Petroleum System Analysis of Small Scale Miocene Troughs in the Pannonian Basin, Results of a 3D Basin Modeling Case Study from Southern Hungary*  
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Abstract  
The role of the Early to Late Miocene age source rocks in the Late Neogene petroleum system of the Pannonian Basin is undoubtedly significant, but less investigated as it would be necessary. Only few general publications exist which describe these sediments and their importance. We focused on the understanding of the Neogene tectono-stratigraphic development and petroleum systems of these small-scale syn-rift grabens in southern Hungary. We have developed a workflow for the organic geochemical, seismic and facies interpretation, basin subsidence and finally 3D basin modeling to better understand the Miocene-Pliocene age hydrocarbon system in a 1620 km² study area. This area covers two, small scale (less than 200-400 km² each) troughs fulfilled with syn- and post-rift deposits with large thickness but significantly different structural evolution. During our investigation six source rock beds were identified and built into the model. Thousands of meters of Early-to-Middle Miocene, (Karpatian age) sediment was accumulated in the “pull apart”, but later structurally partly inverted Kiskunhalas Trough in the south, where four moderate-to-good quality (2 wt.% estimated original total organic carbon [TOC], 200 HI), dominantly gas-prone, immature to wet gas mature source rock beds were identified. In the overlying Middle Miocene (Badenian age) sediments, a younger, generally good quality (2 wt.% estimated original [TOC], 300-500 HI, Type II and II-S), oil-prone, dominantly oil mature source bed was identified. This layer as the regional Miocene source rock plays the main role of the known hydrocarbon accumulations. The 3D basin and petroleum system modelling helped understanding the hydrocarbon migration into the already discovered fields as well as identified possible future exploration objects.
PETROLEUM SYSTEM ANALYSIS OF SMALL SCALE MIocene TROUGHS IN THE PANNONIAN BASIN, RESULTS OF A 3D BASIN MODELING CASE STUDY FROM SOUTHERN HUNGARY

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**Area of Investigation**

**Goals:**
- Enhanced understanding of the local petroleum system
- Define the YTF potential
- Mitigate the source/migration risk for future HC exploration targets

**Facts:**
- 1620 km² area of investigation
- In the vicinity of Miocene/Pliocene sediment filled grabens
- Proven HC generation & accumulation area
- 23.3 million Sm³ oil + 25.1 billion Sm³ gas in place volume discovered so far
- Most prolific HC accumulations:
  - Szank (10.4 million Sm³ oil + 14.1 billion Sm³ gas in place)
  - Kiskunhalas-NE (7.2 million Sm³ oil + 2.2 billion Sm³ gas in place)
DATASET

- Approximately 110 wells and additional field data were available (with limitations inside mining plots)
- Vintage 2D (approx. 200 lines)
- 2 pcs of 3D volumes
- Published datasets and literature (especially for geochemical data)
- Only 15 wells with any kind of geochemical data in the vicinity of the study area
WORKFLOW

seismic interpretation, estimation of ages

identification of erosion events

lithology, compaction

estimation of paleo water depth

stratigraphical and event history model

investigation of organic geochemical parameters of source rocks

model of maturation history

estimation of paleo heat flow

role of faults during migration

(Erseth et al., 2007)
NE-SW striking half-grabens/pull apart grabens

Neogene sedimentary system but with major differences in synrift phase:

KIHA Trough rifted from late Ottnangian, rapid sedimentation in Karpatian. Late Karpatian inversion which formed a structural high on the Northern part of the trough

SOL Trough rifted from Early Badenian (late Karpatian?), no significant Karpatian sedimentation and inversion

Postrift phase: thermal subsidence, deposits of Lake Pannon

Generalized lithological column

Based on Magyar et al. 2006.
SEISMIC INTERPRETATION – 3D GEOMETRICAL MODEL

- 15 interpreted and 8 calculated (with erosional events) horizons
- All surfaces are depth converted
- 3D geometrical model was built in PetroMod

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FACIES AND PALEO-WATER DEPTH ESTIMATION

➢ Paleomorphological reconstruction – flattening
➢ Facies determination – wells + paleomorphology
➢ Water depth – lithology + paleontology + paleomorphology
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- Water depth – lithology + paleontology + paleomorphology

Model parameters:
- X: 370 grid points
- Y: 550 grid points
- 100 m grid resolution
- W-E: 37 km
- S-N: 55 km
➢ 4 source rock layers in the Karpatian sequence (3 in Kiha-I and 1 in THL Ba E-1) – distribution heterogeneity?

➢ 1 Badenian source layer (Makó F.), evidence in the study area

➢ 1 Lower Pannonian source layer (Endrőd F.), based on literature, no direct data
ORGANIC GEOCHEMISTRY – BADENIAN SOURCES

➢ S-rich oil + evaporite occurrences indicate (indirectly) the presence of Type II-S kerogen in SOL trough

➢ Understanding of spatial and quality distribution of source rock facies
  ➢ TOC: 1.36-1.67 wt%,
  ➢ HI: 300-526 mg/g
  ➢ Type-II, II-S
The preparation work defined the elements of the HC system.

For each of the source layers, the input parameters were determined (data or literature).
The preparation work defined the elements of the HC system.

For each of the source layers the input parameters were determined (data or literature).

The spatial and genetic relationships between the HC system elements were properly clarified.

Based on Magyar et al. 2006, Badics et al. 2011.
MODELING RESULTS – MATURATION HISTORY

- Complex burial history because of the complicated tectonic/geological settings = different maturation history for the subbasins

- In general the Kiskunhalas Trough is more gas prone, the Soltvadkert Trough is more oil prone, and the timing of maturation is significantly different

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Top Karpatian SR4

- Constant 1000 m thick Pre-Neogene Basement with facies belts (Haas et al., 2010)
- Detailed paleogeography
- Slight Pliocene & late Sarmatian inversion & erosion included
MODELING RESULTS – PRESENT DAY MATURITIES

Maturity maps

- Constant 1000 m thick Pre-Neogene Basement with facies belts (Haas et al., 2010)
- Detailed paleogeography
- Slight Pliocene & late Sarmatian inversion & erosion included
MODELING RESULTS – PRESENT DAY MATURESIES

Maturity maps

➢ Constant 1000 m thick Pre-Neogene Basement with facies belts (Haas et al., 2010)
➢ Detailed paleogeography
➢ Slight Pliocene & late Sarmatian inversion & erosion included
MODELING RESULTS – PRESENT DAY MATURES

Top Karpatic SR1 (~ Top Karpatic)

Maturity maps

- Constant 1000 m thick Pre-Neogene Basement with facies belts (Haas et al., 2010)
- Detailed paleogeography
- Slight Pliocene & late Sarmatian inversion & erosion included
MODELING RESULTS – PRESENT DAY MATURITIES

Top Badenian (~ Top Miocene)

- Constant 1000 m thick Pre-Neogene Basement with facies belts (Haas et al., 2010)
- Detailed paleogeography
- Slight Pliocene & late Sarmatian inversion & erosion included
Top Endröd marl

Maturity maps

➢ Constant 1000 m thick Pre-Neogene Basement with facies belts (Haas et al., 2010)
➢ Detailed paleogeography
➢ Slight Pliocene & late Sarmatian inversion & erosion included
Relation between applied kinetic vs maturation is visible

“Fingerprint” of the source and maturation heterogeneity could be observed in the field distribution

Multi-dimensional understanding is required for the proper HC exploration activity
Simulated oil (green) & gas (red) accumulations & HC flow vectors, Badenian layer, perspective view from SW with the lithology of Badenian layer shown.
MODELING RESULTS – CALIBRATIONS AND YTF

- Within the 3D basin model area, 1100 Million tons of oil and 422 Million ton oil-equivalent gas has been generated. Most of the generated volume has been lost (retained within the kerogen and pore network, dispersed in the shaly lithologies and lost to the surface through seepage).

- The current total discovered HCIP is 20 Million ton oil and 18 Million ton oil-equivalent gas.

- In such pull-apart basins, the accumulation/generation ratio could be much higher than the observed 2.5% (see Biteau et al. 2010).

- Based on our current calculations the study area contains approx. 5.5 Million ton oil and 5 Million ton oil-equivalent gas in place as Yet-To-Find potential in subtle conventional traps.

- Calculated OHCIP volumes for each modeled (discovered/predicted) accumulations

- Comparison of modeled vs calculated volumes of discovered accumulations is a good tool for calibration, but large dependency from the input parameters

- Conclusion: The model is capable to predict properly the known/possible locations of the accumulations, but do not use for direct volumetric estimation!
Conclusions

➢ Based on the results of the 3D modeling we...
  ➢ Enhanced our understanding of the Neogene HC system
  ➢ Can estimate the generated and YTF HC volumes more accurately than before
  ➢ Defined a new trend for HC exploration and
  ➢ Could influence and better define the future exploration efforts within this geologically complex and matured exploration area

Suggestions, to do

Strategy

➢ Focus the further exploration program (3D, drilling) to the northern part of the study area

Model

➢ Develop our understanding of the spatial and quality variations of the source rocks and reservoirs (e.g. new organic geochemical measurements, test new kinetics, more detailed mapping, etc.)

➢ Include the proven bacterial gas generation processes into the modeling
THANK YOU FOR YOUR KIND ATTENTION!
QUESTIONS?
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