS LMR UP LR
Oper: MICHAELSEN Inlet :
Peak: 1000.00 mmu Label wndw: 1907 > 2493 Masses: 128 > 253
Area: 0, 4.00 Baseline : 0, 3 Label : 0, 40.00

FIGURE 7



CHRO: BMRARO19 ver 1 on UIC 3 1 9-AUG-94 Elapse: 00:03:05.3 1
Samp: KARLAYA-1 2345.09-2345.22M Start : 19:59:10 3218
Comm: DB-5 30M, 10 PSI ON-COL, ICL=BMAROM, 200MA 1100V,S=150 M=60
Mode: EI +Q3MS LMR UP LR
Oper: MICHAELSEN Inlet :
Peak: 1000.00 mmu Label wndw: 1909 > 2426 Masses: 128 > 253
Area: 0, 4.00 Baseline : 0, 3 Label : 0, 40.00

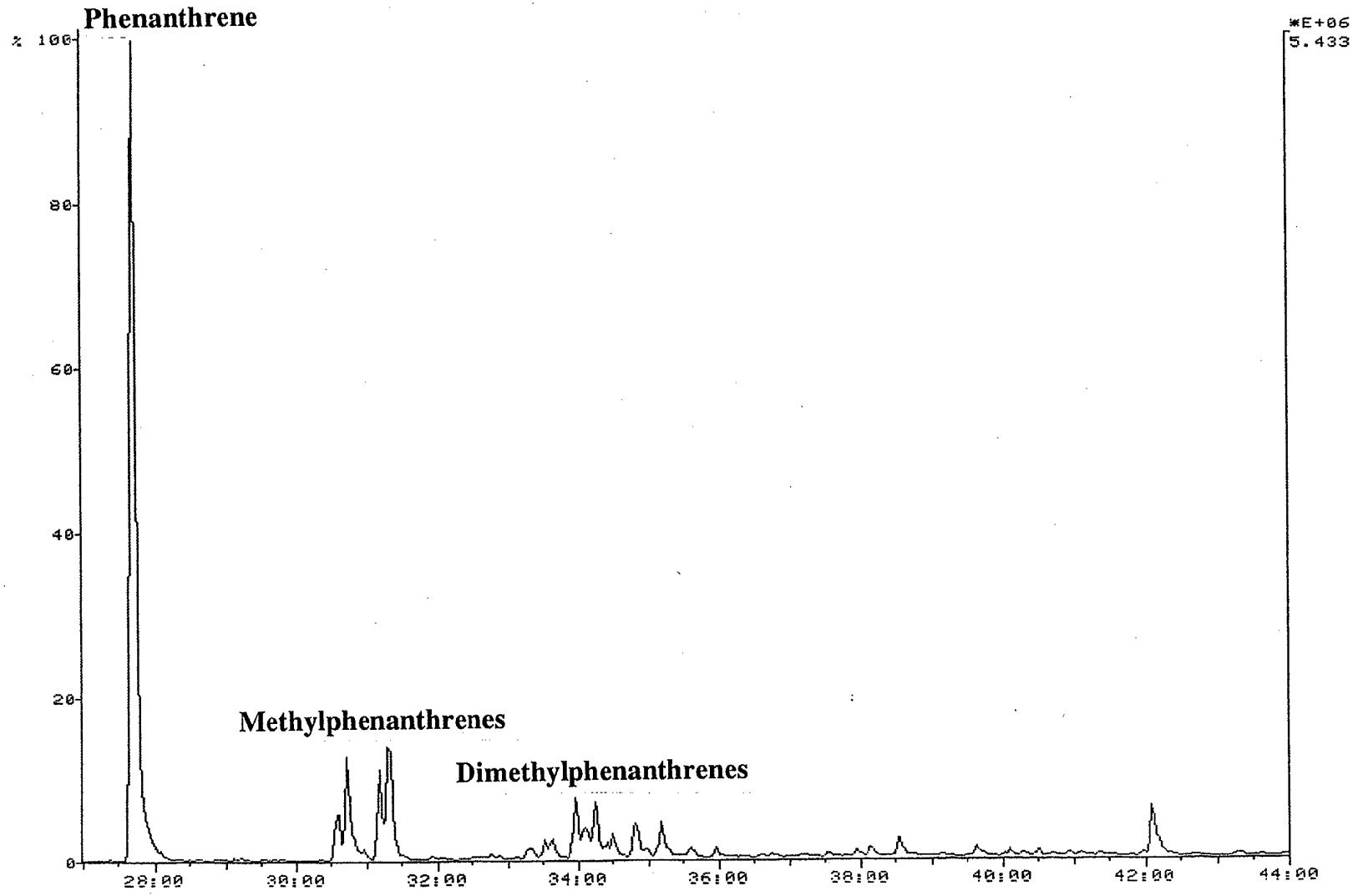
FIGURE 8



0618

CHRO: BMRARO9 ver 1 on UIC 3 1 10-AUG-94 Elapse: 00:03:05.4 1
Samp: LAKE MAURICE WEST-1 416.15-418.25m Start : 06:51:54 3217
Comm: DB-5 30m,10psi on-col,ICL=BMAROM,200uA 1100V,S=150 M=60
Mode: EI +Q3MS LMR UP LR
Oper: MICHAELSEN Inlet :
Peak: 1000.00 mmu Label wndw: 1907 > 2493 Masses: 128 > 253
Area: 0, 4.00 Baseline : 0, 3 Label : 0, 40.00

FIGURE 9



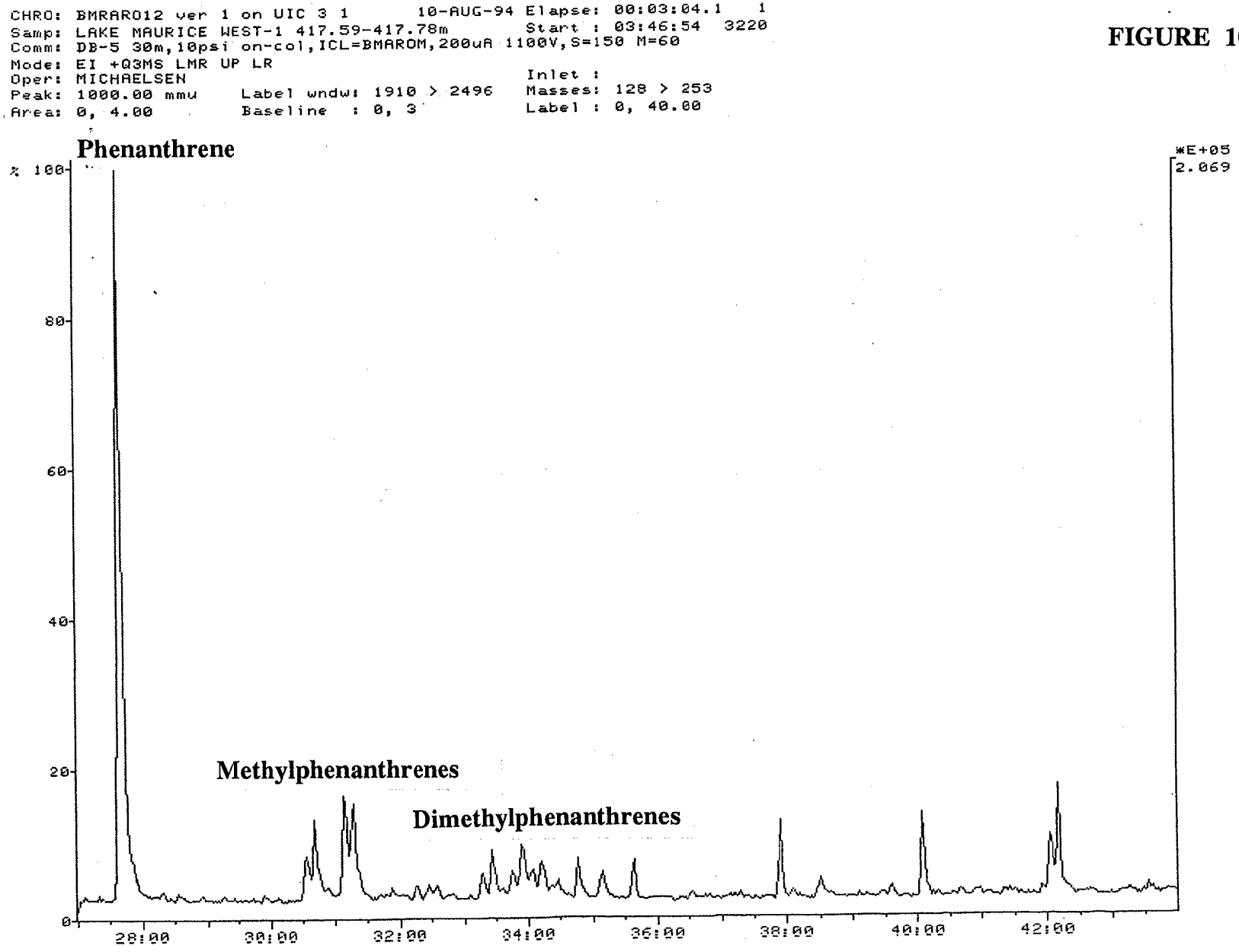


FIGURE 10

0620