Origin and Alteration of Natural Gas and Liquid Hydrocarbons in the Austrian Molasse Basin*

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Abstract

The Molasse Basin, extending from Geneva to Vienna, is the northern foreland basin of the Alps and comprises Eocene to Miocene shallow to deep marine sediments. Within the Austrian sector, two petroleum systems can be distinguished: a thermal petroleum system comprising Lower Oligocene source and Cenomanian and Eocene reservoir rocks; a biogenic gas system in Oligocene and Miocene strata. However, geochemical data suggest a mixing of thermogenic and biogenic hydrocarbons in these horizons. The aim of the present study is to understand the origin, migration and alteration of natural gas and condensate in the Molasse Basin. To reach this goal several natural gas samples non-associated and associated with oil were analyzed for molecular and isotopic composition as follows: $^{12}$C/$^{13}$C in CH₄, C₂H₆, C₃H₈, C₄H₁₀ and CO₂; 1H/2H ratios in CH₄ have also been determined. Additionally twelve condensate samples were examined for biomarkers and specific compounds composition as well as carbon isotopic composition of individual n-alkanes and acyclic isoprenoids. Oil associated gas samples contain methane (68.2–91.6 vol.%) and higher hydrocarbons (up to hexane) with small amount of nitrogen and traces of carbon dioxide. Carbon isotopic composition in methane ranges from $-68.2\%$ PDB to $-39.6\%$ PDB showing that next to typical thermogenic gas ($\delta ^{13}$C > $-45\%$) isotopically light methane occurs, formed most probably due to biodegradation of pre-existing oils. In contrast, the primary biogenic gas from Oligo/Miocene deposits consists almost exclusively of methane (96.2–98.7 vol %) with carbon isotopic composition ranging between $-48.5\%$ PDB and $-65.3\%$ PDB. Isotopically heavy carbon in methane, occurrence of wet gas components (higher hydrocarbons) and locally even liquid hydrocarbons in immature formations indicate mixing with thermogenic hydrocarbons from deeper stratigraphic units. Coexistence of strongly altered condensates with primary bacterial dry gas in reservoir rocks with relatively low temperature (below 60°C) supports the concept of methane
generation due to biodegradation of higher hydrocarbons. The results of the on-going project point out that geochemical characteristics of gas fields in the Molasse Basin are a result of interplay of different processes, like thermogenic gas generation, primary (from solid organic matter) and secondary biogenic gas generation (from biodegradation of pre-existing oils), migration and mixing processes.

References Cited


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Content:

1. Geology
2. Experimental
3. Results
   3a. Oil/gas deposits
   3b. Gas deposits
   3c. Migration model
4. Conclusions
Study Area -
Austrian Molasse Basin
Stratigraphy

after Wagner, 1998
Hydrocarbon Systems

- Microbial gas
- Thermogenic hydrocarbons

Source Rock
- Oligocene/Miocene
- Oligocene

Reservoir Rock
- Puchkirchen / Hall Fm
- Cretaceous / Voitsdorf Fm

after Wagner, 1996
Schmidt & Erdogan, 1996

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Molecular composition:
Gas Chromatography-MS, FID, TCD, FPD

Stable C and H isotope composition:
Gas Chromatography-Isotope-Ratio
Mass Spectrometry
Oil and associated gas fields – Cr/Eocene

Oil field + assoc. gas

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**Results**

- **Microbial**
- **Biodegradation**
- **Thermogenic**

**Graphical Data**

- **Eocene**
- **Eocene+CE**
- **CE**

**References**

- Bernard et al., 1978, Fabel & Stahl, 1984

**Authors**


**Location**

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Gas fields – Oligocene/Miocene

Gas fields
Oil field + assoc. gas

Imbricated Molasse
Helvetic/Flysch

Calcareous Alps

10 km

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Mixing.

Bernard et al., 1978, Fabel & Stahl, 1984


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Oil-condensate correlation

Gas fields
Oil field + assoc. gas

Condensate in gas deposits

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Oil-condensate correlation - Biomarkers

Schwanenstadt-26 (Oil)

Puchkirchen-31 (Oil)

Atzbach-6 (Cond.)

Zapf-4 (Cond.)


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Oil-condensate correlation – Compound specific isotope analyses

Bechtel et al., 2013


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Oil-condensate correlation – Light HC fraction

Intensity

Time (min)

3: isobutane
4: isopentane
5: 2,2-dimethylbutane+2,3-dimethylbutane
6: 2-methylpentane
7: 3-methylpentane
8: 2,2-dimethylpentane
9: 2,4-dimethylpentane
10: 2,2,3-trimethylbutane
11: 2,2,3-trimethylpentane
12: 3,3-dimethylpentane
13: benzene
14: 2-methylhexane
15: 2,3-dimethylpentane
16: 1,1-dimethylcyclopentane
17: 1,1,3-trimethylcyclopentane+2,2-dimethylhexane
18: ethylcyclopentane
19: 2,5-dimethylhexane
20: 2,3,4-trimethylpentane
21: toluene

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Oil-condensate correlation – Light HC fraction

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Oil-condensate correlation – Light HC fraction

Evaporative fractionation

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Migration model – foreland

- Gas fields
- Oil field + assoc. gas

Condensate in gas deposits

Imbricated Molasse
Helvetic/Flysch

Calcareaous Alps

10 km


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C3 Mud-Gas
Migration model - imbricates

- Gas fields
- Oil field + assoc. gas

Condensate in gas deposits

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Conclusions

• HC biodegradation in oil reservoirs – isotopically light methane
• Thermogenic contribution in microbial gas deposits
• Condensate – oil – similar geochemical features
• Vertical migration from Eocene carrier beds
• Vertical migration from overpressured imbricates
• Possible undiscovered oil deposits 😊