

Application of Diamondoids as Maturity Indicators for Condensate from Drava Depression, Croatia

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Abstract

Diamondoid hydrocarbons were investigated in gas-condensates reservoirs from the Drava Depression, Croatian part of the Pannonian Basin, to define thermal maturity of condensates. The largest gas and gas-condensate fields in Croatia are Molve, Kalinovac, and Stari Gradac, located in the northwestern part of the Drava Depression. This area has extremely complex structural, lithological, and stratigraphic features that have resulted in the specific physical characteristics of the discovered hydrocarbon fluids. Bulk properties reveal that samples have high concentration of light aromatic hydrocarbon (BTEX) and low sulphur, and some of them are waxy; Stari Gradac and Severovci.

Origin and maturity parameters of condensate were investigated and correlated based on gas chromatography (GC) and gas chromatography coupled to mass spectrometry (GC-MS) techniques. The value of diamondoid based maturity parameters, like methyldiamantane index 40–50 % indicate high level of thermal maturity corresponding to vitrinite reflectance 1.1–1.6 %. Condensate samples were not biodegraded, as shown by high API density values and the absence of unresolved complex mixture (UCM).

Keywords

Diamondoid hydrocarbons, condensate, Drava Depression, maturation

1 Introduction

Thermal maturity is an important parameter in assessing petroleum evolution in sedimentary basins.¹ The type of hydrocarbons generated (oil or gas) depends on the type of organic matter (type of kerogen) present in the rock, and to some extent, its maturation history. During sediment deposition, organic matter is exposed to elevated temperatures and pressures. The change of kerogen to petroleum under this condition over a long period is also known as maturation. These changes mainly include temperature reactions of cracking or pyrolysis (thermal cracking) of large molecules, and the formation of smaller molecules with lower energy content and increased stability. Determination of thermal maturity level of the organic matter source rocks and hydrocarbons in the reservoir is very important in source rock-oil correlation studies, and in solving the very complex problem of hydrocarbon migration from the source rocks to the reservoir rocks.

Diamondoids show extreme thermal stability during exposure to high temperatures, therefore these compounds are used in the determination of thermal maturity of high maturity crude oils and condensates. Diamondoid hydrocarbons have general molecular formula $C_{4n+6}H_{4n+12}$. The saturated hydrocarbons have three-dimensionally fused cyclohexane rings, which results in highly symmetrical diamond-like structure. The simplest compounds are adamantane ($C_{10}H_{16}$) and diamantane^{1,2} ($C_{14}H_{20}$) (Fig. 1).

These compounds are more stable than any other hydrocarbons, and once formed, are also resistant to biodegradation processes.^{2–4} Most “normal” oil samples have a

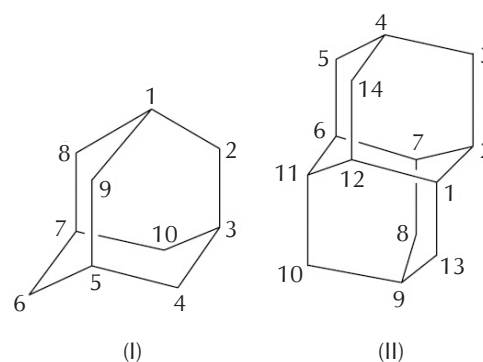


Fig. 1 – Structure and numbering of adamantane (I), and diamantane (II) (adapted from Nasir and Fazeelat²)

Slika 1 – Struktura i označavanje adamantana (I) i diamantana (II) (prilagođeno iz Nasir i Fazeelat²)

high concentration of other biomarkers (hopanes and steranes), and a low concentration of diamondoids. Conversely, highly mature samples of oil and condensate generally contain a high concentration of diamondoids, and very low concentration of other biomarkers^{5,6} or in some cases are completely absent. During cracking to which hydrocarbons are exposed at high temperatures and pressures,^{7–11} diamondoids remain concentrated in condensate samples due to their extreme thermal stability compared to other groups of hydrocarbons.^{12,13}

Different geochemical methods, such as vitrinite reflectance, pyrolysis, and biomarker maturity ratios from bitumen/oil can be used to indicate the level of thermal maturity and type of organic matter. Vitrinite reflectance (R_o) is the most commonly used thermal indicator, and meas-

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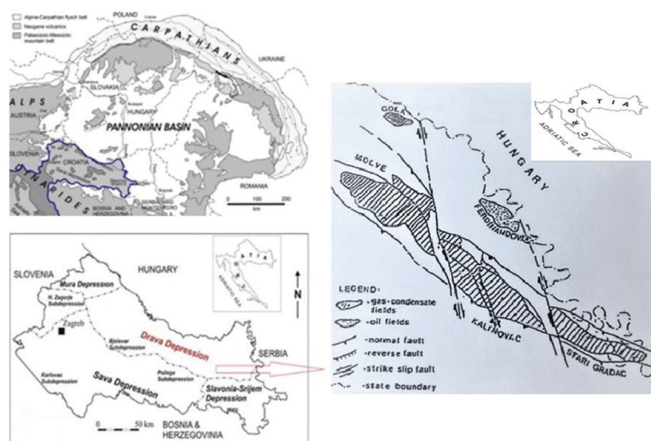


Fig. 2 – Map showing location of gas-condensate producing fields within the Drava Depression, Croatian part of the Pannonian Basin (adapted from Barić *et al.*¹⁶)

Slika 2 – Karta prikazuje lokaciju plinsko-kondenzatnih proizvodnih polja unutar Dravske depresije, hrvatski dio Panonskog bazena (prilagođeno iz Barić *i sur.*¹⁶)

ure of the percentage of incident light reflected from the surface of vitrinite particles by the method of optical microscopy. Vitrinite is a coaly organic maceral derived from the connective tissue of vascular plants. The reflectance of vitrinite increases with heat, with the increase in the degree of maturity of the organic matter. Most maturity parameters derived from bitumen/oil biomarkers are used in mathematical equations to calculate vitrinite reflectance (R_c ; calculated vitrinite reflectance) of kerogen at the time of bitumen/oil generation.

The use of diamondoids as an indicator of the thermal maturity of hydrocarbons is based on different thermal stability of the methyl isomer of diamondoids. For example, 1-methyl-adamantane (1-MA) is more stable than 2-methyl-adamantane (2-MA), 4-methyldiamantane (4-MD) is more stable than 1-methyldiamantane (1-MD) and 3-methyl-diamantane (3-MD). Hence, the ratios 1-MA/ (1-MA + 2-MA) and 4-MD/ (1-MD + 3-MD + 4-MD) should increase with increasing thermal maturity.²

In this study, diamondoids were used along with bulk properties, *n*-alkanes, isoprenoid parameters, and biomarkers in the aromatic fraction (methylphenantren index) to calculate vitrinite reflectance and estimate thermal maturity of condensates from Drava Depression, Croatia, which is difficult to find otherwise because of extremely low concentration of biomarkers in saturate fractions of these samples.

2 Geological settings

The Pannonian Basin is the largest extensional basin in a back-arc tectonic setting that formed during the Miocene in Central Europe. It is bordered by the Alps to the west and Carpathian Mountains to the east and north^{14–17} (Fig. 2).

The Croatian part of the Pannonian Basin covers an area of approximately 26,000 km², and is divided into the Dra-

va, Sava, Mura, and Slavonija-Srijem depressions (Fig. 2). Each of these basins also has its own local characteristics, similarities, and differences in evolution, sedimentary environment, transport mechanisms and tectonics, and the boundaries between the depressions are mountains.^{18,19} The gas and gas condensate fields of Molve, Kalinovac, and Stari Gradac are located in the northwestern part of the Drava Depression (Fig. 2).

The development of the basin includes the periods of the Neogene and Quaternary, and the deposition, thickness, and deformations of rock structures are indicators of tectonic activity. All rocks are classified according lithostratigraphic nomenclature (Croatian lithostratigraphic nomenclature) for the western part of the Drava Depression¹⁹ (Fig. 3). Described rocks are divided in two groups; the first group comprises younger Neogene-Quaternary (Tertiary) sediments, while the second group consists of Paleozoic-Mesozoic basement. Tertiary sediments are clastic rocks, while basement rocks are represented by carbonates, magmatic and metamorphic rocks.

There are several lithostratigraphic formations defined within the Neogene and Quaternary sediments. The oldest one, Moslavačka gora Formation (Fig. 3) is divided into two lithostratigraphic members (Mosti member is approximately of Lower/Middle Miocene age, and younger Križevci

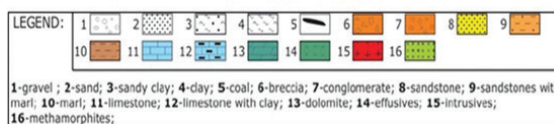
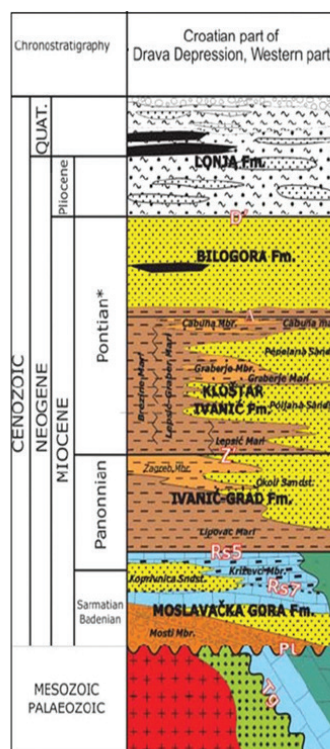


Fig. 3 – Lithostratigraphic column of western part of Drava Depression (modified from Malvić and Cvetković¹⁹)

Slika 3 – Litografski stupac zapadnog dijela Dravske depresije (prilagođeno iz Malvić *i Cvetković*¹⁹)

member is approximately of Lower Pannonian age). The sediments of the Ivanić-Grad Formation Ivanić-Grad are often labelled as “Banatica” deposits, due to the characteristic fossil shell *Congerina banatica*. The environment is predominantly fresh water lakes. Sediments of Lower Pontian, Kloštar-Ivanić Formation, (Fig. 3), are labelled as “Abichi” deposits according to the characteristic fossil shell *Paradacna abichi*. Sediments of Upper Pontian – Bilogora Formation, (Fig. 3), are also called “Rhomboidea” deposits according to fossil shell *Congerina rhomboidea*.^{18–21} Depositional environments are divided in several fresh-water lacustric and fluvial areas. The sediments are represented by clayey marlstones, marlitic clay, and clay (depending on compaction), and lesser parts of sandstone or sand. Lonja Formation is mostly represented by clay, sandy clay, and sand. In the deepest part deposited are silt, marly clay or sandy marlstone, with lignite intercalations.^{15–17}

The producing horizons lie at depths exceeding 3000 m and are characterised by specific pressure and temperature anomalies. The reservoir rocks are naturally fractured and the system of fractures controls the production rate and hydrocarbon migration trend. The reservoir is characterised by a very high initial pressure, up to 500 bar and reservoir temperature range between 180 and 198 °C. Measurement of temperatures in the same well exceed 230 °C at depth of 4000–4300 m.^{14–17}

3 Experimental

3.1 Samples

Condensate samples were collected in glass bottles from the producing fields northwestern part of the Drava Depression, and stored in the refrigerator at 4 °C. Before analysis, the samples were stabilised at room temperature. The locations of producing fields are shown in Fig. 2.

3.2 Bulk properties

API gravity was determined using ASTM D5002 method on an Anton Paar DMA 4500 digital density analyser. This test method covers the determination of density, relative density, and API gravity of samples that may be handled in a normal fashion as liquids at test temperatures between 15 and 35 °C.

Pour point was determined using ASTM D97 method on manual tester INKO LAB. After preliminary heating the sample was cooled at a specified rate, and examined at intervals of 3 °C for flow characteristics. The lowest temperature at which movement of the specimen is observed is recorded as the pour point.

Paraffin wax content was measured using UOP 46 test method. Sample was dissolved in petroleum ether and clarified using fuller’s earth. Petroleum ether was evaporated and the clarified oil redissolved in an acetone-petroleum ether mixture. This solution was then chilled to –18 °C and filtered through a cold filter funnel, the wax being collected on mat in the funnel. The wax was then washed from the mat into a weighed flask, using hot pe-

troleum ether. Petroleum ether was evaporated, and the wax weighed.

Sulphur content was measured on instrument Leco SC-144DR. Sample was weighed into a combustion boat and placed in pure oxygen environment at 1350 °C. After complete combustion process, concentration of SO₂ from sulphur was measured using infrared detection cell. The instrument converts this value to percentage value using sample weight and appropriate calibration curve.

3.3 Capillary gas chromatography (GC)

GC analysis of condensate was performed on an Agilent 7890A gas chromatograph fitted with 50 m × 0.25 mm i.d. DB-petro column with film thickness of 0.5 µm, and using helium as carrier gas. A constant flow mode and flame ionisation detector were employed. The gas chromatography oven temperature was held initially at 35 °C for 10 min, then ramped to 40 °C at 1 °C min⁻¹, increased to 320 °C at 8 °C min⁻¹, and maintained at this temperature for 60 min.

3.4 Gas chromatography-mass spectrometry (GC-MS)

Gas chromatography-mass spectrometry (GC-MS) of the saturated and aromatics fractions from condensate was carried out using quadrupole mass spectrometer Agilent MS 5975C interfaced with an Agilent 7890A gas chromatograph. GC 7890 A was fitted with 30 m × 0.25 mm i.d. HP-5MS column with a film thickness of 0.25 µm, and using helium as carrier gas. The GC oven temperature was ramped from 60 °C to 145 °C at 15 °C min⁻¹, increased to 315 °C at 2 °C min⁻¹, and maintained at this temperature for 15 min. The mass spectrometer was operated in electron impact (EI) mode at 70 eV. Saturated and aromatics fractions were dissolved in isooctane and analysed in full-scan mode (50–560 scan range). Diamondoids were examined from saturate fraction using m/z 187 (methyldiamantane). Identification of phenantrene and methylphenantrene from aromatic fraction was based on multiple ion fragmentogram m/z 178 and 192, respectively.

3 Results and discussion

4.1 Bulk properties

The condensate well depths and group parameters of investigated condensate are shown in Table 1. Crude oils are classified into heavy, medium, and light, based on API gravity. Heavy crude oils have API gravity ≤ 20°; medium 20–40°, and light crude oils 40–45°, while condensate have API gravity >45°. The samples analysed in this study have API value between 48–57° (Table 1) and are classified as condensates. API gravity is also a bulk physical property of oils that can be used as an indicator of thermal maturity.^{9,10} The pour point (PP) is generally associated with paraffinicity or the content of solid paraffin. The term highly paraffinic oils and condensates mainly refers to the high concentration of C₂₀₊ n-alkane in the sample. Also, crude oil derivatives from terrigenous organic matter (OM) general-

Table 1 – Basic properties of the condensate samples
 Tablica 1 – Osnovna svojstva uzoraka kondenzata

Properties	Sample name				
	Sev-1	Mol-31R	Mol-25	Kal-15	Stg-6
°API	48.51	49.77	52.05	56.73	52.84
% paraffin wax	4.0	0.5	0.05	0.03	3.5
PP/°C	+15	-6	-24	<-36	+6
%S	0.17	0.21	0.21	0.25	0.14
Pr/C ₁₇	0.28	0.28	0.26	0.26	0.25
Ph/C ₁₈	0.20	0.20	0.20	0.21	0.19
Pr/Ph	1.45	1.60	1.70	1.91	1.48
CPI	1.02	1.01	1.21	1.20	1.02
LER	0.33	0.24	0.32	0.80	0.58
WAX	0.17	0.04	0.01	0.00	0.10
heptane value (H)	36.20	38.02	33.76	34.95	39.91
isoheptane value (I)	4.70	4.42	4.59	4.31	4.41
benzene/n-C ₆ (A)	1.73	1.52	1.42	0.54	0.41
toluene/n-C ₇ (B)	2.26	2.03	1.83	0.85	0.70
n-heptane/MCH (F)	1.62	1.47	1.49	1.53	1.69

CPI = $2C_{29}/C_{28}+C_{30}$; LER = $(C_4+C_5+C_6)/(C_{12}+C_{13}+C_{14})$; WAX = $(C_{27}+C_{28}+C_{29})/(C_{12}+C_{13}+C_{14})$; H = $100nC(\Sigma CH \text{ to } MCH)$; I = $(MH(2\text{- and } 3\text{-}))/DMCH(1t3\text{-}, 1t3\text{- and } 1t2\text{-})$; CPI – carbon preference index; LER – light end ratio; WAX – wax index; H – heptane value; CH – hydrocarbons; MCH – methyl-cyclohexane; I – isoheptane value; MH – methyl-heptane; DMCH – dimethyl-cycloheptane; c – cis; t – trans

ly have high paraffinic content and high PP. The data listed in Table 1 show that samples Severovci-1 (Sev-1) and Stari Gradac-6 (Stg-6) have high value of PP of up to +15 °C and +6 °C, respectively. These sample also have high concentration of paraffin wax and are waxy in nature, while the samples with low concentration of paraffin wax show very low PP and are nonwaxy in nature: Molve-31R (Mol-31R), Molve-25 (Mol-25), and Kalinovac-15 (Kal-15) (Table 1).

Sulphur compounds are undesirable in crude oil because of the costs of sulphur removal and environmental problems associated with sulphur compounds. The crude oils are classified as sour or sweet, based on sulphur content > 1 % and < 1 %.² The sulphur content of analysed samples was low (< 0.25 %), thus, these samples are sweet and commercially valuable.

4.2 n-Alkanes and isoprenoids distributions

The distribution of n-alkane provides useful information on the source of organic matter, thermal maturity, and biodegradation.^{22,23} For all investigated condensate samples, the distribution patterns of n-alkane was very similar; these samples mainly have bimodal n-alkane distribution.

Distribution of n-alkanes obtained by gas chromatography as well as Total Ion Chromatogram (TIC), obtained by

GC-MS chromatography show the bimodal distribution of n-alkanes, with a maximum at n-C₁₆ and n-C₃₀. Fragmentograms of n-alkanes m/z 71 are shown in Fig. 5. The maximum in the distribution pattern of n-alkanes in high molecular weight reflects that the source generating these samples had high contribution of terrestrial organic matter.

Carbon preference index (CPI) is a maturation parameter, and it shows the ratio of odd and even long-chain n-alkanes. Immature organic matter is characterised by the dominance of odd n-alkanes, and as the degree of maturity increases, the dominance of odd n-alkanes decreases, and the CPI is close to 1. The analysed samples showed no odd predominance of n-alkane, CPI is close to 1. This feature is attributed to high thermal maturity of these samples. The absence of unresolved complex mixture (UCM) in distribution pattern of n-alkane, indicates that samples had not undergone biodegradation.

Pristane to phytane (Pr/Ph) ratio in crude oil and source rocks reflect redox potential in the depositional environment and nature of organic matter. The Pr/Ph ratio (from 1.45-1.91; Table 1) indicates the oxic conditions in the depositional environment, as well as significant terrigenous influence. The ratio of isoprenoids to the corresponding n-alkanes (Pr/nC₁₇ and Ph/nC₁₈ ratio; Table 1) is primarily a maturity parameter and is expected to be low in all condensate samples (0.20; Table 1). On the other hand, biodegradation processes cause an increase in this ratio due to the faster removal of n-alkanes compared to isoprenoids; however, these samples did not undergo biodegradation processes. The Pr/nC₁₇ versus Ph/nC₁₈ plot proposed by Peters et al., also provide useful information of kerogen type and depositional conditions of organic matter. The source of organic matter is mainly mixed type II-III kerogen deposited under suboxic/oxic conditions (Fig. 4). Such organic facies in most cases generates condensates at high temperatures and pressures.

The gasoline fraction of the condensates has a high concentration of light aromatics (benzene, toluene, and xylene). High content of light aromatics is particularly characteristic of condensates from Severovci-1 and Molve fields (Fig. 6).

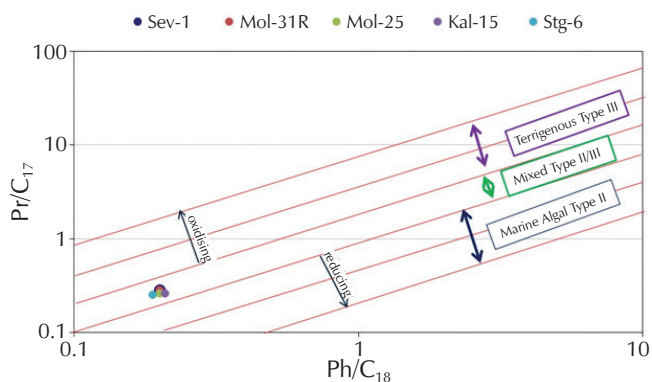


Fig. 4 – Pr/nC₁₇ vs Ph/nC₁₈ plot (Peters et al.⁸) in condensates from Drava Depression, Croatia

Slika 4 – Odnos Pr/nC₁₇ prema Ph/nC₁₈ (Peters i sur.⁸) u kondenzatima Dravske depresije, Hrvatska

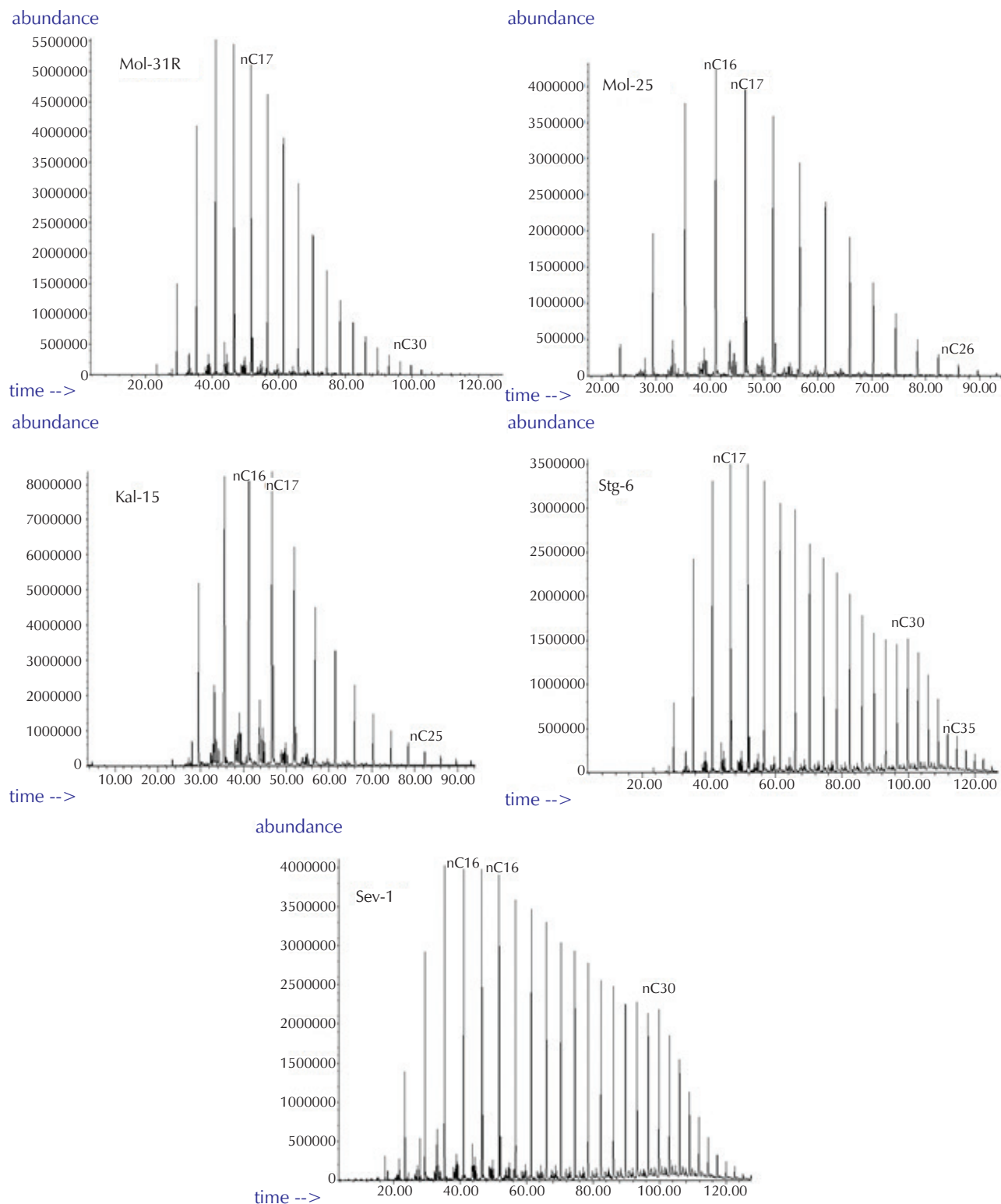


Fig. 5 – Chromatograms of *n*-alkanes (*m/z* 71) from GC-MS analyses showing distribution of *n*-alkanes in condensates from Drava Depression, Croatia

Slika 5 – Kromatogrami *n*-alkana (*m/z* 71) dobiveni GC-MS analizom prikazuju distribuciju *n*-alkana u kondenzatima Dravske depresije, Hrvatska

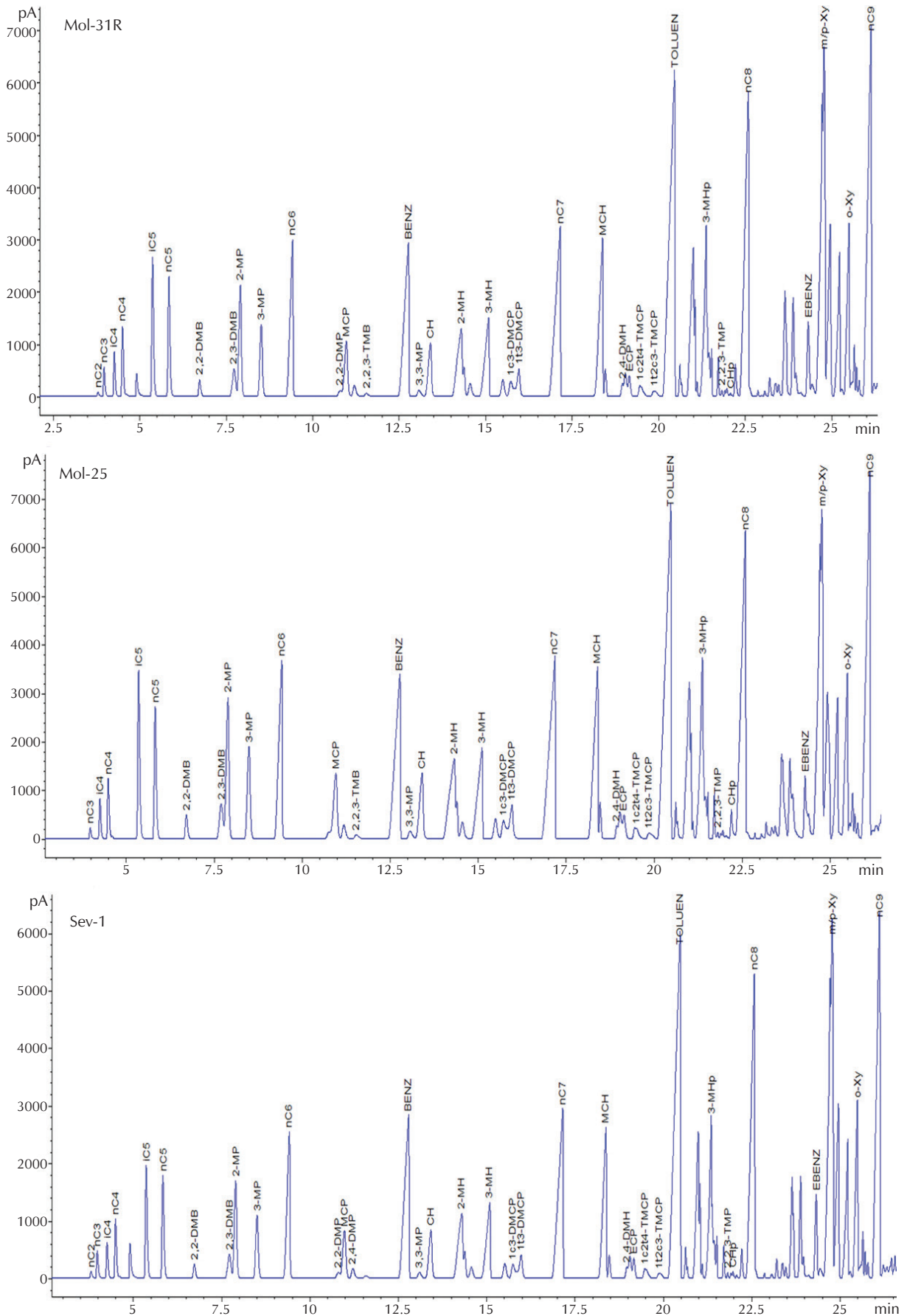


Fig. 6 – Gas chromatogram of the gasoline fraction condensates from Drava Depression, Croatia; BENZ-benzene; TOLUEN-toluene
 Slika 6 – Plinski kromatogram gazolinske frakcije kondenzata Dravske depresije, Hrvatska; BENZ-benzen; TOLUEN-toluen

4.3 Maturity assessment from methylphenanthrene index

Biomarkers in the aromatic fraction are preferably used as parameters for calculating the maturity assessment of hydrocarbons, and the source rocks that generated these hydrocarbons. To calculate the maturation parameters, phenanthrene and methylphenanthrene were used as the most abundant compounds in the triaromatic hydrocarbon fraction.²⁴

Maturity parameters derived from phenanthrene and methylphenanthrene biomarkers are used for calculating the vitrinite reflectance (R_c) of kerogen at the time of condensate generation. The vitrinite reflectance increases with the increase in the degree of maturity of the organic matter. The degrees of thermal maturity are: (1) immature in the stage of diagenesis ($< 0.5\text{--}0.7\%$ R_o); (2) mature in the early stage of catagenesis, *i.e.*, in the main zone of oil generation (oil window) ($> 0.5\text{--}0.7$ to $< 1.3\%$ R_o); (3) overmature in the late phase of catagenesis, *i.e.*, the main zone of condensate and wet gas generation (from 1.3 to 2.2% R_o), and (4) overmature in the phase of metagenesis ($> 2.2\%$ R_o) followed by metamorphism of organic matter.

In order to interpret the obtained results, it is important to list the processes that take place during thermal maturity of hydrocarbons. Parameters based on isomerisation ($\alpha \rightarrow \beta$) and methylation-demethylation reactions of methylated phenanthrenes are used to assess the degree of maturation of bitumen in source rocks and oil. In the early and main phase of the oil generation zone, alkylation (methylation) reactions of the aromatic ring predominantly take place while demethylation processes begin at higher stages of maturity ($R_o \geq 1.3\%$). The oldest defined phenanthrene maturation parameter is the methylphenanthrene index 1, $MPI-1 = 1.5 \times (2+3-MP)/(1+9-MP+P)$ (Table 2). It is based on the isomerisation of α to β methylphenanthrene and on the possible formation of 2- and 3-MP by direct methylation of phenanthrene. However, the phenanthrene has high thermal stability, and when the α isomers begin to degrade at higher stages of maturity, only the phenanthrenes will remain. Consequently, the MPI-1 will decrease again at a late stage of the oil window. The MPI-1 can be converted into vitrinite reflectivity and have a positive linear relationship between 0.65% to 1.35% R_o and a negative linear relationship from 1.35 to 2.00% R_o .

However, the 3-methylphenanthrene and 2-methylphenanthrene are thermally more stable, and in all samples, the peaks were expected to be much higher than 1-methylphenanthrene and 9-methylphenanthrene.

All condensates were expected to show a high degree of maturity based on methylphenanthrene index (MPI-1, MPI-2 and MPI-3). MPI-1 was also used to calculate the corresponding vitrinite reflection, assuming high maturity $R_c > 1.3$ ($2.3\text{--}0.6 \times MPI-1$) (Table 2). All analysed condensates showed high maturity ($R_c > 1.5$) except condensate Stg-6 ($R_c = 0.7$). The obtained value is unrealistic, and could be result of the methylation and demethylation processes of phenanthrene that occurred in parallel at such a high degree of maturity.

Table 2 – Maturity parameters of investigated condensates based on phenanthrene and methylphenanthrene m/z 178+192 distribution

Tablica 2 – Parametri zrelosti ispitivanih kondenzata na temelju raspodjele fenantrena i metilfenantrena m/z 178+192

Investigated condensates	MPI-1	R_c	MPI-2	MPI-3
Sev-1	1.30	1.52	1.47	2.62
Mol-31R	1.10	1.64	1.24	3.57
Mol-25	1.04	1.68	1.17	3.20
Kal-15	1.50	1.40	1.73	4.52
Stg-6	2.61	0.73	3.05	4.74

$MPI-1 = 1.5 \times (3MP+2MP)/(P+9MP+1MP)$; $R_c = 2.3\text{--}0.6 \times MPI-1$; $MPI-2 = 3 \times 2MP/(P+1MP+9MP)$; $MPI-3 = (3MP+2MP)/(9MP+1MP)$; MPI – methylphenanthrene index; P – phenanthrene; MP – methylphenanthrene

4.4 Diamondoid hydrocarbons as indicators of thermal maturity

The use of diamondoids as an indicator of the thermal maturity of hydrocarbons is based on different thermal stability of the methyl isomer of diamondoids (4-methyldiamantane shows higher thermal stability compared to 1 and 3 methyl isomers of diamondoids).

Diamondoids were identified in the Severovci-1 (Fig. 7) and the Molve condensate samples (Mol-31R and Mol-25), which is additional evidence of the connection of the Severovci-1 condensate with the Molve field condensates. These condensates were probably generated at the same stage of thermal maturity from the same type of kerogen. Based on the calculated methyldiamantane index (MDI; Table 3), and calculation of vitrinite reflection, these samples are highly mature condensates (Table 3; $R_c = 1.3\text{--}1.6$). In the Kal-15 and Stg-6 samples, diamondoids were not found, or were present in too low concentrations to be identified by this analytical method.

Table 3 – Maturity parameters of investigated condensates based on methyldiamantane m/z 187 distribution

Tablica 3 – Parametri zrelosti ispitivanih kondenzata na temelju raspodjele metildiamantana m/z 187

Investigated condensates	MDI%	R_c
Sev-1	44	1.3–1.6
Mol-31R	50	1.3–1.6
Mol-25	42	1.3–1.6

$MDI(\%) = 4-MDI/(1-MD+3-MD+4-MD) \times 100$; MDI – methyldiamantane index; MD – methyldiamantane

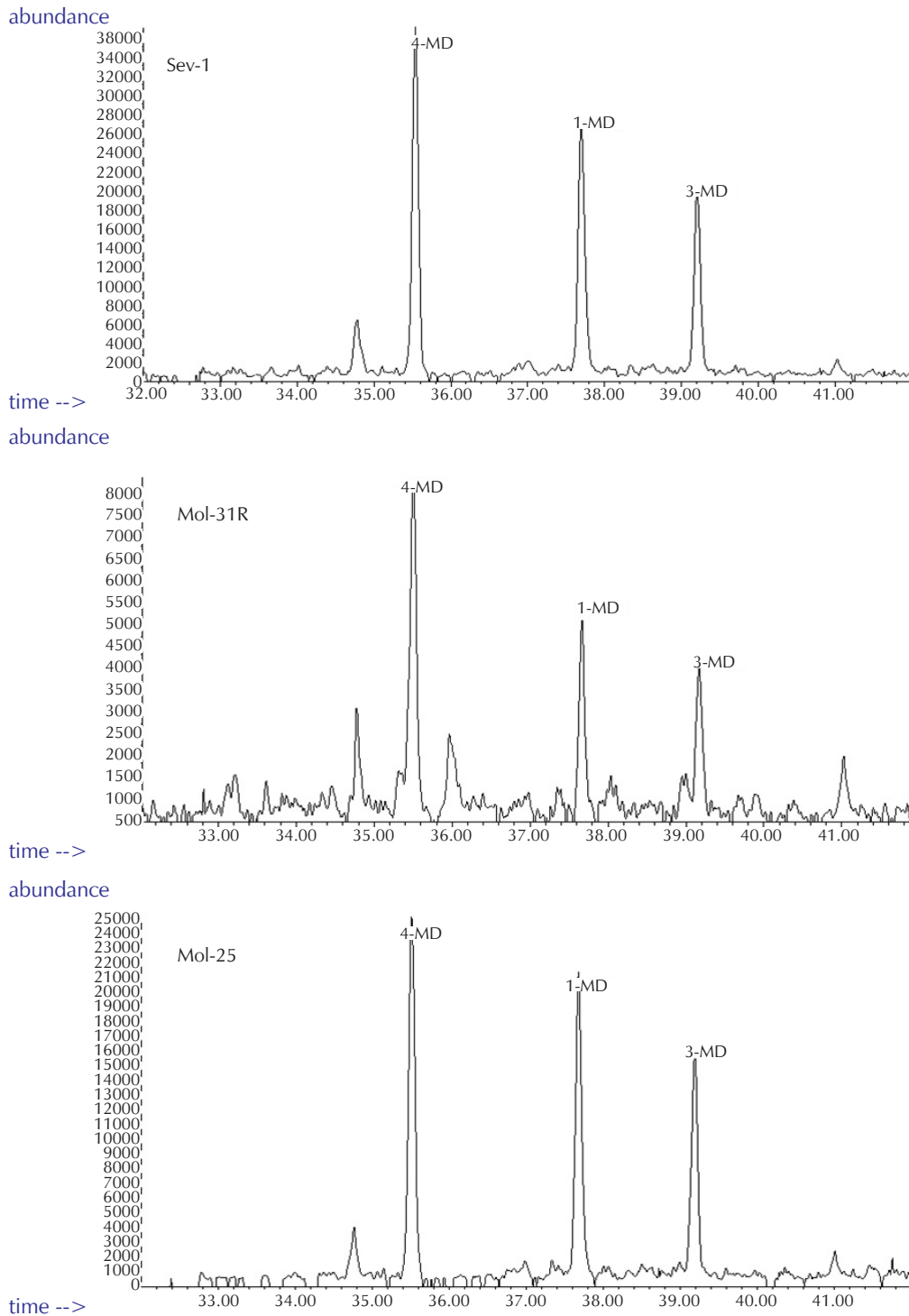


Fig. 7 – Chromatograms of methyl-diamantane (m/z 187) from GC-MS analyses showing distribution of methyl-diamantane in condensates from Drava Depression, Croatia

Slika 7 – Kromatogrami metildiamantana (m/z 187); GC-MS analiza prikazuje distribuciju metildiamantana u kondenzatima Dravske depresije, Hrvatska

4 Conclusions

Based on geochemical correlation of Severovci-1 and the nearest condensate fields (Molve-31R, Molve-25, Kalinovac-15, and Stari Gradac), it can be concluded that these condensates were generated at the same or similar maturity level of organic facies corresponding to mixed type

kerogen II/III with a pronounced dominance of terrestrial facies in suboxic/oxic conditions.

Based on the comparison of the gasoline fraction of condensates, the greatest similarity was shown by the condensate Severovci-1 with the analysed condensates from the Molve field (Molve-31R and Molve-25). The similarity

of the Severovci-1 condensate with the Molve field condensate is the presence of diamondoids in the Severovci-1 and Molve condensates. These compounds were not identified in the Kalinovac-15 and Stari Gradec-6 samples. Maturation parameters calculated from methyladamantane and methylphenanthrene index showed that the condensates from the Drava Depression reached a high level of thermal maturity corresponding to a vitrinite reflectance of 1.3–1.6 %.

Diamondoids are still relatively unexplored biomarkers for determination of thermal maturity of Pannonian Basin condensates. Therefore, more oil and condensate samples, and further geochemical petroleum investigations are needed to gain a better understanding of the application of diamondoids for determination of the thermal maturity of organic matter, which would lead to more confident conclusions.

List of abbreviations

Popis kratica

BTEX	– benzene, toluene, ethylbenzene and xylene – benzen, toluen, etilbenzen i ksilen
GC	– gas chromatography – plinska kromatografija
GC-MS	– gas chromatography-mass spectrometry – plinska kromatografija-masena spektometrija
UCM	– unresolved complex mixture – kromatografski nerazdvojeni spojevi
MA	– methyl-adamantane – metiladamentan
MD	– methyladamantane – metildiamantan
OM	– organic matter – organska tvar
PP	– pour point – točka tečenja
CPI	– carbon preference index – indeks preferencijalnih ugljikovih atoma
LER	– light end ratio – gubitak laganog kraja
WAX	– wax index – indeks krutih parafina
H	– heptane value – heptanski indeks
I	– isoheptane value – izoheptanski indeks
TIC	– total ion chromatogram – ukupni ionski kromatogram
MPI	– methylphenanthrene index – metilfenantren indeks
R_c	– vitrinite reflectance (calculated) – vitrinitna refleksija (izračunata)

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SAŽETAK

Primjena diamantoida kao pokazatelja zrelosti kondenzata Dravske depresije, Hrvatska

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Diamantoidni ugljikovodici ispitivani su u plinsko-kondenzatnim ležištima Dravske depresije, hrvatski dio Panonskog bazena, da bi se odredila termička zrelost kondenzata. Ta najveća plinska i plinsko-kondenzatna polja u Hrvatskoj – Molve, Kalinovac i Stari Gradac – smještena su u sjeverozapadnom dijelu Dravske depresije. Složene strukturne, litološke i stratigrafske značajke tog područja utjecale su na pojavu ugljikovodika posebnih fizikalnih karakteristika. Osnovna svojstva pokazuju visoku koncentraciju laganih aromatskih ugljikovodika (BTEX) i nisku koncentraciju sumpora, a neki od njih sadrže visok udio krutih parafina; Stari Gradac i Severovci.

Parametri porijekla i zrelosti kondenzata karakterizirani su i korelirani metodama plinske kromatografije (GC) i vezanim sustavom plinska kromatografija – masena spektrometrija (GC-MS). Parametar zrelosti na bazi dijamantoida, poput metildijamantanskog indeksa 40–50 % ukazuje na visoku razinu termičke zrelosti koja odgovara refleksiji vitrinita 1,1–1,6 %. Uzorci kondenzata nisu biodegradirani, što pokazuju visoke vrijednosti API gustoće i odsutnost kromatografski nerazdvojenih spojeva (engl. *unresolved complex mixture*, UCM).

Ključne riječi

Diamantoidi, kondenzati, Dravska depresija, zrelost

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