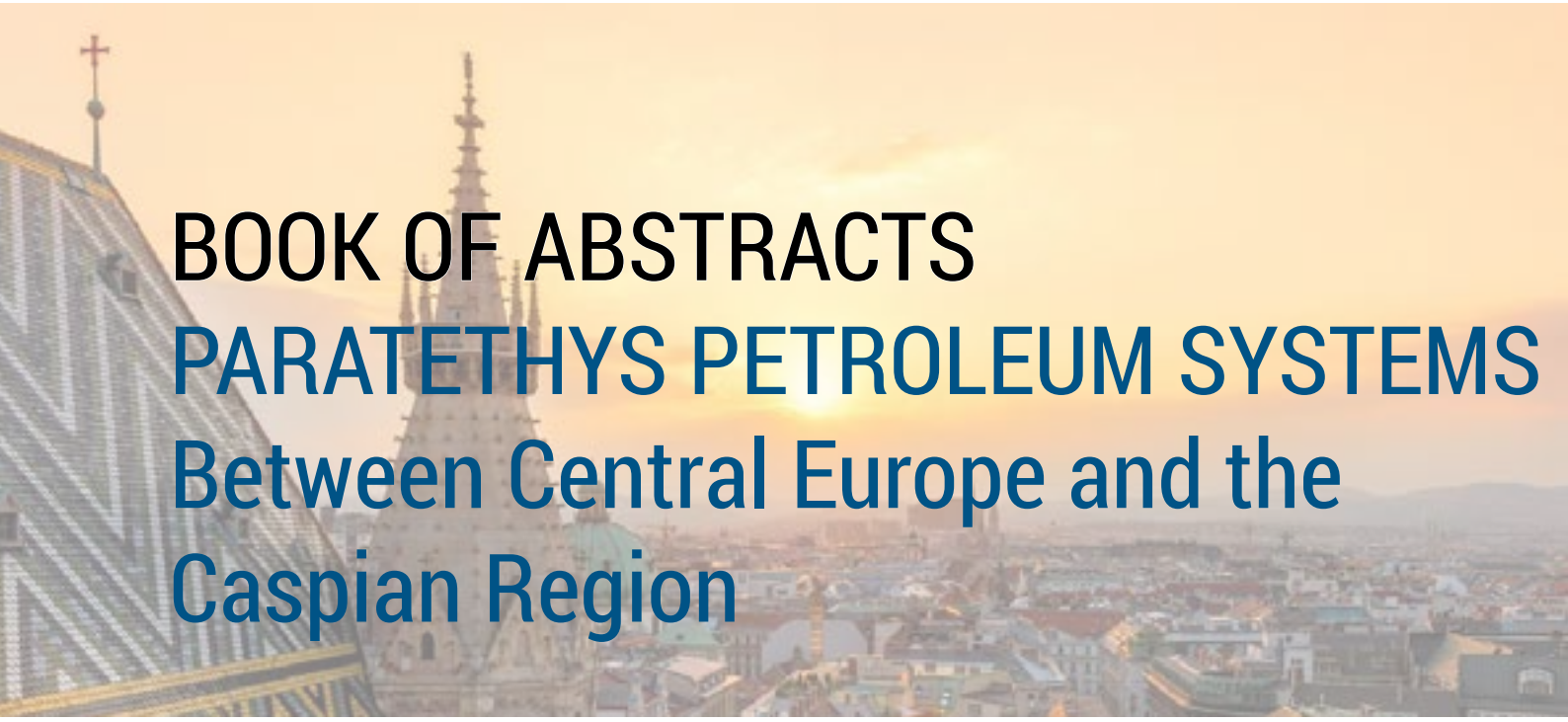
AAPG Europe Region

Europe Regional Conference

26 - 27 March 2019

Hotel Hilton Vienna
Vienna - Austria



BOOK OF ABSTRACTS

PARATETHYS PETROLEUM SYSTEMS
Between Central Europe and the Caspian Region

Sponsors

OMV

ExxonMobil

EMERSON

RAG Exploration & Production

Schlumberger

Media Partner

GEO ExPro

https://erc.aapg.org/2019/

WELCOME

On behalf of the Organizing and Advisory Committees, it gives us great pleasure to invite you to join us in Vienna, Austria, for the AAPG European Regional Conference and Exhibition to be held on March 26-27, 2019.

The theme we have chosen for this conference, "Petroleum Systems of the Paratethys", refers to the general geologic understanding of a unique and quite complex collage of basins and folded belts stretching from the Alps to the Caspian region, and beyond. More specifically, this conference will concentrate on the petroleum systems of the Paratethys from a hydrocarbon exploration and geoscience perspective. The geographic focus will be on the large Pannonian, Black Sea, Caspian Sea basins and various Alpine folded belts and their foredeep/foreland basins in the same region including the Alps, Carpathians, Balkans, Pontides, Crimea and the Caucasus. Our Technical and Advisory committees worked hard putting together an exceptional technical programme addressing various aspects of our collective understanding of the petroleum systems in this large geographic area. After the dramatic drop of the oil price in the last few years, we see now a steady recovery and renewal of E&P activities in the Paratethys region. This trend is especially true for areas which were previously underexplored or for basins which offer new frontiers for the use of the latest oil and gas exploration technologies. We are proud to offer a wide-ranging selection of oral and poster presentations in a technical programme which, given the large number of abstract submissions, we had to organize into three parallel oral sessions. In the selection process we have also put an emphasis on having a healthy mix of professionals from both the industry and the academia.

We hope that all the explorers and geoscientists working on projects in the broader Paratethys region will not only enjoy the conference itself but will also find the time to explore beautiful Vienna and Austria!

CO-CHAIRS
Gabor Tari and Dr Reinhard Sachsenhofer

Gabor Tari
OMV

Reinhard Sachsenhofer
University of Leoben

CONFERENCE COMMITTEE

ORGANISING COMMITTEE

Reinhard Sachsenhofer
Gabor Tari
Bernhard Grasemann
Michael Wagreich
Peter Seifert
Gary Ingram
Peter Krois
Ute Sattler
Herwig Peresson
Hans-Gert Linzer

ADVISORY COMMITTEE

Werner Piller
Oleg Mandic
Stjepan Coric
Imre Magyar
Katalin Milota
Orsolya Sztano
Gabor Bada
Anita Nyerges
Michal Kovac
Jan Golonka
Anna Waskowska
Maciej Kotarba
Piotr Dziadzio
Piotr Krzywiec
Pawel Poprawa
Csaba Krezsek
Sorin Filipescu
Cristina Ungureanu
Iuliana Vasilieva
Dejan Radivojevic
Marko Cvetkovic
Alan Vranjkovic
Mirka Trajanova
Andrea Moscariello
Jon Mosar
Arjan de Leeuw
Liviu Matenco
Sierd Cloetingh
Dan Palcu
Wout Krijgsman
Michael Drews
Nikola Botoucharov
Aral Okay
Zuhtu Bati
Ozgur Sipahioglu
Nuno Pimentel
Rui Pena Reis
Anatoliy Nikishin
Joan Flinch
Juan Soto
Ivan Karpenko
Alexander Kitchka
Elshan Abdullayev
Nazim Abdullayev
Mohammad Fallah
Michael Simmons
David Boote
Stephen Vincent
Christiaan van Baak
Earl O'Callaghan
Ritchie Wayland
Neil Hodgson
Richard Jakeman
Alexei Milkov
Andrew Madof
Matthias Harzhauser
Philipp Strauss

CONFERENCE AT A GLANCE

Coffee Breaks sponsored by

EMERSON

Field Trips sponsored by

OMV

MARCH 26th 2019	
Registration	8.00am - 9.00am
Coffee Breaks	9.50am - 10.20am and 3.20pm - 4.00pm
Lunch	12.20pm - 1.40pm
MARCH 27h 2019	
Registration	8.00am - 8.40am
Coffee Breaks	10.20am - 10.40am and 3.20pm - 4.00pm
Lunch	12.20pm - 1.40pm

Marta Diaz
Event Organiser - AAPG Europe
Email: mdiaz@aapg.org

AAPG Europe Region

Where to find us:
21-22 New Row, WC2N 4LE, London, UK
+44 (0) 207 836 3201 aapg.org/global/europe

PROGRAMME - 26 March 2019 Room A

13	Plenary Talk : Hydrocarbon source rocks in the Paratethys area: An overview - R. Sachsenhofer
	Plenary Talk : Petroleum Systems of the Paratethys Region: An Introduction - D. Boote
	PETROLEUM SYSTEMS IN THE PARATETHYS - Chairs: N. Abdullayev and Vincent
14	Application of compound specific carbon isotope analysis to improved oil-source correlations in the Paratethys area R. Sachsenhofer
15	Geochemistry of natural gases from the Paratethys petroleum systems A. Milkov
16	The Sachrang Member: implications for Toarcian black shale accumulation in the Tethys realm D. Misch
17	Oil-source rock correlation in the German part of the Alpine Foreland Basin: new insights into the petroleum system D. Gross
18	Recent studies on Oligocene deep-water deposits of the North Alpine Foreland Basin L. Scheucher
19	Geological re-evaluation of the mature reservoirs of the Hochleiten-Pirawarth Fields (Vienna Basin) I. Schretter
	PETROLEUM SYSTEMS IN THE PARATETHYS - Chairs: Poprawa and Waskovska
20	The source rock potential and thermal maturity of the Menilite Formation: A new insights from the Czech Republic P. Jirman
21	Some similarities and contrasts in geochemistry and maturity observed among Oligocene Menilite Fm. and its stratigraphic analogues in the Western Paratethys and Caspian region J. Francu
22	Sedimentary environments of the Oligocene Krosno Beds, a new interpretation in the Polish Outer Carpathians P. Dziadzio
26	Petroleum systems and yet-to-find discoveries of Carpathian foredeep and Western margin of East-European Platform: deep dive through regional multi-basin 3D PS modelling I. Karpenko
28	Biogenic Gas Potential of the Romanian Carpathian Foredeep: A Quantitative Seismic Study of the Bobocu Field, Focsani Depression, Romania I. Gyorfi
	PETROLEUM SYSTEMS IN THE PARATETHYS - Chairs: Boote and Kotarba
29	Methane Hydrates as a Tertiary Methane Source in the Transylvanian Basin Z. Unger
30	From transgression to regression: Late Miocene lacustrine successions at the junction zone of the Pannonian Basin and the Apuseni Mts. I. R. Bartha
31	Middle and Upper Miocene source rock facies of Dilj Mt., Sava Depression, Pannonian Basin M. Cvetković
32	Definition of turbidite channels distribution using porosity-thickness maps, case study Pannonian reservoir, Sava Depression K. Novak Zelenika
33	New insights into the tectono-stratigraphic evolution and hydrocarbon systems of the Pannonian Basin: a 2D basin modeling study A. Bartha

PROGRAMME - 26 March 2019 Room B

STRATIGRAPHY AND SEQUENCE STRATIGRAPHY - Chairs: Magyar and Piller	
34	Current status of the Central Paratethys Neogene stratigraphy O. Mandic
35	Strontium isotope dating of some key Central Paratethyan sites G. Less
36	Chronological evolution constrains of the northern Pannonian Basin by authigenic 10Be/9Be dating: Danube Basin case studies M. Šujan
38	The Early Evolution of the Molasse Foreland Basin, Austria: Depositional Environment and Stratigraphic Architecture of Deep-Water Deposits C. Jaikla
39	The early Miocene Calcite Minimum Interval: Pinning down upper Ottnangian Molasse stratigraphy M. Palzer-Khomenko
40	Regional tectonics versus global climate – which process governed the depositional environments in the Central Paratethys? M. Harzhauser
STRATIGRAPHY AND SEQUENCE STRATIGRAPHY - Chairs: Mandic and Simmons	
41	An integrated stratigraphic cross correlation through the major oil fields in the Vienna Basin, Austria M. Kranner
42	A revised sequence stratigraphic framework and depositional model of the (Austrian) Vienna Basin based on 3D seismic survey and its application for future near field hydrocarbon exploration. W. Siedl
43	A concise development history of the Vienna basin S. Rybar
44	Chemostratigraphy and lithostratigraphy of Sękówka Creek between Gorlice and Sękowa –surface offset for oil&gas exploration wells of the Silesian Unit (Outer Carpathians) J. Hejnar
45	Changes in calcareous nannoplankton assemblages and the evolution of biomarkers in the Hungarian Paleogene Basin (Central Paratethys) A. Nyerges
STRATIGRAPHY AND SEQUENCE STRATIGRAPHY - Chairs: Sztano and van Baak	
46	Paleoceanographic evolution of the Hungarian Paleogene Basin during the Early Oligocene on the basis of the micropaleontological and geochemical data István Vető
47	The Miocene in Slovenia, western Central Paratethys; an overview M. Trajanova
49	Integrated bio-magnetostratigraphy of the Badenian reference section Ugljevik in southern Pannonian Basin - implications for the Paratethys history (middle Miocene, Central Europe) O. Mandic
50	Lake Pannon calcareous marls in the SW Pannonian Basin: lithology, stratigraphy and bounding surfaces K. Sebe
51	Chronostratigraphy and geochronology of the Pannonian Stage in the Central Pannonian Basin I. Magyar

PROGRAMME - 26 March 2019 Room C

FOLDED BELTS AND STRUCTURAL GEOLOGY - Chairs:Grasemann and Sosson	
53	Overpressure and stress configuration of the North Alpine Thrust Front and Foreland Basin, SE-Germany M. Drews
54	Stress field in the frontal part of the eastern alps from image logs N. Levi
55	The North Alpine Foreland Basin between two thrust belts: exploration potential leftover? H.G. Linzer
56	Kinematic Mo delling in the Austroalpine Fold-and-Thrust Belt as a tool for de-risking in hydrocarbon exploration M. Habermueller
57	Structural model and hydrocarbon plays in the westernmost Polish Outer Carpathians K. Starzec
58	Miocene syn-rift structural evolution and sedimentation along the Kapos Line (Mid-Hungarian fault zone): implications for the convergence of ALCAPA and Tisza B. Musitz
FOLDED BELTS AND STRUCTURAL GEOLOGY - Chairs: Drews and Linzer	
60	A New Thick-skinned Kinematic Model for the Transylvanian basin and Surrounding Orogens: Implications for Hydrocarbon and Ore Exploration K. J. Szilamér
61	Early Mesozoic tectonics of Northern Dobrogea: structural inheritance of the Black Sea Basins Y. Sheremet
62	Alternative Structural interpretations for the Middle Miocene deformations of the Getic Basin, Romania Z. Schleder
63	Structural evolution of the western Black Sea margin (Bulgaria) M. Louterbach
FOLDED BELTS AND STRUCTURAL GEOLOGY - Chairs: Schleder and Sheremet	
64	Influence of inherited crustal faults zones on the location and inversion of the Caucasus and Black Sea basins M. Sosson
65	Complex shortening tectonic style in the undisturbed Alpine foreland: Example from the Geneva Basin (Switzerland) and implications for subsurface geo-fluid circulation A. Moscariello
66	The Control of Pre-Existing Faults on the Development of Thrust-Related Folds in the Kura Foreland Fold-and-Thrust Belt (Norio License Block, Onshore Georgia) P. Pace
67	Decreasing uncertainty of MT data interpretation in shallow subsurface by using a comprehensive interpretation of independent geophysical datasets. Case study from eastern part of Polish Outer Carpathians. J. Wazny
68	Methodology for Electromagnetic Noise Removal From Magnetotelluric Data Using Machine Learning Techniques as a Tool for Improved Structural Interpretation – Case Study From Eastern Carpathians" P. Hadro

PROGRAMME - 27 March 2019 Room A

PETROLEUM SYSTEMS IN THE PARATETHYS - Chairs: Georgiev and Hodgson	
69	Petroleum system analysis of small scale Miocene troughs in the Pannonian basin, results of a 3D basin modeling case study from southern Hungary V. Lemberkovics
70	3D Petroleum System Model of Southeastern Part of Pannonian basin G. Bogicevic
71	Petroleum systems analysis based on simulation results of a 2D numerical model, eastern Pannonian Basin Z. Harold
72	Thermal history and Hydrocarbon Potential of the PermoCarboniferous below the Eastern Molasse Basin, Austria H. Jäger
73	Early-Middle Jurassic Sedimentary Basins in the Southern Part of the Moesian Platform - Development and Hydrocarbon Favours G. Georgiev
PETROLEUM SYSTEMS IN THE PARATETHYS - Chairs: Dziadzio and Karpenko	
74	Geochemical conditions of Maikop (Oligocene-lower Miocene) sediment accumulation in the eastern Caucasian Basin, NE Paratethys Y. Gavrilov
75	The hydrocarbon potential of Miocene rocks in Azerbaijan (Maikop Group, Diatom Suite) V. Aghayeva
76	Diamondoids reveal one of the world's deepest petroleum systems, South Caspian Basin, Azerbaijan N. Goodwin
77	Features of the geological setting and development of Maikop deposits of Eastern Paratethys in connection with oil and gas occurrence V. Kalabin
79	The Eastern Black Sea: The next Oil Super-basin in Paratethys N. Hodgson
PETROLEUM SYSTEMS IN THE PARATETHYS - Chairs: Botoucharov and Cvetkovic	
80	Mapping depositional systems from the East Balkan thrust belt to the southwest Black Sea – provenance and reservoir quality implications at the transition between Peri- and Para-Tethys S. Vincent
81	Evaluation of heterolithic thinbeds and impact to oil in place in OMV Petrom offshore field Sinoe U. Bieg
82	Evolution and petroleum potential of the Meso-Cenozoic basins of the Crimean-Caucasus region and the surrounding waters of the Black and Azov Seas. M. Kruglyakova
83	Identification of electrical and petrophysical rock types based on core and well logs: utilizing the results to delineate prolific zones in a deep water sandy package, South Caspian Sea basin N. Jafarzadeh

PROGRAMME - 27 March 2019 Room B

STRATIGRAPHY AND SEQUENCE STRATIGRAPHY - Chairs: Harzhauser and Trajanova	
84	On the arrival and evolution of the Danube in the Dacian Basin, Romania C. Krezsek
85	Biostratigraphy and depositional environments of Late Miocene to Early Pliocene rocks in the Dacian Basin (SE Romania) M. Casas-Gallego
86	Sedimentary architecture and depositional controls of a Pliocene river-dominated delta in the semi-isolated Dacian Basin E. Jorissen
87	Sand injectite occurrence in the Western Black Sea A. Otealanu
89	Karaburun (NW Turkey): A Key Oligocene Section on the Margins of Paratethys M. Simmons
STRATIGRAPHY AND SEQUENCE STRATIGRAPHY - Chairs:Coric and Gavrilov	
90	Sediment volumes and sedimentation rates in the South Caspian Basin: distribution, sources and age constraints N. Abdullayev
91	Establishing a stratigraphic reference section for the Middle Miocene marine deposits of Azerbaijan C. G. C. Van Baak
92	Understanding the Akchagyl and Apsheron in the Greater Caspian Sea Region: new biostratigraphic insights K. Richards
93	The Eastern Paratethys during the Messinian Salinity Crisis Y. Rostovtseva
94	The South Caspian Basin subsidence and its bearing on depositional environment of Upper Barremian-Lower Aptian successions (Tirgan Formation), Western Koppet-Dagh (NE Iran) B. Ariafar
SEAWAYS AND EUSTACY IN THE PARATETHYS - Chairs: Krezsek and Krois	
95	Further 2D seismic reflection evidence for a Messinian-style drawdown in the Black Sea at the end Eocene G. Tari
96	What triggered 20 million years of anoxia in central Eurasia? C. G. C. Van Baak
97	Black Sea eustatic variation through time to assess the impact of the sedimentary load in order to refine the timing for hydrocarbon accumulation L. Calle-Benavides
98	A potential connection between the Mediterranean and the Black Sea during the Messinian Salinity Crisis: the Sakarya Bosporus G. Tari
99	Discovery of a deep-basin fluvial system documents drawdown during the Messinian salinity crisis A. Madof

PROGRAMME - 27 March 2019 Room C

UNCONVENTIONAL EXPLORATION - Chairs: Milkov and Sachsenhofer	
100	Unconventional shale exploration challenges, Pannonian Basin, Hungary A.E. Csoma
101	Pore imaging of Late Miocene calcareous marl from the Pannonian Basin (Tótkomlós Member, Endrőd Formation) and comparison with North America productive calcareous marls G. Mallarino
102	Tight and shale unconventional reservoirs in the Outer Carpathians (Poland, Ukraine, Czech Republic) P. Poprawa
103	Sub-conventional petroleum play related to the mudstone-dominated heterolithic reservoirs of the Miocene Outer Carpathian Foredeep Basin (SE Poland) P. Poprawa
104	An unconventional shale-oil source rock in eastern Paratethyan realm: Lower Oligocene Mezardere Formation, Thrace Basin, NW Turkey K.Gürgey

POSTERS

PETROLEUM SYSTEMS IN THE PARATETHYS - Chairs: Francu and Vetö	
105	Compressibility of reservoir and seal of a petroleum system from the Molasse basin: Porolasticity as a useful indicator for material fatigue of an underground gas storage C. Dietl
106	An evaluation of petroleum system elements in the Zagros Belt, Kurdistan, Northern Iraq using carbonate hosted seeps, petroleum-biomarkers and surface enhanced Raman scattering A. Faqi
107	Reconstructing the depositional environment of Upper Eocene reservoir sandstones in eastern Upper Austria L. Scheucher
108	Exploring for a Missing Play, a close 3D Look on the Mesozoic below the Western Austrian Molasse H. Sperl
109	Petroleum Systems and Reservoir Distribution Laws in the Pannonian Basin - Romanian sector D. Cristea
110	Active hydrocarbon systems of the Black and Caspian Sea basins I. Guliyev
111	Depositional conditions of organic matter in the Miocene strata - a biomarkers approach (Polish Carpathian Foredeep) P. Kosakowski
112	Miocene hydrocarbon system offshore the Romanian Black Sea M. Naumova
113	Hydrocarbon potential of the Oligocene – Lower Miocene Menilite Formation and the Cretaceous Shypot Formation in the Ukrainian Outer Carpathians J. Rauball
114	New insights into the petroleum systems in the Tbilisi area, Kura Basin, Georgia M. Pupp
115	Petroleum System Elements in Carpathians Foredeep Molasse (Romania) C. Pene
116	Organic matter dispersed in Menilite Beds from Silesian Nappe – hydrocarbon evidence (Outer Carpathians - Poland) - preliminary results M. Waliczek
117	Comparison of isotopic composition and origin of natural gases in the Miocene strata of the two selected zones of the Polish Carpathian Foredeep M. Kotarba
118	Hydrocarbon generation potential of Paleogene sediments in the Hungarian Paleogene Basin S. Körmös
119	Hydrocarbon source rock potential of the Lower Oligocene İhsaniye Formation (Karaburun, Turkey) E. Tulan
120	Hydrocarbon source rock potential of Oligocene to Lower Miocene diatomaceous rocks in Sibiciu de Sus, Romania E. Tulan
121	Evaluating seal potential of the chalk-type cap rocks from the Węglówka Oil Field, Outer Carpathians, Poland G. Machowski
122	Facies distribution of the Lower and Middle Miocene rock formations in Eastern part of the Drava depression D. Rukavina
123	Triassic rift sedimentation in Eastern Moesia, Romania A. Stoica
124	Hydrocarbon system evaluation on mud log well data in the Southeastern Pannonian Basin, Hungary S. Hussain
125	The Dukla Unit in the middle part of the Polish Outer Carpathians as a hydrocarbon play K. Starzec
126	Source rock and hydrocarbon potential evaluation based on palynofacies and geochemistry of the sedimentary rocks, Danube Basin T. Vlček
127	Thermal history modelling of Dolna Kamchia basin (onshore) – implications for source rock maturity N. Botoucharov

128	Digital mapping of deformation bands and open fractures, Yasamal anticline, Azerbaijan: Developing a predictive model of flow reduction in analogue South Caspian anticlinal structural traps M. Vrabec
129	Subsidence history of the central Danube Basin (Gabčíkovo depression) P. Nováková
130	Hybrid event beds in a Late Miocene lacustrine turbidite system, Makó Trough, Pannonian Basin D. Zima
131	Application of surface geochemistry survey in the HC exploration J. Csizmeg
132	An Overview of Petroleum Source Rocks of Serbian part of Pannonian Basin S. Teslic
133	3D thermal history modelling of the Black Sea basin B. Takács
134	Angle and architecture of merging slopes: implications on deep-water sediment accumulations D. Vági
135	Palaeoenvironmental Analysis and Hydrocarbon Source Rock Potential of Permo-Carboniferous Shales Below the Eastern Molasse Basin, Austria H. Jäger
136	Organic Maturation and Thermal History of the Eastern Molasse Basin, Austria H. Jäger
137	Geochemistry of oil in the Terek-Caspian Foredeep (Middle Caspian Basin) R. Sachsenhofer
138	New insights into the configuration of Permo-Carboniferous Grabens in St Gallen, Northern Switzerland and its Implication on Geo-Energy Prospectivity Eruteya
139	Modelling of the Petroleum System in the St. Gallen Area: Implication for Geothermal Risk Assessment Omodeo-Salé

	STRATIGRAPHY AND SEQUENCE STRATIGRAPHY - Chairs: Nyerges and Wagreich
140	The Rift Sequence Stratigraphy of the Itebej Field (Pannonian Basin, Serbia) S. Ivanišević
141	The study of the oligocene electrofacieses in the Paratethys region D. Cristea
142	Organic-rich turbidites in the Upper Cretaceous of the Magura Basin (Outer Carpathians) – palaeontological and lithological record from the Świątkowa Member of the Ropianka Formation A. Waśkowska
143	Pleistocene Caspian sea-level changes: onshore reconstruction of the Kura Basin coastline evolution E. Jorissen
144	In search of Oligocene Oil Reservoirs in the autochthonous Molasse in Upper Austria: Image Log Analysis of deep water clastics U. Exner
145	Biostratigraphy and paleogeography of the Slovenj Gradec Basin (Slovenia, Central Paratethys) S. Coric
146	Additionaly calcareous nannoplankton bioevents of the Central Paratethys during Miocene S. Coric
147	Tracing the late Miocene evolution of the NW Pannonian Basin using the authigenic 10Be/9Be dating and biostratigraphy: Broader Eisenstadt-Sopron Basin case study M. Šujan
148	Late Miocene variation of accommodation in the Drava Trough: stratigraphic forward modeling and field observations A. Kovács
149	A key section for the Early Pannonian (Late Miocene) of the Transylvanian Basin (Romania): integrated stratigraphic results from the Gusterita clay pit D. Botka

POSTERS

	FOLDED BELTS AND STRUCTURAL GEOLOGY - Chairs: Fodor and Peresson
150	Structural development of south Caspian deep structures A. Javadova
151	Geodynamic mechanisms of formation of the Black and Caspian sea structure V. Kerimov
153	Palinspastic reconstruction of a regional cross-section through the Carpathian Bend Zone: Implications of salt tectonics on the structural inventory and HC traps. K. Amberger
154	Interplay between Tectonics and Sedimentation in the Upper Cretaceous Molasse Base: New Play Types in a Mature Basin U. Exner
155	The Carpathian-Pannonian basins of eastern Paratethys from S Poland to Hungary - a review of recent exploration activities P. Gawenda
156	Evidences of strike-slip deformation associated with the Mid-Miocene rotation and collision of the Southern Carpathians A. Druga

	UNCONVENTIONAL EXPLORATION - Chairs: Csoma and Mallarino
158	Organic porosity is an important factor in the formation of hydrocarbon accumulations in low-permeable shale strata of the Maikop series of the Black and Caspian Sea basins R. Mustaev
159	Oil and Gas in the Mura-Zala Basin (NE Slovenia) M. Markič
160	Pore system characterization of the high-maturity Lower Llandovery shale reservoir of the Narol-Biłgoraj zone (SE Poland) A. Pstrucha
161	Application of the XRF measurements for unconventional potential assessment based on a field section of the Sękówka Creek (Outer Carpathians) M. Wojtowicz
162	Diagnostic textural and structural features of eolianites and their reservoir potential: an example from the Atlantic Coast of Morocco E. Nicklas

	CHANGING SEAWAYS IN THE PARATETHYS - Chairs: Madof and Tari
163	Clay Mineralogy of Miocene Mudstones of the Lower Austrian Molasse Basin M. Meszar
164	Evidence of Badenian Marine Transgression in Belgrade (Serbia) F. Andjelkovic

Hydrocarbon source rocks in the Paratethys area: An overview

Reinhard F. Sachsenhofer – reinhard.sachsenhofer@unileoben.ac.at – Montanuniversitaet Leoben, Chair Petroleum Geology
Sergey V. Popov – serg.pop@mail.ru - Paleontological Institute, Russian Academy of Sciences
Achim Bechtel – achim.bechtel@unileoben.ac.at - Montanuniversitaet Leoben, Chair Petroleum Geology
Reinhard Gratzer – reinhard.gratzer@unileoben.ac.at - Montanuniversitaet Leoben, Chair Petroleum Geology
Doris Gross – doris.gross@unileoben.ac.at - Montanuniversitaet Leoben, Chair Petroleum Geology
David Misch – david.misch@unileoben.ac.at - Montanuniversitaet Leoben, Chair Petroleum Geology
Gabor Tari – Gabor.Tari@omv.com - OMV Exploration and Production GmbH, Trabrennstraße 6-8, 1020 Vienna, Austria

The Paratethys area contains more than 2500 hydrocarbon accumulations with combined recoverable reserves of 95 billion barrel oil equivalent. Many of these accumulations have been charged by Eocene, Oligocene and Miocene source rocks of supra-regional importance.

Highly oil-prone Middle Eocene (Kuma-type) marls and limestones, several tens of metres thick, are especially important in the Eastern Paratethys. In the Caucasus area of Georgia and Russia they may generate 1 to 2 tons of hydrocarbons per square meter (tHC/m²).

Oligocene and Lower Miocene (Menilite/Maikop-type) organic matter-rich pelitic rocks extend across the entire Paratethys area. Lower Oligocene rocks show a very high lateral continuity. For example, carbonate-rich layers with very specific endemic fauna representing the brackish-water “Solenovian Event” can be traced from the western to the eastern margin of the Paratethys over a distance of 3000 km. In contrast, vertical variations in lithology are significant and reflect different stages of basin isolation, which also control the source potential of these rocks. TOC contents locally exceed 20 wt.% and HI values can be as high as 800 mgHC/gTOC. Typically, the source potential is higher in the Central Paratethys (especially Carpathians; >70 tHC/m²) than in the Eastern Paratethys (up to 4 tHC/m²). The most outstanding succession is exposed in the Ukrainian part of the Eastern Carpathians, where the Menilite Formation contains shales with a net thickness of more than 1000 m containing in average 4.9 wt.% TOC and a high petroleum potential (Rock Eval S1+S2: 22.5 mgHC/gTOC)

Middle and Upper Miocene rocks are the main source for oil and thermogenic gas in the Pannonian Basin and for biogenic gas in different parts of the Central Paratethys, the Black Sea area, and in the Ciscaucasian (Chokrakian). The Middle to Upper Miocene Diatom Suite of Azerbaijan is also an excellent, highly oil-prone source rock with TOC contents up to 20 wt.% and HI values up to 850 mgHC/gTOC. Within onshore sections, the organic matter-rich interval is about 60 m thick. If these rocks are mature in the Southern Caspian Basin, they may generate more than 3 tHC/m², but it is likely that the succession is much thicker in the basin´s depocenter.

Application of compound specific carbon isotope analysis to improved oil-source correlations in the Paratethys area

Reinhard F. Sachsenhofer – reinhard.sachsenhofer@unileoben.ac.at – Montanuniversitaet Leoben, Chair Petroleum Geology
Reinhard Gratzer – reinhard.gratzer@unileoben.ac.at - Montanuniversitaet Leoben, Chair Petroleum Geology
Achim Bechtel – achim.bechtel@unileoben.ac.at - Montanuniversitaet Leoben, Chair Petroleum Geology

Compound-specific carbon isotope analysis (CSIA) of individual n-alkanes and isoprenoids is a powerful tool in oil-source correlations. The purpose of the present contribution is to review CSIA data from source rocks and oils in different petroleum provinces in the Paratethys area and to use this technique, together with other organic geochemical proxies, for improved oil-source correlations.

In a first part of the presentation isotope patterns from different potential Mesozoic and Cenozoic source rock intervals are reviewed. The results show major differences between Triassic and Upper Miocene source rocks. For example, specific layers with the Lower Oligocene source rock interval in the Alpine Foreland Basin and the Carpathians are characterized by a unique V-shaped pattern resulting from 13C depleted medium chain length n-alkanes (minimum at C21). The V-shaped isotopy pattern is restricted to sediments deposited during nannoplankton zones NP21 and NP22 and the lowermost part of NP23. In overlying Oligocene sediments (upper part of NP23 and NP24) the V-shaped pattern disappears as long-chain n-alkanes (e.g. C29) become lighter and mid-chain n-alkanes (e.g. C21) heavier. In addition, none of the investigated Eocene source rocks showed a comparable pattern. Hence, although the factors controlling the changes in isotopy are not yet fully understood, CSIA allows very detailed oil-source correlations.

In the second part of the talk, CSIA is applied to oils in the Alpine Foreland Basin, the Alps and the Carpathians. V-shaped isotope patterns suggest that most oils in the Alpine Foreland Basin have been generated from the Schöneck Formation deposited during NP21 and NP22. Surface seeps within the German sector of the Alps near Tegernsee (S Munich) also show the V-shaped pattern and, therefore, prove vertical migration from the oil kitchen beneath the Alps to the surface. In contrast, oils from the western part of the basin (SW Germany, Switzerland) accumulated in Mesozoic reservoirs as well as a few oils in the Austrian part of the basin (including surface seeps in the Austrian sector of the Alpine nappes) have been charged by various Mesozoic source rocks. Furthermore, CSIA confirms that most Carpathian oils have been generated by the Oligocene to Miocene Menilite Formation and that the contribution of Cretaceous source rocks is minor.

Geochemistry of natural gases from the Paratethys petroleum systems

Alexei V. Milkov – amilkov@mines.edu – Colorado School of Mines, USA

The Paratethys includes the Pannonian, Black Sea, Caspian Sea basins as well as Alpine foredeep/foreland basins (the Alps, Carpathians, Balkans, Pontides, Crimea and the Caucasus). In this presentation, I will discuss and interpret geochemical data on >700 gas samples from petroleum reservoirs and seeps in the Paratethys's basins. To interpret the origin of gases and various processes that affected the gases, I used recently revised gas genetic diagrams. Specifically, the genetic diagram of δ13C of methane (C1) versus C1/(C2+C3) helps distinguish thermogenic gases (early mature, mid-mature (oil-associated) and late mature) from primary microbial gases generated from dispersed organic matter at relatively low temperatures, secondary microbial gases generated from biodegraded petroleum, and abiotic gases. However, as genetic fields of various gases overlap on this diagram, two other diagrams help better constrain the origin of gas. The genetic diagram of δ2H of methane versus δ13C of methane helps better distinguish abiotic gases, and the genetic diagram of δ13C of methane versus δ13C of CO2 helps identify the presence of secondary microbial gas. Critically, a holistic integration of gas geochemical data (both hydrocarbon and non-hydrocarbon gases) with the geological settings of petroleum accumulations is needed to reliably interpret the origin of natural gases and the process that affected them after the generation.

It appears that natural gases from the Paratethys petroleum systems have a variety of origins, including thermogenic gases of different maturity, primary microbial gases, and secondary microbial gases originated from petroleum biodegradation. Although most natural gases are dominated by hydrocarbons, there are gases relatively enriched in CO2 and H2S, highlighting the presence of inorganic gases and various fluid-altering processes such as thermochemical sulfate reduction. Gas data and interpretations provide valuable insights into the sources of oil and gas and the post-accumulation processes that affect petroleum accumulations in the sedimentary basins of Paratethys.

Keywords: natural gas, petroleum, methane, isotopes, source rocks

The Sachrang Member: implications for Toarcian black shale accumulation in the Tethys realm

Neumeister, Stefan – st.neumeister@hotmail.com – Montanbehoerde West, Salzburg
Misch, David – david.misch@unileoben.ac.at – Montanuniversitaet Leoben
Sachsenhofer, Reinhard – reinhard.sachsenhofer@unileoben.ac.at – Montanuniversitaet Leoben
Gawlick, Hans-Jürgen – hans-juergen.gawlick@unileoben.ac.at – Montanuniversitaet Leoben
Gratzer, Reinhard – reinhard.gratzer@unileoben.ac.at – Montanuniversitaet Leoben

Whereas Eocene to Miocene source rocks are of special importance in the Paratethys, a significant number of fields are also charged by Mesozoic source rocks including Lower Jurassic (Toarcian) black shales. The early Toarcian was a period of intense accumulation of organic matter (OM)-rich marine sediments under anoxic conditions, which globally occurred in epicontinental areas of the western Tethyan region at that time. Despite considerable variation in local settings, the Early Toarcian Global Anoxic Event (T-OAE) is suggested as one of the main driving forces for the deposition of major source rock units in central and northern Europe (e.g. Posidonia Shale of Germany), as well as OM-rich shales and shaly carbonates in locally restricted basins throughout the Alpine Tethys. Numerous other influencing factors, such as a low-salinity surface-water layer that facilitated intense water-column stratification, or sea-level fluctuations that controlled the supply of oxygen-rich waters to semi-restricted basins in the western European shallow epicontinental sea, are under debate.

A Toarcian black shale section of 45 m thickness is exposed near the village Sachrang, giving name to the Sachrang Member of the Middle Allgäu Formation, which includes other successions such as the Bächental bituminous marl. The Sachrang profile investigated here can be separated into a lower Unit 1 and an upper Unit 2. Unit 1 is 18 m thick and shows an average total organic carbon (TOC) content of 1.9 wt.% (max. 8.0 wt.%). Unit 2 covers 16 m of black shale with an average TOC of 6.2 wt.% (max. 12.6 wt.%). Both sub-units show high average hydrogen indices (410 and 560 mgHC/gTOC, respectively) and a low amount of terrestrial macerals (vitrinite & inertinite) in organic petrography, suggesting predominance of type II kerogen. The thermal maturity is generally low (<0.4 %Ro). Both organic blooms and a higher preservation rate likely caused the increased accumulation of organic matter in Unit 2, for which strongly anoxic conditions are proposed based on very low Pr/Ph ratios (<0.7). In contrast, suboxic conditions prevailed during deposition of Unit 1, suggested by the occurrence of intermediate Pr/Ph ratios (up to 2) and high Mn contents, which are indicative for Mn fixation in carbonates that requires a certain oxygen level. Enhanced alkalinity at the bottom of Unit 2 is caused by the onset of sulfate reduction during anoxia.

Elevated gammacerane indices at the base of Unit 2 indicate elevated salinity in a restricted basin setting with intense water column stratification, while an upwards increasing trend of C27/C29 sterane ratios points to a relative sea level rise during deposition of the upper black shale unit. Both parameters correlate well between the investigated succession in Sachrang and the Toarcian sections in Bächental (Bächental bituminous marls) and Dotternhausen (Posidonia Shale). The negative carbon isotope excursion associated with the T-OAE is slightly visible at the transition between Unit 1 and Unit 2, but it is likely that carbon and oxygen stable isotope compositions of carbonates are strongly influenced by diagenetic overprint as well, documented by a strong depletion in 13C at the bottom of Unit 1. The importance of lower order changes caused by regional influencing factors is indicated by cyclic trends in the carbon isotopic composition of organic matter. Interactions of global (e.g. eruption of large igneous provinces) and local phenomena during black shale accumulation at the Toarcian shelf are still a matter of controversy, but this study points to an influence of both, similar to the nearby Bächental basin. Interestingly, a TOC-poor uppermost Unit 3 is missing in Sachrang, again pointing to an important influence of the local basin setting, as the Bächental time-equivalent is characterized by a debrite layer in its uppermost part, caused by turbiditic flows.

Keywords: Toarcian, Sachrang, Black Shale, Alpine Tethys, Oceanic Anoxic Event

Oil-source rock correlation in the German part of the Alpine Foreland Basin: new insights into the Petroleum System

Gross, Doris – Doris.Gross@unileoben.ac.at – Chair Petroleum Geology, Montanuniversitaet Leoben, 8700 Leoben, Austria
Co Authors:
Bechtel, Achim – Achim.Bechtel@unileoben.ac.at – Chair Petroleum Geology, Montanuniversitaet Leoben, 8700 Leoben, Austria
Dax, Florian - Chair Petroleum Geology, Montanuniversitaet Leoben, 8700 Leoben, Austria
Gratzer, Reinhard – Reinhard.Gratzer@unileoben.ac.at – Chair Petroleum Geology, Montanuniversitaet Leoben, 8700 Leoben, Austria
Pupp, Magdalena – Magdalena.Pupp@unileoben.ac.at – Chair Petroleum Geology, Montanuniversitaet Leoben, 8700 Leoben, Austria
Sachsenhofer, Reinhard F. – Reinhard.Sachsenhofer@unileoben.ac.at – Chair Petroleum Geology, Montanuniversitaet Leoben, 8700 Leoben, Austria
Sweda, Martin – Chair Petroleum Geology, Montanuniversitaet Leoben, 8700 Leoben, Austria

The Alpine Foreland Basin (AFB), located in the western part of the Paratethys, is a minor oil and a moderate gas province. Major hydrocarbon production began in the 1950s from Mesozoic and Cenozoic strata.

In contrast to Austria, where oil is charged exclusively from Lower Oligocene units (Schöneck, Dynow, Eggerding fms.), strong indications for additional Mesozoic source rocks exist in the German sector of the basin. In order to reach a better understanding of the petroleum system in the German sector, bulk parameters (TOC, TC, and Rock Eval pyrolysis), biomarker and isotopy analysis of potential source rocks have been performed. In addition, the molecular and compound-specific isotopic composition of oil samples have been studied.

Mesozoic source rocks are restricted to the western part of the German AFB and include potential source rocks in several stratigraphic horizons (Lettenkeuper, Lias Alpha, Lias Epsilon (Posidonia Shale), Dogger Alpha/Beta, Malm Alpha). The Posidonia Shale holds a good petroleum potential, but the potential of the remaining rocks must not be neglected.

Lower Oligocene source rocks are lateral extensive, but are missing in the westernmost part of the German AFB. Similar to Austria, the Schöneck Formation exhibits a good to very good petroleum potential. The potential of the marly Dynow Formation is fair (carbonate-rich samples) or very good (carbonate-poor samples). Vertical trends of biomarker proxies are similar to those in the Austrian part of the basin showing lateral continuous depositional environments. The Schöneck and Dynow formations together can generate about 0.5 tons of hydrocarbons per m². Oil in the eastern part of the German AFB (E of Munich) is stored in Cenomanian and Eocene reservoirs. Biomarker and isotope data show that these oils have been charged by the Lower Oligocene. This holds true for most oils in Oligocene reservoirs (Baustein Beds) W of Munich. An increasing contribution of Mesozoic oil is observed in western deposits indicated by variations in compound-specific isotopic composition of oils. Oil in Mesozoic reservoirs in the westernmost part of the German AFB is derived from Mesozoic source rocks. Significant variations in isotope patterns suggest that several Mesozoic source rocks contributed to these oils.

Keywords: biomarker, compound-specific isotopic composition, oil-source correlation, Oligocene source rocks, Mesozoic source rocks

Recent studies on Oligocene deep-water deposits of the North Alpine Foreland Basin

Scheucher, L.(1), Graham, S.A.(2), Lowe, D.R.(2), Jaikla, C.(2), Kremer, C.H.(3), Exner, U.(1), Reutemann, M.(1), Linzer, H.G.(1) & Wiesmayr, G.(1)

(1) RAG Exploration & Production, Schwarzenbergplatz 16, 1015 Wien
(2) Stanford Project on Deep-water Depositional Systems, Department of Geological Sciences, 450 Serra Mall, Stanford University, Stanford, CA 94305-2220
(3) Department of Earth, Environmental and Planetary Sciences, Brown University, Box 1846, 324 Brook Street, Providence, RI 02912

The collaboration of RAG with Stanford University in the frame of the "Stanford Project on Deep-water Depositional Systems" (SPODDS) has resulted in many projects on deep-water strata of the North Alpine Foreland Basin (NAFB). This is of particular importance as nearly all gas (and gas storage) fields in Upper Austria and Salzburg are located in deep-water reservoir rocks. Thus, the detailed understanding of the evolution, architecture and reservoir potential of these deep-water deposits is crucial for a successful E&P strategy. In general, deep-water conditions in the NAFB commenced in early Oligocene (Rupelian) times and persisted until the late early Miocene (Burdigalian). Reservoir rocks are present in Zupfing (ZF; Rupelian/Chattian), Lower Puchkirchen (LPF; Chattian), Upper Puchkirchen (UPF; Aquitanian) and Hall (HF; Burdigalian) Formations.

The UPF and lower HF were extensively studied throughout the years on both local and regional scales. Those studies show that a large, low-sinuosity axial channel belt with a width of some 3-5 km was present in Aquitanian and early Burdigalian times. This channel belt can be traced for more than 100 km from west to east. Some 2000 m of core from more than 100 wells were logged in the past 15 years and a wide range of reservoir and non-reservoir lithofacies, ranging from mudstones to conglomerates, has been identified. Stratigraphic architecture and lithofacies distribution of the UPF channel belt are now well known. Main reservoir units are formed by deposits of high-density turbidity currents within the channel belt, including thick-bedded sandstones (Lowe S3 divisions) and clast-supported, sand-matrix conglomerates (Lowe R1 to R3 divisions). Additionally, medium to thin-bedded sandstones representing low-density turbidity currents deposited in overbank splays and tributary channels are also of economic importance.

Recent exploration activities and drilling results revealed the need for studying the LPF and ZF in similar detail. The onset and early development of the channel belt and its architecture and reservoir distribution are poorly understood. Two recent studies focus on these issues and preliminary results show that there are differences in seismic architecture and lithofacies distribution (see also Jaikla et al., this volume: The Early Evolution of the Molasse Foreland Basin, Austria: Depositional Environment and Stratigraphic Architecture of Deep-Water Deposits). Although also present in the UPF and HF, large MDTs seem to play a dominant role and are a primary control on the stratigraphic architecture of the channel belt. MDTs occur as longitudinally- and transversely-emplaced (sourced from the south) types and have a significant influence on (1) the northward migration of the channel and (2) the reservoir distribution. Such MDTs, although generally regarded as waste zones, can contain ponded reservoir units on top. Detailed knowledge of the stratigraphic architecture of these MDTs will provide important information on the spatial distribution of associated reservoir units and thus, is crucial for estimating the reservoir risk for future gas exploration wells.

Keywords: NAFB, deep-water deposits, Oligocene, Puchkirchen Fm., Zupfing Fm., axial channel belt, MDT

Geological re-evaluation of the mature reservoirs of the Hochleiten-Pirawarth Fields (Vienna Basin)

Author: Schretter, Isabell – isabell.schretter@omv.com – OMV Austria Expl. & Production GmbH
Author: Zamolyi, Andras – andras.zamolyi@omv.com – OMV Expl. & Production GmbH
Co Author: Finsterwalder, Rudolf - rudolf.finsterwalder@omv.com – OMV Austria Expl. & Production GmbH

The Hochleiten-Pirawarth Fields are located in the Vienna Basin, Austria, approximately 30 km to the Northeast of Vienna. The comprehensive modelling and re-evaluation effort focused on sediments deposited in near-shore environments in the Middle to Late Miocene. The Vienna Basin formed a part of the Central Paratethys at this time. The deposition was defined by the transgressive-regressive cycles resulting in a mixed layer-cake to jigsaw-type reservoir architecture. The regional NE-SW oriented structural feature of the Steinberg Fault system and its multiple hanging wall splays generate the highly compartmentalized Hochleiten-Pirawarth Fields.

The Hochleiten Field started production in 1977; 75 wells were drilled with production from 11 reservoirs. Cumulative production is 2.74 million tons of oil and 283 million Nm3 of gas (Nov. 2018). The Pirawarth Field started production in 1958; 115 wells were drilled with production from 13 reservoirs. Cumulative production is 2.92 million tons of oil and 485 million Nm3 of gas (Nov. 2018).

Due to the long life of both fields and differing views on their remaining potential, an integrated study was initiated at the end of 2015. Aim was to achieve a holistic view of both fields and to increase the chance of success of future wells.

To reduce geological uncertainty in the highly compartmentalized area a field-scale depth processing was performed on a merged seismic dataset covering both fields. The established multi-layer velocity model greatly increased confidence in the structural picture. Based on this approach a comprehensive structural model was created for a large spatial area, vertically covering the Neogene reservoirs. For the geomodel a larger areal extent was also chosen to minimize possible boundary effects. To enhance overall quality a complete petrophysical re-evaluation of available log data for all Hochleiten and selected Pirawarth wells was carried out. The then-generated property model utilizes a net to gross approach that creates a net log using global porosity and VShale cutoffs, while variogram analysis was carried out for each single reservoir horizon separately.

For future well planning efforts supported by the geomodel, the estimation of hydrocarbon volumes in place had a very high priority. To achieve robust results, different volume calculation methods were applied to determine the recoverable hydrocarbon volumes initially in place (STOIIP, GIIP): (1) a stochastic Monte-Carlo approach, (2) the static model, and (3) several applied reservoir engineering methods. The results of all volume calculations were reviewed and agreed by an interdisciplinary team.

The presented Hochleiten-Pirawarth geomodel is the first holistic modelling effort integrating both fields. Finalized in October 2018, the study yielded a realistic view of the complex reservoir geology, revised volumes and new ideas for future wells.

Keywords: reservoir, re-evaluation, modelling, volumes

The source rock potential and thermal maturity of the Menilite Formation: A new insights from the Czech Republic

Jirman, Petr – p.jirman@seznam.cz – Department of Geological Sciences, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic
Geršlová, Eva – gerslova.eva@gmail.com – Department of Geological Sciences, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic

The Eocene-Oligocene boundary in the Paratethys region represents a period associated with a major extinction event followed by Oligocene to Early Miocene anoxic events. Furthermore the Oligocene Menilite Formation or its stratigraphic equivalents sourced a number of petroleum provinces within the Paratethys area.

The Menilite Formation in the territory of the Czech Republic is subdivided from base to top into the Subchert Member (NP22), Chert Member (upper NP22 to lower NP23), Dynów Marlstone (NP23) and Šitbořice Member (upper NP24 to lower NP25). To cover the whole sequence of the formation, a 40 outcrop samples from the Loučka section (Silesian Unit) was accompanied by 37 cores samples representing the Šitbořice Member of Ždánice Unit. The lithological variations represented by non-calcareous shales, marlstones and cherts reflect strongly varying depositional environment causing variations in both the geochemical parameters and hydrocarbon potential. The Loučka section where most of the Subchert Member, whole Chert Member and Dynów Marlstone and lowermost part of the Šitbořice Member are exposed represents an excellent opportunity to study the factors controlling the organic matter-rich layers deposition.

The Menilite Formation contains mainly type II kerogen based on both the Rock-Eval hydrogen index (HI) and organic petrography. Type I kerogen was observed in the Chert Member (HI up to 725 mg HC/g TOC), while admixtures of type III kerogen were indicated predominantly in the Šitbořice Member. Based on the HItrue and organic petrography observations, type II and I kerogen prevails. The Menilite Formation holds mostly "good" source rock potential even the TOC ranges up to 16.5 wt%. The Chert Member is the most prolific among the members in both TOC (average 5.9 wt%) and petroleum potential (average 45.1 mg HC/g rock). The thermal immaturity of the organic matter was confirmed by Rock-Eval Tmax (from 400 up to 433°C) and vitrinite reflectance (from 0.24% to 0.31%).

Considering the results of this study the Menilite Formation may represent very promising source rock even in the Czech Republic where other source rocks are in the foreground of interest. Higher thermal maturity which may reaches favourable conditions for hydrocarbons generation is expected especially beneath the Magura Group of Nappes.

Keywords: Menilite Formation, Outer flysch Carpathians, Oligocene, Source rock potential, Kerogen type, Thermal maturity

Some similarities and contrasts in geochemistry and maturity observed among Oligocene Menilite Fm. and its stratigraphic analogues in the Western Paratethys and Caspian region

"Paratethys petroleum system elements"

Francu, Juraj – juraj.francu@geology.cz – Czech Geological Survey Brno
Bubik, Miroslav – miroslav.bubik@geology.cz – Czech Geological Survey Brno
Pereszlényi, Miroslav – miroslav,pereszlenyi - Czech Geological Survey Brno
Akper Feyzullayev – fakper@gmail.com – Geology Institute of ANAS, Baku
Milicka, Jan – jan.milicka@iniba.sk – Comenius University Bratislava

Menilite and Maykop Fms. were deposited in the Paratethys during the Oligocene to Miocene time due to convergence of the African and Arabian plates with Eurasia. These organic rich oil and gas source rocks show several geochemical similarities reflecting the changes in the depositional environment and bioproductivity. A series of depositional phases are distinguished within these strata poor in macrofossils. Eocene variegated shales were deposited in a partly oxygenated open marine environment and have a very low hydrogen index (HI<80 mg HC/g TOC) and generative potential <1 mg HC/g rock. Later during the isolation of the northern Tethys is marked by deposition of calcareous clays and marls with total organic carbon of 1-2% and rather low HI.

The sea level drop and tectonic separation of the Paratethys from the rest of the Tethys resulted in deposition of black marl with TOC as high as 6% and HI of 300-400 mg/g. The environment became restricted in oxygen during the late Oligocene with stratified water column, brackish at the sea level and highly saline and anoxic at the sea bottom. The number of species decreased significantly and the diatoms became the dominant group. The biomarkers such as highly branched isoprenoids (HBI) are sensitive indicators of this silica rich and carbonate poor member. Similar biomarker pattern was found in Maikop formation in the South Caspian basin and in genetically related oils in the entire Paratethys basin.

The chert-rich beds are covered by a marly member with HI over 500 mg/g and TOC of 5-6% followed by Late Oligocene/Miocene low-carbonate shale with low HI and Low generative potential thicker turbidites with alternating organic-rich and -poor strata.

Thermal maturity distribution provides a specific pattern typical for syntectonic foreland basins, where the sediment were detached shortly after deposition and formed the frontal part of the thrust and fold belts of the Alps, West Carpathians and Caucasus. Numerous well profiles show steeply inclined strata with negligible to very low increase in vitrinite reflectance with depth. A systematic increase in thermal maturity and related burial and uplift is documented from Austrian to Czech, Polish and Slovak segments of the apical part of the West Carpathians. From there on, the thermal maturity decreases to the SE, what applies also from the internal to more external overthrust units.

Sedimentary environments of the Oligocene Krosno Beds, a new interpretation in the Polish Outer Carpathians

Author: Dziadzio, Piotr. S. – dziadzio@inig.pl – Oil and Gas Institute-National Research Institute, Kraków, Poland
Co Author: Higgs, Roger – rogerhiggs@geoclastica.com ¬– Geoclastica Ltd., UK
Co Author: Drozd, Arkadiusz – drozd@inig.pl – Oil and Gas Institute-National Research Institute, Kraków, Poland

Introduction

This paper presents a new concept of the tectonic and depositional environment of the Menilite-Krosno Beds classic flysch deposits (Dżułyński et al. 1959; Książkiewicz 1975, 1977) in the Polish Outer Carpathians (Fig. 1). The Menilite Beds and the overlying Krosno Beds, both historically interpreted as deep-marine deposits, are here reinterpreted as shelf deposits of a large lake, occasionally ocean-connected, which may have resulted in fully marine conditions at times. The new depositional model proposed here is based on the discovery of abundant wave-formed sedimentary structures (recently, farther west, the Magdalena Sandstone Member of the Menilite Beds has been reinterpreted as shelfal rather than deep; Dziadzio et al. 2016) and on paleogeographic reconstructions by Rögl (1999) for Early Oligocene and Early Miocene times (corresponding essentially to the Menilite-Krosno Beds) which show that the Carpathian region was within a large enclosed water body, a remnant of the formerly through-going Paratethys seaway, isolated from the world ocean for much of Oligo-Miocene time, forming a freshened sea or giant lake (Vakarcs & Magyar 2004) here named "Lake Krosno", a hydrologically open remnant-ocean lake trapped in a long collision belt at an early stage of collision, evolved from the Paratethy seaway. The great majority of Menilite-Krosno sand beds are interpretable as hyperpycnites and wave-modified hyperypcnites, supplied by rivers, mainly longitudinally from the west.

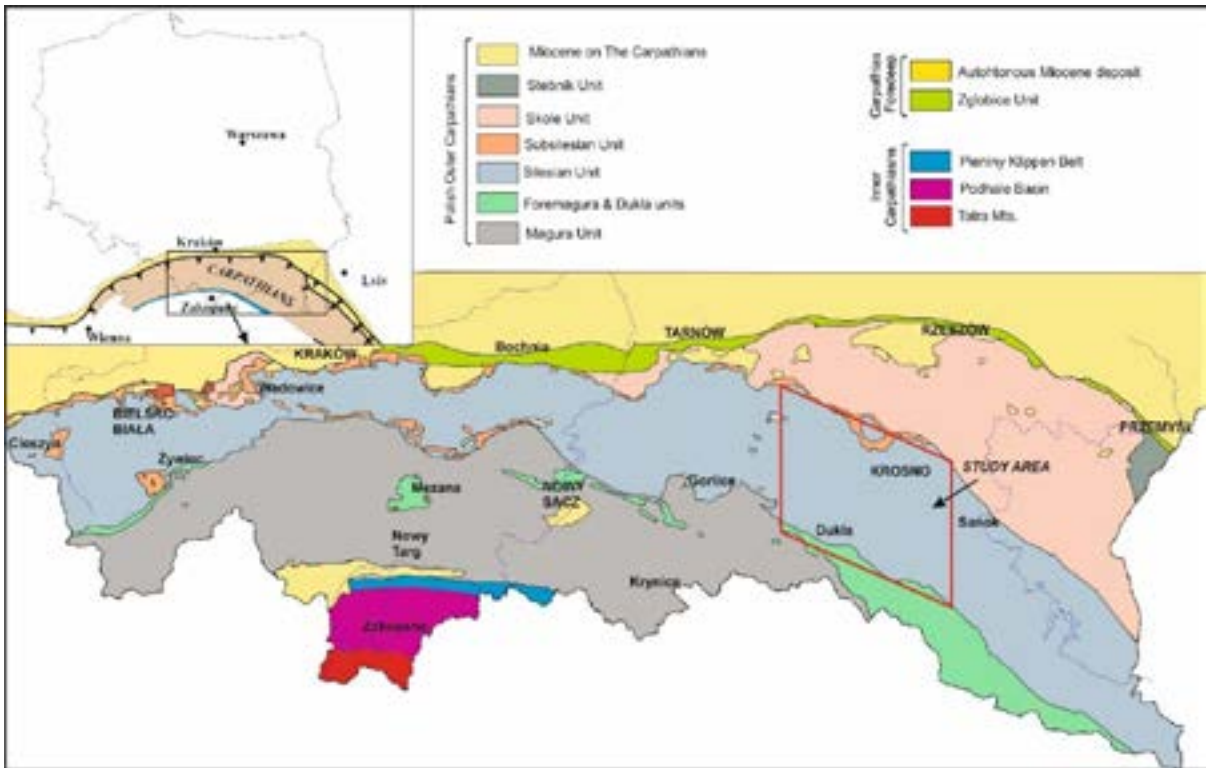


Fig. 1. Location of the study area (simplified and modified Geological Map of the Carpathians based on Geological Atlas of the Outer Carpathians and their Foreland (1988-1989).

New depositional model of the Krosno Beds

Like all foreland flysch (also known as miogeosynclinal flysch as opposed to eugeosynclinal flysch; see discussion and references in Higgs 2014), the Menilite-Krosno Beds are characterized by bed 'packeting', i.e. alternating packets, generally 1-30m thick, of thinner (mm or cm) and thicker (usually cm or dm) event beds, attributable to eustatic sea-level oscillations transmitted over the lake sill (Hiss 1991, 2014, 2017). Evidence for shelfal sedimentary conditions includes the following sedimentary structures and compositional attributes: hummocky cross stratification (HCS); pot casts ("whirls balls" of Dżułyński et al. 1957); gutter casts; symmetrical ripples (including vortex ripples); near-symmetrical ripples (indicating a combined flow comprising a one-way sediment-supplying current accompanied by a wave-induced oscillatory flow); interference ripples (symmetrical or near-symmetrical); sinusoidal lamination (rounded, symmetrical or near-symmetrical ripples climbing vertically or near-vertically); multidirectional tool marks; hooked grooves; non-orthogonal (to nearly parallel) ripple crests and sole marks on the same event-bed; and conspicuous muscovite and terrigenous plant matter mostly present in fine and very-fine sandstone beds interpretable as hyperpycnites (see below and Zavala et al. 2011, 2012). No evidence of subaerial conditions has been found. There is also no evidence of sedimentation in the beach/coast zone and no tidal structures were seen, although west of the research area such structures (tidal rhythmites) have been described in the uppermost part of the Menilite Beds (Dziadzio 2018, in press).

There is also evidence for low salinity (brackish or fresh) and for reduced bottom oxygenation of the Menilite-Krosno basin (Lake Krosno). These are: low diversity of fossils (benthonic megafossils) and trace fossils (see Książkiewicz 1977); low degree of visible vertical bioturbation; scarcity of pyrite (cf. Berner & Raiswell 1984); presence of syneresis cracks; the nature of benthonic foraminifera (Książkiewicz 1975, 1977), dominating in the older horizons, which almost completely disappeared and were replaced by calcareous types in the Krosno Beds (an additional possible factor is soupy bottom-mud due to low salinity). The Menilite-Krosno scarce benthonic-foram fauna comprises both agglutinated and calcareous genera (Książkiewicz 1975). However, it differs strongly from the "flysch-type agglutinated fauna" composed entirely or mainly of agglutinated taxa, characteristic for eugeosynclinal flysch (Higgs 2014). Mixed agglutinant-calcareous faunas like that of the Menilite-Krosno Beds typify miogeosynclinal flysch (Higgs, 2014). Higgs (2014) suggested that these faunas are only "pseudo-bathyal" ("false bathyal" of Higgs, 2017a), being misinterpreted as bathyal due to a misleading combination of: (A) reworking of true deep-water taxa from adjacent accretionary-wedge mountains and (B) dysoxia of flysch-shelf bottom-mud (i.e. fairweather) due to permanent lake-water stratification.

A possible explanation for low diversity of trace fossils and scarcity of vertical ones is that Lake Krosno salinity for much of the time was low (brackish or fresh), rendering the bottom-mud weakly cohesive (characteristic of open lakes, cf. Higgs 1991) and therefore(?) exceptionally watery (soupground or perhaps ultra-soupground), detrimental to the visibility of burrows (very strongly compressed by compaction; cf. Schieber 2014) and unfavorable in the first place for many types of burrowing animals.

The vast majority of sandstone event-beds in the Menilite-Krosno Beds can be interpreted as hyperpycnites and wave-modified hyperypcnites (rather than the near-universally assumed slump-generated turbidites), supplied mainly longitudinally by sediment-laden rivers. Based on all of the above: (A) these sandstone beds were probably deposited on a shelf (i.e. the feeder-delta slope may have been too low/short for slumps to evolve into turbidity currents); and (B) lowered salinity (very prone to hyperpycnal flow; see below) occurred for much of the time, especially during lowstands, corresponding to the thicker-bedded packets.

Thus, most sandstone beds in the Menilite-Krosno Beds can be interpreted as wave-modified hyperpycnites with

HCS and/or other wave-formed sedimentary structures (see Higgs 1991, Myrow et al. 2002). Those sandstone beds capped by ripple cross lamination and (slightly) asymmetrical ripples are habitually assigned to the Bouma Tc division, implying unidirectional flow. However, combined-flow ripples (i.e. near-symmetrical ripples) and corresponding cross lamination differ only subtly from their unidirectional-flow counterparts (e.g. Harms 1969; Higgs 1984; Myrow et al. 2002) and have hitherto been overlooked in the Menilite-Krosno Beds, as have the truly symmetrical ripples. Each such sandstone bed can be interpreted as the product of a flood event accompanied by a storm, resulting in a wave-modified hyperpycnite with HCS and/or other wave-formed sedimentary structures (cf. river-fed wave-modified turbidites of Myrow et al. 2002, Pattison, 2005).

It is this combination of eustasy, early collision in a very long (>1,000 km) collision belt, floods and storm waves that explains the unique character of foreland flysch, including the Menilite-Krosno Beds (i.e. packeted; entirely shelfal; few or no intervals with fully marine fauna) by generating five specific controlling factors: (1) a low-salinity lake, that by definition is (2) very prone to hyperpycnal flow, both during floods and fair weather (rivers need more than fifty times more suspended sediment to underflow the sea compared to a freshwater lake; Mulder and Syvitski 1995), hence (3) massive fluvial-sediment transfer directly to the shelf, greatly slowing the (bypassed) delta's progradation onto the shelf; (4) storm-wave 'shaving', limiting shelf aggradation, maintaining the shelf's intrinsic equilibrium profile (Higgs 2010, 2014); and (5) fluctuations in water depth and brackishness by glacioeustatic incursions over the lake sill (Higgs 1991), the rapidity of these eustatically driven lake-level rises and falls causing the trademark bed-packeting of foreland flysch (Higgs 2014, 2017).

Summary

All of these facts strongly suggest deposition of the Menilite-Krosno Beds on the shelf (i.e. between storm- and fair-weather wave base) in a vast remnant-ocean lake, called here "Lake Krosno", evolved from Paratethys. The low salinity of the basin (lake) justifies the interpretation of the majority of sandstone beds as hyperpycnites. The shelf equilibrium profile governed by storm erosion, intrinsic to all shelves, limited sediment aggradation, while delta progradation was slowed by the lake's low salinity favoring delta bypass by hyperpycnal flow, delaying the eventual overrunning of the shelf by deltaic deposits (Higgs 1991, 2014, 2017).

Keywords: Polish Outer Carpathians, Oligocene, Krosno Beds, depositional model

The authors would like to thank Polish Oil and Gas Company (POGC) for permission to publish the results of research on the Krosno Beds. Project financed by POGC.

References

Berner, R.A. & Raiswell, R. 1984. C/S method for distinguishing freshwater from marine sedimentary rocks. Geology 12, 365-368.
Ciurej, A. & Haczewski, G. 2012. The Tylawa Limestones – a regional marker horizon in the Lower Oligocene of the Paratethys: diagnostic characteristics from the type area. Polish Geological Institute, Geological Quarterly 56, 833–844
Dziadzio, P.S., Matyasik, I., Garecka, M. & Szydło, A. 2016. Lower Oligocene Menilite Beds, Polish Outer Carpathians: supposed deep-sea flysch locally reinterpreted as shelfal, based on new sedimentological, micropalaeontological and organic-geochemical data. Oil and Gas Institute - National Research Institute), Kraków, Monograph 213, 120p.
Dziadzio P. S., 2018. Sedimentary environment of the Menilite Beds in the Stróże Thrust Sheet, Silesian Unit, Carpathians. Nafta-Gaz. No 11, (in press).
Dżułyński, S., Radomski, A. & Ślączka, A. 1957. Sandstone whirl balls in the silts of the Carpathian-flysch. Annales Societatis Geologorum Poloniae 26, 107-129.
Dżułyński, S. & Ślączka, A. 1959. Directional structures and sedimentation of the Krosno Beds (Carpathian flysch). Annales Societatis Geologorum Poloniae 28, 205-260.
Geological Atlas of the Outer Carpathians and their Foreland, 1988-1989, (Coord.: D. Poprawa, J. Nemcok), Państwowy Instytut Geologiczny, Warszawa.

Haczewski, H. 1989. Coccolith limestone horizons in the Menilite-Krosno Series (Oligocene, Carpathians) – identification, correlation and origin. (In Polish, with English summary.) Annales Societatis Geologorum Poloniae 59, 435-523.
Harms, J.C. 1969. Hydraulic significance of some sand ripples. Geological Society of America Bulletin 80, 363-396.
Higgs, R. 1984. Possible wave-influenced sedimentary structures in the Bude Formation (Lower Westphalian, south-west England), and their environmental implications. Proceedings of the Ussher Society 6, 88-94.
Higgs, R. 1991. The Bude Formation (Lower Westphalian), SW England: siliciclastic shelf sedimentation in a large equatorial lake. Sedimentology 38, 445-469.
Higgs, R. 2010. Why do siliciclastic shelves exist? How do they differ from "ramp margins?" New sequence stratigraphic aspects vital for petroleum exploration. American Association of Petroleum Geologists Search and Discovery Article #40527, 12p.
Higgs, R., 2014. Shelf model for "deep-sea" flysch turbidites and implications for outcrop analogs. American Association of Petroleum Geologists Search and Discovery Article #70157, 19p.
Higgs, R., 2017. Reinterpreting the paleosalinity and water depth of peripheral foreland basin flysch. American Association of Petroleum Geologists Search and Discovery Article #30508, 83p. http://www.searchanddiscovery.com/documents/2017/30508higgs/ndx_higgs.pdf
Książkiewicz, M. 1975. Bathymetry of Carpathian Flysch Basin. Acta Geologica Polonica 25, 309–367.
Książkiewicz, M. 1977. Trace fossils in the flysch of the Polish Carpathians. Palaeontologica Polonica 36, 1–208.
Mulder, T. & Syvitski, J.P.M. 1995. Turbidity currents generated at river mouths during exceptional discharges to the world oceans. Journal of Geology 103, 285-299.
Myrow, P.M., Fischer, W. & Goodge, J.W. 2002. Wave-modified turbidites: combined-flow shoreline and shelf deposits, Cambrian, Antarctica. Journal of Sedimentary Research 72, 641-656.
Pattison, S.A.J. 2005. Storm-influenced prodelta turbidite complex in the lower Kenilworth Member at Hatch Mesa, Book Cliffs, Utah, U.S.A.: implications for shallow marine facies models. Journal of Sedimentary Research 75, 420–439.
Rögl, F., 1999. Mediterranean and Paratethys. Facts and hypotheses of an Oligocene to Miocene paleogeography (short overview). Geologica Carpathica 50, 339-349.
Schieber, J. 2014. Traces in the dark – sedimentary processes and facies gradients in the Upper Devonian - Lower Mississippian upper shale member of the Bakken Formation, Williston Basin, North Dakota, U.S.A. – discussion. Journal of Sedimentary Research 84, 837–838.
Vakarcs, G. & Magyar, I., 2004. Freshened seas or giant lakes: eustacy and history of the Paratethys. American Association of Petroleum Geologists Search and Discovery Article #90034 (abstract).
Zavala, C., Arcuri, M. & Valiente, L.B., 2012. The importance of plant remains as diagnostic criteria for the recognition of ancient hyperpycnites. Revue de Paléobiologie, Genève, 11, p. 457–469.
Zavala, C., Arcuri, M., Gamero Diaz H., Contreras C. & Di Meglio M., 2011. A genetic facies tract for the analysis of sustained hyperpycnal flow deposits. [W:] Sediment transfer from shelf to deep water-Revisiting the delivery system (Eds R. M. Slatt and C. Zavala). AAPG Stud. Geol. 61, p. 31–51.

The authors would like to thank Polish Oil and Gas Company (POGC) for permission to publish the results of research on the Krosno Beds. Project financed by POGC.

Petroleum systems and yet-to-find discoveries of Carpathian foredeep and Western margin of East-European Platform: deep dive through regional multi-basin 3D PS modelling

"Ukrainian sector of Carpathians region is the least studied and poorly highlighted. This study presents deep dive into petroleum systems evolution based on first ever developed regional multi-basin 3D model and its numerous simulations of Western Ukrainian petroleum province covering area of 50 000 sq km (excl. Carpathians foldbelt). Study simulates and examines separate independent biogenic, thermogenic convention and unconventional petroleum systems."

Dr. Karpenko Ivan - karpenkoi@naftogaz.com – NJSC Naftogaz of Ukraine
Prof. Karpenko Alex – karpenko.geol@gmail.com – Taras Shevchenko National University of Kyiv
Dumenko Sergei – dumenkos@gmail.com – Viva Exploration LLC
Rudnik Bogdan – bogdanrudnyk@gmail.com - Taras Shevchenko National University of Kyiv

Study area. The modeled area covers 50 000 sq km within most of Western Ukraine: Eastern Carpathian foredeep (Bilche-Volytsa area), Volyno-Podillya platform area, Lviv Paleozoic deep coal basin. Current study and developed model do not cover Carpathian fold belt, as super-intensively folded ridges require different modelling approaches. Geological overview. The sedimentation history and geological sections of basins and sub-basins is formed by wide specter of stratigraphic units from Ediacarian-to-Devonian (635-358 Ma) within Volino-Podillya plate, by dominance of Devonian and Cretaceous sediments (358-80 Ma) in Lviv Paleozoic coal basin and by Jurassic-to-Neogene (180-7 Ma) within Carpathian foredeep. Sedimentary cover of Ukrainian sector of Eastern European Platform nowadays deepens from NE to SW and its lithofacial variation reflects the paleo-geographic conditions of Baltica paleo-continent margin with continental, alluvial, shelf and deep marine facies-families. The Carpathian mountains were formed during the Alpine orogeny in the Mesozoic and Tertiary ages which dramatically changed structural and tectonic characteristic of the region. Alpine orogeny led to formation of hundreds of parallel and longitudinal fault systems which are situated all over the Carpathian fold belt, controlling terraces of underlying basement and forms blocks of adjoining surrounding sub-basins. Together with the formation of Carpathian fold belt, adjoining deepening Pre-Carpathian foredeep sub-basins were filling with thin-interbedded fine-grained clastic sediments throughout Neogene age. Neogene lies over intensively eroded Mesozoic (K+J) basement.

Petroleum occurrence and petroleum systems. Study area hold over 50 discovered to date oil and gas fields with absolute majority of accumulations occur in Neogene strata (41% of discovered hydrocarbons) and a few massive accumulations in Mesozoic basement accounting 44% of discovered hydrocarbons. Heavy oil accumulations in Jurassic unit and wet gas in Cretaceous unit indicates presence of thermogenic petroleum system within Mesozoic section, while absolute dominance of dry natural gas in Neogene section is explained by predominance of biogenic petroleum system in Carpathian foredeep. Neogene section as a primary gas-producing play is represented by fine-grained thin-interbedded clastics with poor quality of shallow thick reservoirs. Underlying Mesozoic plays were very intensively eroded thus understanding of source rocks and reservoirs distribution is quite a challenge. There are some papers on source rocks in Ukrainian sector of Carpathians and numerous geochemical studies highlights organic-rich formations in Polish sector of Pre-Carpathian sub-basins which is well extrapolates to nearby Ukrainian sub-basins. Moreover, older and deeper organic-rich formations present within the study area but poorly studied with uncertain/poor generation potential and quite uncertain distribution around the region due to deficit of data.

Model: First ever developed multi-basin 3D model covers 50 000 sq km, prepared from combination of numerous regional structural maps, profiles and complex data-sets from tens of deep wells. Data out of numerous research

studies was integrated into the model: on stratigraphy and lithofacies distribution, on paleo-depositional environments, on present petroleum systems and geochemistry, etc. Regional distribution of heatflow and its paleo trends was determined via 1D modelling. Model includes a number of biogenic and thermogenic petroleum systems, which were calibrated using known discovered hydrocarbon accumulations.

Findings. Fulfilled study by using developed model and numerous simulations highlights regional petroleum systems, correlates them with known discoveries and allocates areas with petroleum accumulations yet-to-find. Also, new plays were identified as very likely to hold undiscovered multi-MMBOE accumulations. Developed model is quite confident and accurate, as simulated hydrocarbon accumulations correlates well with known to date discovered oil and gas accumulations. Current study, at this stage, had rather regional objectives but integration of additional data could significantly clarify areas of interest to generate certain prospects and quantify potential.
Keywords: basin analysis, multi-basin model, petroleum system, 3D, modelling, Carpathians, foredeep, Western Ukraine, yet-to-find, biogenic, thermogenic, regional

Biogenic Gas Potential of the Romanian Carpathian Foredeep:
A Quantitative Seismic Study of the Bobocu Field, Focsani Depression, Romania

Istvan Gyorfi and Henry Aldorf
Claren Energy Corp.,
880-580 Hornby Street, V6C 4B6 Vancouver, Canada

Biogenic gas is an elusive exploration target for the petroleum industry. It is thought to account for over 20% of the world's gas resources (Rice and Claypool, 1981), however remains largely unexplored. Most accumulations outside established areas are found by accident while drilling for thermogenic gas or oil. Biogenic gas is generated at low temperatures (<75deg Celsius) by decomposition of organic matter through anaerobic microorganisms. Geologically speaking the key control on biogenic gas generation is the burial rate of the source-rock. The optimum burial rate for a basin depends on the geothermal gradient, and varies from about 200 to 1000m/Ma.

The Carpathian Foredeep is a flexural basin controlled by the tectonic load exerted by the eastward- advancing Carpathian Fold and Thrust belt. The Focsani Depression is located in the North-Eastern part of the Moesian Platform and is integral part of the Carpathian Foredeep. It represents the most active depositional zone, especially in the Neogene. According to deep seismic sounding (and some well control) the thickness of the sedimentary cover reaches roughly 18km, from which 6 km belong to the Sarmatian, Pliocene, and Quaternary.

On the eastern rim of the Focsani Basin there are a number of gas fields of biogenic origin (Bobocu, Ghergheasa, Rosioru, Boldu Balta Alba and Stancesti). In between 1970-1990 the Bobocu Gas field has produced from 15 wells 33 Bcf gas. There are 6 Pliocene (Pontian) reservoirs situated between 2460m and 2820m depth with porosities in between 15-20% in average. The gross thickness of the reservoirs varies in between 5-15m. A 75km2 3D seismic survey was acquired in 2012 and is of reliable quality. The seismic data has been reprocessed in 2016 in order to adopt a more amplitude friendly processing sequence. The analysis of the reprocessed data proves that the thicker gas sands (>10m gross thickness) are mappable throughout the survey. Following the initial interpretation of the seismic data simultaneous inversion was run, completed later by a spectral decomposition study. These datasets are consistent in indicating that there is a 20 Bcf 2C remaining gas resource associated with the known gas producers, while the deeper Meotian and Sarmatian undrilled prospects have an additional exploration upside of 60 Bcf gas in place.

The quantitative interpretation workflow applied to Bobocu, is largely de-risking drilling activity and could be applied successfully to other similar assets in Romania and world-wide.

Methane Hydrates as a Tertiary Methane Source in the Transylvanian Basin

Unger, Zoltán – zunger@shpbv.eu - Oil&Gas Development Central Kft. – Budapest,
- ELTE-SEK-Laboratory of the Instruments – Szombathely – Hungary
LeClair, David – dleclair@shpbv.eu - Oil&Gas Development Central Kft. – Budapest – Hungary
Györfi István – istvangyorfi56@yahoo.com – RomGaz – Târgu Mureș - România

The Transylvanian Basin as a back arc and a piggy back basin has a thick lithosphere. In this so-called cold basin there are salt deposits over which biogenic gas was trapped (Krézsek et al 2010). The rate of the generated gas related to the rock volume of this post-salt basin strongly exceeds the average. This allows for the presumption that this methane could have multiple sources. Besides the well-known biodegradation of the organic matter from the sedimentary sequence we suppose to have a secondary methane source from the ancient Deep Hypersaline Anoxic Basins (DHAB), where considerable amount of methane was produced by bacteria (MedRIFF 1995, Unger&LeClair 2017, 2018). Huge quantities of dissolved methane gets through these DHAB surfaces into normal salty sea water. This methane output originating from the brines was measured by MedRIFF (1995) and published by Karisiddaiah, S. M., (2000), proving an occurrence of daily methane output.

The question is this: where do the escaping methane molecules migrate?
Since in a cold basin, the dissolved methane will be frozen and caught by water molecule clathrates, forming methane hydrates (MH). These methane hydrates can be preserved for geological time on the bottom of the basin, where further methane hydrates could accumulate, adding to the previously frozen ones in the course of basin filling Late Badenian to Late Sarmatian. Once the volcanic activity started in the East Carpathian, the geothermal gradient increased, and the methane hydrates started to dissociate.

1m3 MH yields 0.8m3 freshwater and 164m3 CH_4

This is an endothermic process triggering considerable volume increase and creating overpressure zone. Due to this pressure, methane starts migrating to the current reservoirs and traps. The freshwater generated by dissociation dilutes the reservoir water, reducing its initial salinity (120-200g/l). Such diluted reservoir water (7-12g/l) has frequent occurrence in the Transylvanian Basin; it is mostly characteristic of deep reservoirs related to gas fields such as Grebenișu de Câmpie-Dobra, Păingeni, Corunca, Filitelnic.

Our deduction is this: besides the primary and the secondary methane sources, we face a tertiary methane source and the origin of this is from methane hydrates.

Keywords: deep hypersaline anoxic basin, methane hydrates, dissociation, methane, Transylvanian Basin

References:
Karisiddaiah, S. M., (2000): Diverse methane concentrations in anoxic brines and underlying sediments, eastern Mediterranean Sea Deep-Sea Research I 47 pp. 1999-2008.
Cs. Krézsek, S. Filipescu, L. Silye, L. Maţenco, H. Doust (2010): Miocene facies associations and sedimentary evolution of the Southern Transylvanian Basin (Romania): Implications for hydrocarbon exploration, Marine and Petroleum Geology 27 (2010) 191–214
MedRIFF Consortium, 1995, Three brine lakes discovered in the seafloor of the Eastern Mediterranean. EOS, Transactions of American Geophysical Union 76, 313.
Unger, Z. & LeClair, D. (2017): Parallel Salt and Methane Generation, Possible Paradigm Shifts for Sa lt Generation in Deep Sea Processes, AAPG Search and Discovery Article #51392
Unger, Z. & LeClair, D. (2018): Salt and Methane Generation Initiated by Membrane Polarisation, Earth Sciences. Vol. 7, No. 2, pp. 53-57. doi: 10.11648/j.earth.20180702.12

From transgression to regression: Late Miocene lacustrine successions at the junction zone of the Pannonian Basin and the Apuseni Mts.

Bartha, István Róbert - istir@caesar.elte.hu – Department of Physical and Applied Geology, ELTE
Botka, Dániel - botkadani@gmail.com – Department of Palaeontology, ELTE
Csoma, Vivien - csoma.vivien7@gmail.com – Department of Palaeontology, ELTE
Magyar, Imre - immagyar@mol.hu – MTA-MTM-ELTE Research Group for Paleontology; MOL Plc.
Sztanó, Orsolya - sztano@caesar.elte.hu – Department of Physical and Applied Geology, ELTE

Several large outcrops in the Șimleu Basin – in the junction zone of the Great Hungarian Plain (GHP) and the Apuseni Mts. – expose various deposits formed in the northeastern embayment of the Late Miocene Lake Pannon. One of the key outcrops is Cehei, where the nonconformity between the basement and the lacustrine strata is exposed. Poorly sorted medium-grained sand, imbricated gravel, and boulder-sized clasts host a poorly preserved mollusc assemblage. Steeply dipping bed-sets downlap the unconformity and were deposited as a coarse-grained delta. It indicates flooding of local basement highs, the former source of clasts, during the Lymnocardium conjungens mollusc biochron (~11–9.6 Ma). Further flooding and deepening continued, thus lacustrine marls covered the crystalline basement, older Miocene strata, and the transgressive basal coarse clastics beds. These marls can be recognized above the deltaic topsets at the Cehei exposure and contained a Hungarocypris-dominated ostracod assemblage. Mud-prone sequences are also exposed in the Vârșolţ quarry. Dark grey, bioturbated to laminated mudstones contained a low-abundance mollusc and ichnofossil assemblage, which reveals an open lacustrine environment with alternating dysoxic and aerated bottom conditions and suggests an age of ~11.45–9.6 Ma (Congeria banatica profundal mollusc biozone). The overlying heterolithic beds, i.e. thin intercalations of silty sands, are interpreted as turbidites. As their thickness and grain-size increase upwards, they may indicate the beginning of the overall regression. Thick turbiditic sandstones crop out in the eastern part of the Șimleu Basin, near Zalău. Erosional scours draped by large rip-up mud-clasts and meter-thick amalgamated, structureless sandstones. Lateral facies changes are common, medium-bedded channel-fill sandstone interfingering with thin-bedded turbidites. This succession deposited near the toe of slope in a channel-levee system, where transport directions were from NE to SW. The youngest part of the succession can be studied in several outcrops near Nușfalău and Bocșa. It consists of fine-grained sand and silt. A few-meter-thick upward-coarsening parasequences and various current- and wave-induced sedimentary structures reveal deltaic environments, wave-dominated mouth bars, and distributary channels, prograding from NE to SW. A well preserved, high-abundance mollusc fauna of littoral origin supports the interpretation. The deltaic sediments were formed in the Lymnocardium conjungens biozone (~11–9.6 Ma), similarly to the oldest lacustrine sediments. Thus, the whole depositional sequence, from transgression to regression was formed during a relatively short period of 1.5 million years. It also indicates that filling up of the NE part of the GHP, where age constraining data are scarce, occurred relatively rapidly. These outcrops are also important analogues of well known reservoirs near the margin of the GHP both in Romania and Hungary. Unconformity-related coarse clastics occur at Abrămuţ or Chișlaz, turbidites at Săcueni and deltaic sandstones contain the shallow Suplacu de Barcău oil field nearby.

This work was supported by the Papp Simon Foundation, the MOL Academic Aid Program, and the Hungarian National Research, Development and Innovation Office (NKFIH – 116618).

Keywords: turbidites, delta, biostratigraphy, reservoir

Middle and Upper Miocene source rock facies of Dilj Mt., Sava Depression, Pannonian Basin

Cvetković, Marko - marko.cvetkovic@rgn.hr, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Zagreb, Croatia
Troskot-Ćorbić, Tamara, tamara.troskot-corbic@ina.hr, INA Plc., Zagreb, Croatia
Sachsenhofer, Reinhard - reinhard.sachsenhofer@unileoben.ac.at Department Applied Geosciences and Geophysics Montan-universität, Leoben, Austria
Ćorić, Stjepan - stjepan.coric@geologie.ac.at - Geologische Bundesanstalt, Wien, Austria
Rukavina, David – david.rukavina@rgn.hr, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Zagreb, Croatia
Kolenković Močilac, Iva – iva.kolenkovic@rgn.hr, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Zagreb, Croatia
Saftić, Bruno – bruno.saftic@rgn.hr, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Zagreb, Croatia

The main source rock facies in the Croatian part of the Pannonian Basin belong to the Middle Miocene and lower part of the Upper Miocene. These rocks are mainly identified in deep exploration wells, whereas outcrops are rare. Here we report on three stratigraphically different source rock intervals, which were recently discovered at Dilj Mt on the North-Eastern flank of Sava Depression. The oldest source rock interval is located within a continuous succession characterized by interlayering of marls and sandstones with dominant carbonate grains. The source rocks are dark grey, laminated marls with moderate Corg contents (1.7-3.6%) and HI values (470-510 mgHC/gCorg). The source rocks, up to 7 m thick, contain an abundant marine fauna and were dated into the lower NN5 zone (Early Badenian). Maceral composition and Rock-Eval analysis suggest a mixed Type II-III kerogen. In contrast to the above locality, two other outcrops represent re-sedimented source rocks. The source rock clasts are all of similar age, but the age of the debris breccia differs between the two sites. One locality is represented by a debris breccia interval, about 60 cm thick. Two different source rocks facies can be observed among the clasts, one of massive texture and black colour and one dark grey with thin laminae showing slumping. The massive facies contain 8.0 to 10.8% Corg with HI values from 547 to 578 mgHC/gCorg, while the laminated one contains less Corg values (~5.6%) but with higher HI (604 mgHC/gCorg). Geochemical properties and maceral analysis support the presence of oil-prone Type II kerogen. According to the palaeontological record, both the breccia and clasts are of Sarmatian age. The other outcrop with re-deposited source rocks is more than 2.5 m thick and contains significantly larger clasts compared to the first re-sedimented type outcrop (up to 1 m). The age of the source rock clasts is similar that of the previous debris outcrop. Interestingly, the laminated facies is not slumped like in the previous outcrop, but shows micro-faulting indicating a compressional event. The overlying sediments were biostratigraphically dated as Early Pannonian. Geochemical analysis has not yet been performed on samples from this location, but similar values as in samples from the first outcrop are expected based on similar facies and age. All analysed source rocks show very low thermal maturity (%Ro <0.25, Tmax <430 °C), indicating rather shallow burial and very limited uplift during the last compressional phase of the Pannonian Basin. The study results yield important information for the re-evaluation of the petroleum potential of the basin infill, considering the structural and stratigraphic setting of the source rock intervals within the basin. The same rocks in deeper settings might represent significant active source rock intervals that were inadequately considered in previous exploration.

Keywords: Source rocks, Badenian, Sarmatian, Lower Pannonian, Sava Depression, Pannonian Basin

Definition of turbidite channels distribution using porosity-thickness maps, case study Pannonian reservoir, Sava Depression

Novak Zelenika, Kristina - kristina.novakzelenika@ina.hr – INA Plc.
Brnada, Stipica - stipica.brnada@ina.hr – INA Plc.

One part of field development includes an understanding of the processes in the reservoirs based on sedimentology, which means a proper description of the depositional environments. During the field development, especially in the final stage of the production, knowledge of the reservoir itself must be completely thorough. Only in that way, residual hydrocarbon saturation can be defined.

The sweetness seismic attribute is a very useful tool for such interpretation, since it can describe reservoir quality and the deposition of different lithofacies. Many old fields in Sava Depression have the seismic of poor quality. For that reason, a different way of seeing sand bodies had to be found.

This paper shows that depositional channels of turbidity sandstones, deposited during the Pannonian in the Sava Depression can be described with porosity-thickness maps. Such maps are created from well data. Basically, they are average porosity maps multiplied by isochore maps, which implies 3D geological modelling of the reservoirs. The basic idea is that porosity and thickness, as separate variables, can describe reservoir quality. Higher porosities and greater thicknesses could point to the channel center, while lower porosities and thicknesses point to channel edge. Of course, this maps can apply only to areas covered with wells, but any extraction of the channels to a wider area cannot be done without seismic interpretation.

PetrelTM software was used to construct reliable geological model. Zone is defined by well to well correlation. Difference between top and bottom of the zone represents zone thickness. Porosity was distributed using mathematically advanced ordinary kriging method. Average porosity maps were created from the distributed porosity in 3D model.

Interpreted reservoirs are located in the Sava Depression, Croatia. Their description generally fits in the basin evolution. Two studied reservoirs are of Pannonian age. Both are medium to fine grained sandstones in constant intercalations with basinal marls.

A comparison of the sweetness seismic attribute and porosity-thickness maps shows a good visual match. Still, there is a mismatch in areas with small reservoir thickness and poor seismic. Mathematical proof of a correlation between the sweetness seismic attribute and porosity thickness maps is the determination coefficient “r2 = 0.73” for the area of the highest sandstone thickness and best reservoir properties with clear seismic data.

Keywords: turbidite channels, porosity-thickness maps, Sava Depression, Croatia

New insights into the tectono stratigraphic evolution and hydrocarbon systems of the Pannonian Basin: A 2D basin modeling study

Author: Bartha, Attila - abartha@slb.com - Schlumberger, Germany
Co-Author: Balázs, Attila - balatt@gmail.com - Department of Sciences, Università Degli Studi Roma Tre, Rome, Italy
Co-Author: Szalay, Árpád – dr.szalay@hotmail.com – Independent Exploration Geologist, Szolnok, Hungary

Two-dimensional basin modeling was carried out in the Pannonian basin of Central Europe to investigate the Miocene extension, post-rift evolution, subsequent basin inversion, associated sedimentation, and hydrocarbonn generation (Bartha et al. 2018).

A tectono-sedimentary evolutionary model constrained by seismic and well data represented the input for dynamic modeling. The basin and petroleum systems model was analyzed with a petroleum systems modeling software to integrate the spatial and temporal variations of episodes of subsidence and uplift, sedimentation and erosion, dynamics of biogenic and thermogenic gas generation, migration, accumulation, and loss. The high-resolution approach enabled the impact of the shelf-margin slope progradation and sequential sediment loading on mechanical compaction, pore pressure development, source rock maturation, hydrocarbon charge, and preservation to be assessed.

Generation and migration processes were genetically controlled by the deposition of the SSE-ward-prograding Pannonian (s.l.) shelf-margin slope sediments and repeated tectonic inversions along the Mid-Hungarian fault zone. Different vitrinite reflectance kinetic models were tested, and the impact of different generation reaction schemes on charge were compared. Biogenic gas generation was associated with the deposition of almost the entire sedimentary succession in the studied Jászság and Békés sub-basins; however, the preservation of these gases was limited in time and space. Most of the thermogenic gases were sourced by the deepwater marls in the Békés sub-basin.

The dissolution and diffusion of the gases were also investigated using the numerical model. Dissolution resulted in higher amounts of retained gases in formation waters, which therefore could not contribute to the charge of both known and predicted accumulations. Diffusion transport did not have a major impact on the final migration model because it was restricted to a range of few hundred meters in the Pannonian (s.l.).

Simulation results indicated the development of gas hydrate stability zones in deeper parts of the basin. The hydrates may have played a temporal role in the retention of both thermogenic and biogenic gases, but further investigations are needed to better understand their contribution to the gas accumulations with mixed origins present at shallower depths in the Pannonian basin.

The predicted hydrocarbon phases and compositions are in a good agreement with the results of geochemical analyses of the gas samples from the basin. Even though the hydrocarbon balance showed a predominance of biogenic gases, due to the inefficient sealing, most of them were lost by migration to the surface.

Keywords: Pannonian basin, basin and petroleum system modeling, basin inversion, thermogenic gas, biogenic gas

References
Bartha A, Balázs A, Szalay Á (2018) On the tectono-stratigraphic evolution and hydrocarbon systems of extensional back-arc basins: inferences from 2D basin modelling from the Pannonian basin. Acta Geodaetica et Geophysica. https://doi.org/10.1007/s40328-018-0225-0

Current status of the Central Paratethys Neogene stratigraphy

Oleg Mandic and Mathias Harzhauser
Geological-Paleontological Department, Natural History Museum Vienna, Burgring 7, 1040 Wien, Austria; Email: oleg.mandic@nhm-wien.ac.at; mathias.harzhauser@nhm-wien.ac.at

The Central Paratethys (CP) was an Oligocene to Middle Miocene European epicontinental sea settled north of the Eastern Alps, Dinarides and Carpathians and south of the European platform. It was a highly dynamic area due to the ongoing Alpine orogeny, resulting in a quickly changing paleogeography. Its westernmost parts between Munich and Linz became terrestrial already during the Early Miocene, its southern domain was not part of it before the Middle Miocene. Major control on the Neogene paleoenvironmental development in the CP were tectonics driving the evolution of the Pannonian Basin System (PBS), including initiation of the pull-apart type Vienna Basin and the sag type Transylvanian Basin. The PBS synrift phase was generally constrained to the Early and Middle Miocene, its postrift phase occurred during the Late Miocene and Pliocene, initiating the disintegration of the CP. Thereby, its western domain (Pannonian Basin System) turned into a fully isolated long-lived lake, whereas its eastern domain (Carpathian Foredeep - Dacian Basin) became integrated into the Eastern Paratethys (EP), extending eastwards via Black Sea to the Central Asia. During open marine phases, the CP was an embayment of the proto-Mediterranean Sea, connected via the Slovenian and Rhône basin gateways. Consequently, its stratigraphy correlates in the first line with the Mediterranean one. During endemic events the stratigraphic correlation with the EP, increases.

A regional chronostratigraphic system was developed gradually since the 1950-ties to fix the correlation of the various Paratethyan basins. The Early to Middle Miocene interval include five CP stages - Egerian, Eggenburgian, Karpatian, Badenian, and Sarmatian. The Late Miocene to Pliocene interval also include several formalized “CP stages”. Currently, these are the Pannonian and Cernikian for the PBS lacustrine successions including the Transdanubian as substage of the Pannonian. The Pontian, Dacian and Romanian stages are confined to eastern Paratethyan basins and therefore, its use in the CP is abandoned.

This regional chronostratigraphic system is deeply rooted in the distribution and occurrence of shallow benthic taxa, such as mollusks and benthic foraminifera. These are especially useful during endemic intervals, but do not allow reliable correlations of basinal settings. Therefore, planktic organisms, such as planktic foraminifera and calcareous nannoplankton in marine settings and dinoflagellates in lacustrine deposits, are increasingly used for intra- and interregional correlations. In addition, geochronological methods including Ar/Ar dating of volcanic ash layers, Sr concentration in fully marine shell material, and beryllium-10 cosmogenic dating for Upper Miocene to Quaternary continental deposits, gained increasing interest. Correlation methods depending on calibration by former constrains include magnetostratigraphy and astronomical tuning, yet they both need long continuous successions being very rare. Finally, sequence stratigraphy proved useful for correlation of eustatic sea-level change with the open ocean, but is potentially overprinted by geodynamics.

This is a contribution to the Scientific Project “Stratigraphy, geodynamic development and paleogeography of the Vienna Basin: a cross-border correlation of data between Austria and Slovakia” (Scientific & Technological Cooperation with Slovakia 2018-19, No. SK 09/2018).

Strontium isotope dating of some key Central Paratethyan sites

György Less – foldlgy@uni-miskolc.hu – University of Miskolc, H-3515 Miskolc-Egyetemváros, Hungary
Gianluca Frijia – frjglc@unife.it – Università di Ferrara, Via Saragat 1, I-4412, Ferrara, Italy

Sr-isotope stratigraphy (SIS) dating of most important Central Paratethyan (CPT) sites can lead to a better correlation of the CPT regional stages to the global geological scale, which is in some cases still problematic and contradictory. Our new results are listed below.

SIS data of all samples assigned to the basal and lower part of the Egerian stage [Novaj (H), lower boundary stratotype; Eger, Wind brickyard (H), holostratotype; Csókás (H); Budikovany (SK) and Plesching (A)] suggest an age younger than 25 Ma corresponding to the late and terminal Chattian. SIS data from sites with most primitive miogypsinids (their FO defines the lower boundary of the Egerian) outside the CPT [Porto Badisco (I); Escornebéou (F) and Abesse (F)] mark the late Chattian, too. Thus the age of the base Egerian should be around 24.5–25.0 Ma instead of the earlier 27.6 Ma, which simultaneously raises the problem of the Kiscellian stage (these deposits are not yet successfully tested) since in this case it largely extends into the Chattian.

SIS data from the Bretka (SK) sample assigned to the late, Miocene part of the Egerian suggest the early Aquitanian, in accord with the Monte Aman (I) site outside the CPT containing the same Miogypsina gunteri. Among the localities believed to be traditionally early Eggenburgian, both the SIS data and the presence of Miogypsina tani of the Darnó Conglomerate from Szajla (H) suggest late Aquitanian, which is in agreement with the SIS age from L'Ariey (F), outside the CPT but also with M. tani. SIS data from Fels am Wagram (A) are intermediate between the Aquitanian and Burdigalian, while those from Coruşu (RO) suggest early Burdigalian. Therefore, the Egerian/Eggenburgian boundary should be placed within the Aquitanian (around 21.0–21.5 Ma), in agreement with the SIS ages of samples (Augey and Plantat, both F) with transitional M. gunteri-tani from the type Aquitanian.
New SIS data and also the revision of mollusks and calcareous nannoplankton (NN3) from sites traditionally assigned to the late Eggenburgian (Eggenburg, Brummstubengraben (A); Budafok, Kereszt Hill (H); Lipovany (SK) and Parád, Ilona Valley (H)] suggest that they rather belong to the early Ottnangian. These new data from the last three localities also indicate the Ottnangian closing of the N Hungarian – S Slovakian Paleogene Basin, which is confirmed by the revised age of the overlying Ipolytarnóc rhyolitic tuff (16.9–17.5 Ma), too.

Ottnangian (Ottnang; Limberg, base and top) and Karpatian (Kleinebersdorf) sites from Austria provided systematically younger SIS-ages than those reported in the literature. This discrepancy may be related to an increase of radiogenic Sr in the basin due to the increased erosion of the uplifted N Alps started from the Ottnangian. Further to the east, samples from both sides of the locally assigned Ottnangian/Karpatian boundary in Várpalota, Bánta-puszta (H) and also in Fót (H) provided similar SIS-ages corresponding to the latest Karpatian and mostly to the earliest Badenian. Similar SIS-ages came out from the Karpatian of N Hungary (Múcsony; Sajólászlófalva; Dédes and Csernely) and of NW Slovakia (Cerová-Lieskové).

Since the increase of the 87Sr/86Sr isotope ratio in the World Ocean became very slow starting at ca. 15 Ma, younger SIS-ages have a broad confidence interval. In our Badenian material this is a common case, thus based on their SIS ages our samples could only be arranged within this stage with very low resolution. The only exception is the Várpalota, Szabó quarry (H) site, from where SIS data reliably confirm the early Badenian age given in the literature.

Keywords: Sr-isotope stratigraphy, Central Paratethys, Kiscellian, Egerian, Eggenburgian, Ottnangian, Karpatian, Badenian

Chronological evolution constrains of the northern Pannonian Basin by authigenic 10Be/9Be dating: Danube Basin case studies

Šujan, Michal - miso@equis.sk – Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
Braucher, Régis - braucher@cerege.fr – Aix-Marseille Univ., CEREGE, CNRS INRA, Coll. De France, Aix-en-Provence, France
Klement Fordinál - State Geological Institute of Dionýz Štúr, Bratislava, Slovakia
Peter Joniak - Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
Oleg Mandic - Geological-Paleontological Department, Natural History Museum, Vienna, Austria
Michal Kováč - Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
Samuel Rybár - Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
AsterTeam - Aix-Marseille Univ., CEREGE, CNRS INRA, Coll. De France, Aix-en-Provence, France; Georges Aumaitre, Didier L. Bourlès, Karim Keddadouche, Valery Guillou

Constraining the geochronology of epicontinental depositional record of the Central Paratethys remains still a challenging issue. The authigenic 10Be/9Be dating method provides a strong geochronological tool for the late Cenozoic deposits, with possibility to date the event of sedimentation of clay particles (Bourlés et al., 1989; Šujan et al., 2016). The age calculation is based on the difference of sample 10Be/9Be ratio from initial isotopic ratio, which appeared during deposition. The initial ratio is used as a starting point, from which 10Be/9Be decreases with the half-life of 10Be (1.387 ± 0.012 Ma; Chmeleff et al., 2010), providing a chemically closed system. The ratio is formed during adsorption of beryllium to surface of clay particles in a water column. The source of both isotopes differs, 10Be being formed in the atmosphere by interaction of nitrogen with cosmic rays, while 9Be is derived from chemical weathering of rocks in a drainage basin.

The new data to be presented, follow the the authigenic 10Be/9Be dating pilot study of Šujan et al. (2016) aiming at producing precise timing information about selected depositional events in the Danube Basin (northern Pannonian Basin System). The first studied area (A on the Fig. 1) is located in the Malé Karpaty Mts., bounding the NW margin of the Danube Basin. The shallow lacustrine strata, which overlie pre-Cenozoic basement, contain Pannonian mollusc fauna and their 10Be/9Be age yielded 11.89 ± 0.44 Ma. The same horizon appears in elevation difference of 200 m in basin marginal sequence, which implies the intensity of post-Pannonian vertical movements. 10Be/9Be dating of samples from deltaic to alluvial late Miocene sequence (Beladice and Volkovce fms.; Sztanó et al., 2016) from boreholes (B in the Fig. 1) drilled in the SE margin of the Danube Basin allowed calculating possible accommodation rates for the period 10–8 Ma. These vary not only from the centre towards the basin margin (from 200–300 m/Ma to 130–190 m/Ma), but also along the margin (decrease to 40-90 m/Ma). The area with high accommodation rates match with high channel belt/overbank facies ratio in the alluvial Volkovce Fm. (average 40 % vs. 10 % in low accommodation rate area). Thus, variability in accommodation rate affected the alluvial depositional settings and distribution of channel belt bodies. Another locality of alluvial Volkovce Fm. was studied in the NW margin of the basin (C on the Fig. 1). The 10Be/9Be weighted mean age of 9.02 ± 0.28 Ma, is in good agreement with small mammal biostratigraphy early MN11 biozone, close to the transition between MN10 and MN11 biozones. The presented results show the high potential of the dating method in the Central Paratethys and its increasing reliability within more detailed applications with multiple dated samples providing that the initial ratio can be locally well established. The Slovak Research and Development Agency supported the research under the contracts Nos. APVV-14-0118 and APVV-16-0121.

The Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences (VEGA) supported the research within the project 1/0702/17.

Fig 1: Location of the case studies.

Keywords: geochronology, Pannonian Basin System, cosmogenic nuclides, Lake Pannon, terrestrial facies, lacustrine facies

The Early Evolution of the Molasse Foreland Basin, Austria: Depositional Environment and Stratigraphic Architecture of Deep-Water Deposits

Chayawan Jaikla1, Tim McHargue1, Donald R. Lowe1, Lorenz Scheucher2, and Ulrike Exner2
1Department of Geological Sciences, Stanford University, CA 94305
2RAG Exploration and Production, Vienna, Austria 1015

Sea floor topography resulting from deposition of submarine debris flows can strongly influence the pathways and deposition from subsequent turbidity currents. This study presents a methodology to understand roles of basin-scale mass transport deposits (MTDs) formed in the early stage of a foreland basin on subsequent processes of basin filling. The early evolution of the Austrian Molasse basin is not well understood due to a complex geologic structure near the Alpine fold-and-thrust belt. Seismic data from the coarse-grained gravity flows deposits that accumulated during the early stage of the basin evolution, represented by the Rupelian Sandstone and lower Puchkirchen Formation have different characteristics than those of the well-studied channel complex in the later stages represented by the upper Puchkirchen and basal Hall formations. The upper Puchkirchen and basal Hall formations have been interpreted to deposit along the axis of a 3–5 km wide channel complex that was active along the axis of the Molasse basin. We utilized multi-scale, subsurface data including cores, well logs, and 3D seismic data to understand both the fine-scale sedimentology and the large-scale lithofacies distributions. This study reveals that during the early basin development multiple basin-scale MTDs covering areas of 10s km2 acted as conduits and controlled the deposition of subsequent turbidity currents. We propose three stages of the evolution in the Molasse basin: (1) deposition of MTDs and potentially local turbidites in low topography areas, (2) subsequent turbidity current deposition conforming to antecedent MTD topography, (3) development of an organized and meandering channel complex. MTDs play an important role during the early evolution of the basin controlling the general distribution and facies architecture of overlying turbiditic sandstone deposits. Recognizing the stratigraphic architecture and geometries of MTDs in the subsurface is key to identifying the spatial distribution of these deposits as well as overlying turbidites in the Molasse basin.

The early Miocene Calcite Minimum Interval: Pinning down upper Ottnangian Molasse stratigraphy

Palzer-Khomenko, Markus (University of Vienna, Wien, AUT); Wagreich, Michael (University of Vienna, Vienna, AUT); Knierzinger, Wolfgang (University of Vienna, Vienna, AUT); Meszar, Maria E. (University of Vienna, 1090, AUT); Gier, Susanne (University of Vienna, Vienna, AUT)

The lower Miocene stratigraphy constitutes a major challenge for Paratethys research where both national borders and insufficient biostratigraphic resolution resulted in contradictory stratigraphic concepts. Regional Central Paratethys stages and substages such as the Eggenburgian, Ottnangian and Karpatian pose a high resolution in a floating time/chronostratigraphic framework. Recent work demonstrated, that much of these concepts and models for the Molasse and Vienna Basin and therefore the age of these strata must be revised. But important fossils needed for an explicit allocation to certain regional stages are often absent. Therefore, additional tools and time levels for a detailed stratigraphic correlation are needed such as short-time paleoclimate and/or paleoenvironmental events.

We demonstrate the existence of an interval of sediments in the eastern part of Lower Austrian Molasse Basin with significantly reduced calcite and pyrite contents, identified as “Calcite Minimum Interval” (CMI). These sediments are barren in micro- and nannofossils and correspond to the (exposed) Traisen Formation and its deep distal continuation, the newly defined Wildendürnbach Formation (well data provided by OMV). According to microfossil data from below and above these deposits, a late Ottnangian age (within nannofossil zone NN4) is inferred.

The upper Ottnangian Traisen Formation was deposited in brackish waters attributed to the late Ottnangian Rzehakia Lake System. We interpret the CMI as the biotic, mineralogical and chemical expression of restricted deposition in the Molasse basin during the time interval of the Rzehakia Lake System. This late Ottnangian thus event correlates to the time interval of a distinct phase of brackish lakes in the Paratethys realm due to the Burdigalian Bur4 regression and subsequent sea-level lowstand at around 17.2 Ma, representing the Ottnangian/Karpatian boundary. Therefore, the CMI as expression of this paleoenvironmental event constitutes a valuable tool for an exact localization of the very short (ca. 0.2 Ma) time span of the late Ottnangian with its mostly fossil-free deposits in Lower Austria. This allows the detailed definition and correlation of lithostratigraphic units throughout the lower Austrian Molasse Basin, to the Vienna Basin and to the continuation of the Molasse Basin in the Czech Republic. Furthermore, two in time and space independent sedimentary systems and sand depositional centers are identified in the lower Miocene of the Lower Austrian Molasse Basin. A late Ottnangian sand transport system in the south of the basin delivered the material of the Traisen Formation from the Eastern Alps. The younger (early) Karpatian system delivered clastic material of the massive sands of the Laa Formation overlying the Wildendürnbach Formation from the east, partly from the Western Carpathians (formerly assigned to the loosely defined term “Oncophora beds”) transported through the Vienna Basin.

Regional tectonics versus global climate – which process governed the depositional environments in the Central Paratethys?

Harzhauser Mathias1, Mandic Oleg1, Kranner Matthias 1,2, Piller E. Werner2, Strauss Philipp3, Siedl Wolfgang3
1 Geological-Palaeontological Department, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria; matthias.kranner@nhm-wien.ac.at; mathias.harzhauser@nhm-wien.ac.at; oleg.mandic@nhm-wien.ac.at;
2 Institute of Earth Sciences (Geology and Palaeontology), University of Graz, NAWI Graz Geocenter, Heinrichstraße 26, 8010 Graz, Austria; werner.piller@uni-graz.at
3 OMV Exploration & Production GmbH, Trabrennstraße 6-8, 1020 Vienna, Austria; philipp.strauss@omv.com; wolfgang.siedl@omv.com

The differentiation between the impact of tectonic movements versus expression of global sea level fluctuations is an ongoing discussion in interpreting depositional architecture of sedimentary basins. Large surface or subsurface outcrops, unconformity bound sedimentary bodies observable over a relevant distance, a detailed paleoecological analysis and a tight stratigraphic corset are the prerequisites for any attempt to evaluate the ratio between these mechanisms. Due to their highly active tectonic environment, the Central Paratethyan basins are exceptionally challenging targets to approach this problem. Herein we present the Vienna Basin as an exemplary case to check for fits and misfits of the stratigraphic record with global climate and 3rd order sea level change, based on new 3D-seismic surveys of the up to 6000 m thick Neogene basin fill coupled with an intensive revision and reassessment of biostratigraphic data from numerous wells in its central and northern parts. Especially the change of the tectonic regime, from piggy-back basins with halfgraben formation towards a pull-apart mechanism around the early/middle Miocene boundary is the pivotal point to compare the depositional regimes and their response to global climate change.

An integrated stratigraphic cross correlation through the major oil fields in the Vienna Basin, Austria

Kranner Matthias [1,2], Harzhauser Mathias[1], Mandic Oleg[1], Piller Werner E.[2], Strauss Philipp[3], Siedl Wolfgang[3]
[1] Geological-Palaeontological Department, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria; matthias.kranner@nhm-wien.ac.at; mathias.harzhauser@nhm-wien.ac.at; oleg.mandic@nhm-wien.ac.at;
[2] Institute of Earth Sciences (Geology and Palaeontology), University of Graz, NAWI Graz Geocenter, Heinrichstraße 26, 8010 Graz, Austria; werner.piller@uni-graz.at
[3] OMV Exploration & Production GmbH, Trabrennstraße 6-8, 1020 Vienna, Austria; philipp.strauss@omv.com; wolfgang.siedl@omv.com

The Vienna Basin is an intra-Alpine pull-apart basin, which originated during the early middle Miocene. Due to the complex tectonic setting the intra-basin correlation of the Miocene strata penetrated in the wells drilled within the Vienna Basin remain difficult. Our study aims to have an improved stratigraphic correlation using a north-south seismic cross-section throughout the Vienna Basin. This regional-scale correlation is supported by biostratigraphic data using numerous drill cores from four major oilfields (Rabensburg, Bad Pirawarth, Matzen and Aderklaa).

One of the main objectives is to obtain information about the thickness and stratigraphic range of supposed lower and middle Miocene deposits, as they tend to vary considerably in thickness from well to well. The tectonic setting impedes with a straightforward correlation of single 3D seismic reflectors due to mayor hiatuses between stratigraphic units, therefore the use of biostratigraphic data is critically important. Interpretation and correlation of thickness and distribution of the various Miocene formations is challenging in parts of the Vienna Basin due to major canyon structures and other erosive features. These have been unknown from surface outcrops and therefore existing lithostratigraphic schemes needed a re-evaluation. The main new results are based on benthic and planktic foraminifera with the assignment of the deposits to regional biostratigraphic zones allowing correlation with the global stratigraphic stages. In addition, paleontological data have been used to describe the paleoecological settings and changes of depositional environments.

The integration of well-log data (such as spontaneous potential and resistivity) with 3D reflection seismic data also provided information about the paleoenvironments and paleogeography during the deposition of the Miocene units. Furthermore, misinterpretations concerning the local stratigraphic setting were addressed and resolved. As a result, a new model of intra-basin correlation of the units spanning the Paratethyan Miocene stages of Ottnangian, Karpatian and Badenian, as well as underlying units, such as the Eocene flysch deposits, is accomplished. The new litho- and biostratigraphic scheme for all the seismic units will provide a framework for a refined sequence stratigraphic scheme of the Vienna Basin.

Keywords: Stratigraphy, Miocene, Central Paratethys, Vienna Basin

A revised sequence stratigraphic framework and depositional model of the (Austrian) Vienna Basin based on 3D seismic survey and its application for future near field hydrocarbon exploration.

Siedl Wolfgang[1], Strauss Philipp[1], Harzhauser Mathias[2], Kuffner Thomas[1]
1 OMV Exploration & Production GmbH, Trabrennstraße 6-8, 1020 Vienna, Austria; wolfgang.siedl@omv.com, philipp.strauss@omv.com, thomas.kuffner@omv.com
2 Geological-Palaeontological Department, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria; mathias.harzhauser@nhm-wien.ac.at

In the Austrian part of the Vienna basin, hydrocarbon exploration has taken place for more than 90 years. Over 3400 wells were drilled in this area, developing the giant oil and gas field of Matzen (FUCHS & HAMILTON, 2006). According this data set, several attempts were carried out in the past to set up a sequence stratigraphic framework of the Middle Miocene in the Vienna Basin. Starting in the late 80's, depositional systems and their related petroleum systems were mainly interpreted based on well data. Due to limited quality, seismic data interpretation was of only minor importance.

Detailed work was focused on producing fields. Wells drilled between these production fields were used for cross correlation, to establish a regional sequence stratigraphic framework (KREUTZER, 1986).

Based on a sequence stratigraphic model developed for the southern part of the Vienna Basin (STRAUSS et al., 2006) a new approach of spatial 3D seismic interpretation applied to construct a revised sequence stratigraphic framework of the Middle Miocene (Badenian) in the central and northern part of the (Austrian) Vienna Basin. Seismic survey and well data were used to define relatively conformable successions of genetically related strata. These contemporaneous depositional systems of Badenian successions were used to define system tracts and were calibrated with results of biostratigraphic and sedimentological core data. Third order sequence boundaries and maximum flooding surfaces were selected and correlated with Paratethys sea level curves.

As a next step syn- to postsedimentary tectonic events were included to create gross depositional environment maps (GDE maps), as an important de-risking parameter for play, lead and prospect assessment in the oil industry. Finally, depositional systems of major third order sequences were interpreted and extended to adjacent areas (e.g. to the southern part of the Vienna Basin or the Alpine-Carpathian Foredeep) and incorporated into regional Paratethys palinspastic maps.

A concise development history of the Vienna basin

Samuel Rybár[1], Michal Kováč[1], Branislav Šály[2], Ľubomír Sliva[2], Petronela Nováková[1], Tomáš Vlček[1], Tamás Csibri[1]
[1]-Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
[2]-NAFTA a.s., Plavecký Štvrtok, Slovakia

The Vienna basin came into being due to the Neogene development of the Alpine-Carpathians junction area, which was influenced by the continental oblique collision of the orogenic system with the European platform. The early Miocene development was marked by the Flysch Belt accretionary wedge development in the north-western part. The middle Miocene rifting of the Central Alpine and Central Carpathian basement was followed by subsequent exhumation of mountain ranges in the basin surroundings, which continued to supply material up to the late Miocene. The produced deposits can be studied in outcrops on the eastern margin of the Leitha, Malé Karpaty and in the Brazovské-Čachtické Karpaty Mountains. However full understanding of the depositional systems would not be possible without the knowledge gained from thousands of exploration wells and from 2D, 3D reflection seismic sets. Changing geodynamic conditions within and around the Vienna Basin resulted in the evolution of various basin types. The oldest Burdigalian (Eggenburgian, Ottnangian, and partly Karpatian) deposits belong to a wedge top (piggy-back) basin fill. The following development is represented by initial rifting of the Vienna Basin depocenters which took place during the late Karpatian (Kováč et al. 2004). The basin syn-rift stage depended on regional tectonics, and started after a significant sea level fall around the lower/middle Miocene boundary (Harzhauser et al. 2018). The following global sea level rise together with the accommodation space growth (Kováč et al. 2018) during the Langhian (lower Badenian) is well documented in the Central Paratethys as a whole. During this time the basin can be interpreted as pull-apart or as a fore-arck type. The post-rift subsidence possibly started in the late Serravallian (Sarmatian). The Tortonian (Pannonian) subsidence led to basin overfill and bypass of sediments toward the Danube Basin, situated in the east (Magyar et al. 2013). Acknowledgement: The authors express their gratitude to the research projects APVV-15-0575 and APVV-16-0121. Special thanks goes to the management of NAFTA a.s. for allowing access to reflection seismic data and to the well core repository.

References

Harzhauser M., Theobalt D., Strauss P., Mandic O., and Piller W. E. 2018. Seismic-based lower and middle Miocene stratigraphy in the northwestern Vienna Basin (Austria) Newsletters on Stratigraphy. Published online. DOI: 10.1127/nos/2018/0490
Kováč M., Baráth I., Harzhauser M., Hlavatý I. and Hudáčková N. 2004. Miocene depositional systems and sequence stratigraphy of the Vienna Basin. CFS Courier Forschungsinstitut Senckenberg 246(246),187-212.
Kováč M., Márton E., Klučiar T., and Vojtko R. 2018. Miocene basin opening in relation to the north-eastward tectonic extrusion of the ALCAPA Mega-Unit. Geologica Carpathica 69(3), 254-263.
Magyar I, Radivojević D., Sztanó O., Synak R., Ujszászi K., Pócsik M. 2013. Progradation of the paleo-Danube shelf margin across the Pannonian Basin during Late Miocene and Early Pliocene. Global and Planetary Change 103, 168–173.

Chemostratigraphy and lithostratigraphy of Sękówka Creek between Gorlice and Sękowa – surface offset for oil&gas exploration wells of the Silesian Unit (Outer Carpathians)

Jan Hejnar[1], Krzysztof Starzec[2], Aneta Wronka[3], Wojciech Schnabel[3]
[1]Polish Academy of Sciences - Institute of Geological Sciences, Krakow, Poland
[2]AGH – University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Krakow, Poland
[3]Geokrak Ltd., Krakow, Poland

Geochemical analyses of rocks samples have been conducted and integrated with field-based geological and sedimentological studies in order to evaluate applicability of chemostratigraphy for hydrocarbon exploration. The Gorlice area in the Polish Outer Carpathians, which are the oldest petroleum province in the world, has been chosen for these studies. This geological setting is highly complex due to thrust belt architecture and lateral changes in clastic facies distribution, which significantly affect efficiency of oil&gas exploration. Fold-type structural setting, gives a good opportunity to trace flysh sedimentary sequences outcropping in the field.

Near 2000 m thick geological section along Sękówka Creek has been sampled between Gorlice and Sękowa. The section represents the Eocene to Oligocene interval of the Silesian Unit succession. Geological sampling has delivered 1478 samples for lithostratigraphic and chemostratigraphic purposes. Samples have been crushed, dried and homogenized for geochemical analyses. XRF analyses have been conducted in Geokrak laboratory in Cracow, using portable XRF device Bruker S1 Titan 600, with elemental range from Mg to U. Basing on field-work, lithostratigraphic assignments have been established. Within them facies associations have been distinguished. Correlation of lithostratigraphy with geochemical data reveals that each formation is characterized by a specific geochemical fingerprint. Moreover, numerous chemostratigraphic packages and sub-packages have been differentiated. Analysis of anoxia tracers gave an opportunity to identify source rocks horizons. Additionally, geochemical results provided gamma-ray equivalent curves.

Detailed sampling of field geological section, accompanied by multidisciplinary geological and geochemical approach, provided a unique quality offset data for exploration and production wells. Chemostratigraphy gives an opportunity for high resolution stratigraphic control over drilled section and good match with traditionally used lithostratigraphic units. Source rocks identification brings significant information regarding petroleum system. Gamma-ray equivalents may be used for offset control and enables possibility to drill wells without gamma-ray MWD tools. Application of XRF analysis on field sections as well as archival cores and cuttings could be extremely beneficial for drilling exploration and production wells with XRF cuttings geochemical control.

Changes in calcareous nannoplankton assemblages and the evolution of biomarkers in the Hungarian Paleogene Basin (Central Paratethys)

Anita Nyerges[1], Ádám T. Kocsis[3], József Pálfy[1,2] and Iuliana Vasiliev[4]*

[1] Department of Physical and Applied Geology, Eötvös Loránd University, Pázmány Péter sétány 1/C, Budapest H-1117, Hungary
[2] MTA-MTM-ELTE Research Group for Paleontology, P.O. Box 137, H-1431 Budapest, Hungary
[3] GeoZentrum Nordbayern, Department of Geography and Geosciences, Universität Erlangen-Nürnberg, Loewenichstraße 28, 91054 Erlangen, Germany
[4] Senckenberg Biodiversity and Climate Research Centre (BiK-F), Senckenberganlage 25 D-60325 Frankfurt am Main, Germany
[*]Corresponding author: anyerges@caesar.elte.hu

The Eocene-Oligocene climate transition (EOT) is the last major greenhouse-icehouse shift in Earth history, ending the warm, ice-free early Paleogene world and ushering in the Antarctic glaciation.

The Paratethys was a unique epicontinental sea between ~34–12 Ma, formed after closure of the Neotethys Ocean, in a paleogeographically complex area affected by the ongoing Alpine orogeny. This study is focused on the Hungarian Paleogene Basin within the Central Paratethys, aiming to characterize the effect of the global cooling event in the calcareous nannoplankton assemblages and to reconstruct the paleoenvironmental evolution of the region across the EOT. Calcareous nannoplankton biostratigraphy is focused on documenting the NP 21 zone, which includes the Eocene/Oligocene boundary. Hierarchical cluster analysis allowed us to distinguish five successive assemblages in the studied core section. Thereby defined phases of calcareous nannoplankton community evolution are compared with recently published trends in δ18O and δ13C isotope values and foraminiferal changes, enabling more robust paleoecological inferences. Taxa with preference for oligotrophic and warm surface waters dominate the lowest assemblage. The next assemblage is marked by increased nannoplankton turnover. At the onset of the EOT a phase of eutrophication accompanies the incipient cooling, when taxa adapted to cold surface waters gradually became dominant. Nannoplankton abundance drops to a minimum in the third phase, which is interpreted to represent the arrival of the cooling event. A gradual rebound of nannoplankton abundance is observed in the fourth phase when ameliorating environmental conditions are inferred, possibly affected by regional climate change related to the uplifting Alpine chain. After the end of the EOT the youngest assemblage includes mostly euryhaline taxa which could tolerate an increased rate of freshwater and terrestrial influx. These stepwise changes in calcareous nannoplankton assemblages are comparable to the global trends, suggesting that the environmental and biotic evolution in the Central Paratethys were affected by the onset of Antarctic glaciation and regionally the ongoing Alpine orogeny across the EOT.

The abundance of taxa within Noelaerhabdaceae calcareous nannoplankton family and co-occurring alkenone distribution was also observed in this research project. The main scientific question is who are the primary producers of the long-chain, unsaturated n-ketones in the Central Paratethys marine sediments?

Keywords: EOT, Central Paratethys, calcareous nannoplankton assemblages, multivariate analysis, paleoenvironmental reconstruction, biomarker.

Paleoceanographic evolution of the Hungarian Paleogene Basin during the Early Oligocene on the basis of the micropaleontological and geochemical data

Ozsvárt, Péter – ozsvart.peter@nhmus.hu - MTA-MTM-ELTE - Research Group for Paleontology, POB 137 Budapest, H-1431 Hungary
Vető, István - vetoie3840@gmail.com – consultant, H-1026, Budapest, Balogh Á. u. 18/c, Hungary
Nagymarosy, András – Deceased

We studied two boreholes (Csv-1 and Ad-3) with continuous sedimentary records across the Eocene-Oligocene climate transition from the eastern and western edge of the Hungarian Paleogene Basin in order to better understand the paleoceanographic evolution of this basin. This greenhouse–icehouse climatic transition has been extensively studied worldwide; however, few studies have concentrated on isolated marginal seas, like the Central Paratethys. A coupled use of multivariate statistical analysis of benthic foraminiferal fauna (e.g. oxygen index (BFOI), Q-mode principal component analysis, diversity, etc. of benthic foraminifera) and geochemical data (mostly Carbon and Sulphur isotopes) shows the Hungarian Paleogene Basin underwent a progressive decrease of both of salinity and bottom-water oxygen level during the NP 22. The slowness of this process corresponds to that of the driving mechanism, i.e. of the diffusion of salts from below the storm-base. During the earlier part of the NP 23 the water column was stratified, the oxygen level of the bottom water was very low (<0.2 ml O2/l) and the salinity of the upper water layer was below 12-14‰. The NP 22 and the lower part of the NP 23 correspond the deposition of the frequently laminated Tard Clay, a marly then silty oil source rock of upward improving quality.

In the borehole Csv-1 (the upper part of the NP 23), the Tard Clay is abruptly replaced by the non-laminated, organically lean Kiscell Clay, characterized by re-appearance of rich benthic foraminifera community and presence of marine subtropical nannoplankton association. These phenomena suggest an improvement of connection with the Mediterranean or other surrounding open ocean. A similar scenario may have been observed in the borehole Ad-3, although the uppermost part of the Tard Clay is non-laminated and is discordantly covered by coarse-grained strata followed by the Kiscell Clay. All of this suggests a difference in tectonic activity during the upper part of the NP 23 between the western and eastern edge of the basin.

The rapidity of the re-establishment of normal marine conditions by water inflow from the surrounding open ocean corresponds to that of the driving mechanism, the sinking of the dense seawater to the bottom.

Keywords: Paratethys, Hungarian Paleogene Basin, Benthic Foraminifera, Stable isotopes

The Miocene in Slovenia, western Central Paratethys; an overview

Mirka Trajanova1, Kristina Ivančič[1]
[1]Geological Survey of Slovenia, Dimičeva ulica 14, Ljubljana; mirka.trajanova@geo-zs.si , kristina.ivancic@geo-zs.si

Mayor part of the modern Slovenian territory was covered by the intracontinental see of the Central Paratethys (CP) during the Late Paleogene and the earliest Neogene. The CP basins extended in E-W direction and were surrounded by hilly areas of the Eastern and Southern Alps to the north and west, forming hinterlands and separate inselbergs and submarine highs, and the Dinarides to the west and south-west. In-between, sea pathways toward the Mediterranean were establishing and closing depending on the interplay of global sea level oscillations and tectonic events. In addition, climate changes contributed to development of diverse depositional environments, which enable regional biostratigraphic correlation. The disrupted connections coincided with the global transgression/ regression cycles of Haq et al. (1988). The basins represented accommodation space for deposition of prevailingly clastic sediments, delivered to the basins by fluvio-deltaic systems and gravity flows.
Miocene sedimentary rocks cover mostly E part of the Slovenian territory. They evolved in two major basins, dominantly in the Mura-Zala Basin (MZB) and subordinately in the Styrian Basin. Their structural characteristics reflect gradual approximately E-W directed extensional subsidence of the Pannonian Basin System (PBS) and gradual ingression of the CP Sea from the east toward the west. South of the MZB, smaller Krško Basin existed, which was opened toward the east-southeast. Sedimentary successions in the basins reflect transgression-regression cycles consistent with the global events.

After significant end-Egerian break, marine sedimentation continued in the MZB (Jelen et al., 2008). Its western hinterlands were still exposed to erosion, yielding Ottnangian (?) to Karpatian terrestrial sediments of mostly fluvial character. Talus sediments occur locally, pointing to relatively steep Eastern and Southern Alpine dry land along the northern to western basin's flanks (Ivančič et al., 2018). The rocks of the MZB are divided into five formations: Haloze, Špilje, Lendava, Mura and Ptuj-Grad (Jelen et al., 2008). Each formation has characteristic sedimentary succession, which was deposited from terrestrial to neritic, and bathyal environment, ranging in time from Karpatian to Pontian (Fodor et al., 2011).

Marginal dry land was partly flooded by shallow sea of CP for a shorter period in the transition from Ottnangian to Karpatian. Established marine environment appertains to the first Miocene transgression cycle TB 2.2, correlated with the NN4 Zone (Ivančič et al., 2018). In this period, connection with the Mediterranean was established via the Slovenian corridor. The succession has turbiditic character (Fodor et al., 2011) and is named Haloze Formation.

Transition from the Karpatian to the Badenian is marked by the Styrian unconformity. The beginning of the Badenian (Langhian and Early Serravallian) is characterized by the second transgression pulse. Then, the sea reached its maximum extent (Mandic et al. 2002). It is correlated to the global sea-level rise, and corresponds to the TB 2.3 transgression cycle. During the highstand system tract marginal Slovenj Gradec and Lavanttal Basins were completely flooded, and probably established a connection with the Klagenfurt Basin (Ivančič et al., 2018).
The Haloze Formation is covered by the Špilje Formation deposited in the MZB during Badenian and Sarmatian. The sediments were deposited in shallow marine and terrestrial environments, and reflect exchanging transgressive-regressive cycles of the Badenian and Sarmatian. In the Slovenske Gorice area, transition from the marine Karpatian and Badenian rocks in the western part to the brackish Sarmatian sand and marl is exposed to the east (Bartol, 2014).

South-east of the MZB, i.e. in the B1 unit (sensu Jelen et al., 2008), longer persistence of marine conditions is

documented. The evidence was found in the Upper Panonian and Lower Pontian Lendava formation of which the lower part expresses regression cycle, while the upper part represents delta front. Lendava formation store significant quantities of oil and gas (Hasenhuttl et al., 2001) and oil-prone thermal water (Kralj & Kralj, 2000). The lower Pannonian to Upper Pontian sediments of the Mura formation are divided into delta front and delta plain, while the Ptuj-Grad formation already consists of alluvial sediments, which mark the end of marine deposition. The Paratethys Basins in Slovenia are presented in more detail by Jelen et al. (2008).

References:

Bartol M., Mikuž V., Horvat A. 2011. Palaeontological evidence of communication between the Central Paratethys and the Mediterranean in the late Badenian/early Serravalian. Palaeogeography, Palaeoclimatology, Palaeoecology 394, 144–157.

Fodor, L., Uhrin, A., Palotás, K., Selmeczi, I., Nador, A., Tóth-Makk, Á., Scharek, P., Rižnar, I., Trajanova, M. 2011. Geološki konceptualni model v okviru projekta »Pregled rabe geotermalne energije, ocena podzemnih teles termalne vode in priprava skupnega načrta upravljanja vodonosnikov v Mursko-zalskem bazenu«: T-JAM. Ljubljana, Budimpešta: 60 str.

Haq, B.U., Hardenbol, J., Vail, P.R., 1988. Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. In: Wilgus, C.K., et al. (Eds.), Sea-Level Changes. SEPM, Tulsa, pp. 71–108.

Hasenhüttl, C., Kraljić, M., Sachsenhofer, R.F., Jelen, B. & Rieger, R. 2001. Source rocks and hydrocarbon generation in Slovenia (Mura Depression, Pannonian Basin). Marine and Petroleum Geology, 18/1: 115–132. doi:10.1016/ S0264-8172(00)00046-5

Ivančič K., Trajanova, M., Ćorić, S., Šmuc, A. 2018: Miocene paleogeography and biostratigraphy of the Slovenj Gradec Basin: a marine corridor between the Mediterranean and Central Paratethys. Geologica Carpathica 69/6, 528-544.

Jelen, B., Rifelj, H., Skaberne, D., Poljak, M., Kralj, P., 2008. Slovenian Paratethys basins. In: McCann, T. (Ed.) The Geology of Central Europe: Mesozoic and Cenozoic. Geological Society Pub. House, London, pp. 1098–1102.

Kralj, P. & Kralj, Po. 2000: Thermal and mineral waters in north-eastern Slovenia. Environmental Geology, 39/5: 488–500. doi:10.1007/s002540050455.

Mandic O., Harzhauser M., Spezzaferri S. & Zuschin M. 2002: The paleoenvironment of an early Middle Miocene Paratethys sequence in NE Austria with special emphasis on paleoecology of mollusks and foraminifera. Geobios 35, 1, 193–206.

Integrated bio-magnetostratigraphy of the Badenian reference section Ugljevik in southern Pannonian Basin - implications for the Paratethys history (middle Miocene, Central Europe)

Oleg Mandic [1], Karin Sant [2], Mădălina-Elena Kallanxhi [3], Stjepan Ćorić [4], Dörte Theobalt [1], Patrick Grunert [5], Arjan de Leeuw [6], Wout Krijgsman 2

[1] Geological-Paleontological Department, Natural History Museum, Burgring 7, 1010 Vienna, Austria.
[2] Paleomagnetic Laboratory Fort Hoofddijk, Department of Earth Sciences, Utrecht University, Budapestlaan 4, 3584 CD Utrecht, The Netherlands.
[3] Department of Geology, Faculty of Biology and Geology, Babeș-Bolyai University, M. Kogălniceanu 1, 400084 Cluj-Napoca, Romania.
[4] Geological Survey of Austria, Neulinggasse 38, 1030 Vienna, Austria.
[5] Institute of Geology and Mineralogy, Faculty of Mathematics and Natural Sciences, University of Cologne, Zülpicher Str. 49a, 50674 Köln, Germany.
[6] Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, IFSTTAR, ISTerre, 38000 Grenoble, France

The Central Paratethys was a large-scale Oligo-Miocene epicontinental sea located in Central and Eastern Europe. It was separated from the Mediterranean by the Alpine orogenic belt. The Paratethys progressively flooded the Pannonian back-arc basin that formed during the early to middle Miocene. Along the southern margin of the basin, the maximum extension of the Paratethys onto the flanks of the Dinarides Mountains occurred during the middle Miocene (Badenian). We have studied the most complete middle Miocene (Badenian-Sarmatian) Paratethys section located at this southern margin. It comprises a more than 1.5 Myr long, continuous marine depositional sequence, which is highly relevant for our understanding of the interplay between global climatic and regional geodynamic perturbations in this semi-isolated epicontinental basin. The investigated record is particularly important to assess the impact of the Middle Miocene Climate Transition, the Langhian-Serravallian glacial Mi-3b event, the syn-rift climax of the Pannonian Basin and the Badenian Salinity Crisis. Moreover, we present the first high resolution age model for the regional Badenian stage based on integrated biomagnetostratigraphy. According to our age model, the marine flooding reached the area at ~14.15 Ma, during the regional Badenian stage. Open marine conditions persisted until ~12.6 Ma when the extinction of the fully marine fauna marks the beginning of the regional Sarmatian stage. Sea-level fluctuations are reflected in the section by four transgressive regressive cycles coinciding roughly with 400-kyr-eccentricity periods. The largest sea-level fall occurred after the first cycle and corresponds to the end of the Middle Miocene Climate Transition marked by glacial event Mi-3b. Elsewhere in the Pannonian Basin, this marked drop in base-level triggered deposition of evaporites during the Badenian Salinity Crisis. At Ugljevik however, there are no evaporites and the short-term Mi-3b regression was followed by a transgression and re-establishment of deeper marine conditions at 13.76 Ma, i.e. during the earliest Serravallian. Diversified planktonic and benthic assemblages suggest fully marine conditions with a persistent connection to the Mediterranean at this time. Such conditions prevailed until the mid Serravallian (latest Badenian) when sediment input increased and coastal environments prograded seawards. The Badenian/Sarmatian boundary roughly coincided with a 400-kyr-eccentricity as well as with a 1.2-Myr obliquity minimum.

Lake Pannon calcareous marls in the SW Pannonian Basin: lithology, stratigraphy and bounding surfaces

Sebe, Krisztina - sebe@gamma.ttk.pte.hu – University of Pécs, Department of Geology and Meteorology, Pécs, Hungary
Magyar, Imre - immagyar@mol.hu – MOL Plc. & MTA-MTM-ELTE Research Group for Paleontology, Budapest, Hungary
Kovačić, Marijan - mkovacic@geol.pmf.hr – University of Zagreb, Faculty of Science, Zagreb, Croatia
Sztanó, Orsolya - sztano@caesar.elte.hu – Eötvös Loránd University, Budapest, Hungary
Botka, Dániel - botkadani@gmail.com – Department of Palaeontology, Eötvös Loránd University, Budapest, Hungary
Csoma, Vivien - csoma.vivien7@gmail.com – Department of Palaeontology, Eötvös Loránd University, Budapest, Hungary
Szuromi-Korecz Andrea - kaszuro@mol.hu – Laboratories MOL, MOL Plc., Budapest, Hungary
Krizmanić, Krešimir - kresimir.krizmanic@ina.hr – INA Plc., Zagreb, Croatia
Kovács, Ádám - kovacs.adam13@gmail.com - Eötvös Loránd University, Budapest, Hungary

During the Late Miocene – Early Pliocene, Lake Pannon occupied the Central Paratethys basin. The lower part of its sedimentary succession is dominated by offshore calcareous marls. These marls are already in the viewfield of oil companies also as unconventional exploration targets. Although their industrial importance is potentially high, the widespread subsurface marl bodies have a restricted number of good outcrop analogues to be studied. This paper concentrates on two large sections on the two margins of the Drava Basin, which have recently been studied in detail: the Pécs-Danitzpuszta sand pit in the Mecsek Mts., southwest Hungary and the Našice quarry in the Krndija Mts. in northeastern Croatia. Investigations focused on lithology, fossils, stratigraphy and structural geology, with the aim of constraining the depositional time and environment of the sediments and to infer on factors influencing sedimentation. Results are evaluated together with further own data from smaller outcrops and boreholes and with literature references in the wider region.

In the two main sections calcareous marls overlie Sarmatian sublittoral sediments conformably. In Croatia the base of the Pannonian sediments is indicated by a change in lithology, from laminated marls to thin-bedded limestones. In Hungary the successions seems to be fairly continuous and micro- and macrofauna must be used to locate the boundary. However, in some cases there seems to be a discrepancy between the boundary indicated by molluscs and by foraminifers and/or ostracods. Lithologically, in Croatia the succession starts with an alternation of light grey thin-bedded limestones and calcareous marls, which gradually pass into massive grey marls. In Hungary, the lower part of the column can be a frequent alternation of thin-bedded limestones, marls and clays, while upsection the successions are dominated by light greyish calcareous marls with clay and sand interbeds. In both countries the lowermost unit of the marls contains a mollusc assemblage dominated by Radix croatica and Lymnocardium praeponticum (~11.62–11.45 Ma). Upward this fauna changes into an assemblage representing the Congeria banatica profundal mollusc biozone (~11.45–9.6 Ma) without a sharp change in the lithology. Above the elevated block south of the Mecsek Mts. the deposition of the marls only began in the latter biochron, directly above the Mesozoic basement. Syn-sedimentary fault arrays indicate that subsidence was not only caused by thermal sag but extensional/transtensional brittle deformation also played a role.

While deeper basins like the Drava Trough possess complete Upper Miocene successions, in the studied structurally marginal positions the marl successions are truncated and covered by younger deposits above an angular unconformity. In the Mecsek a deformed sand package above the marls indicates that sedimentation ceased because of the uplift of the immediate hinterland before ~10 Ma. The entire Mecsek area was flooded again between 8-7 Ma. In the Krndija Mts. the sands and silts overlying the marls seem to be somewhat younger than in Hungary based on the mollusc fauna. Sediments of similar lithology and fauna cover the marls unconformably also in N Bosnia and in the Fruška Gora in Serbia. These points refer to a regional geodynamic driver behind flooding in this part of the Pannonian Basin.

Keywords: Upper Miocene, unconformity, biostratigraphy, Drava Basin

Chronostratigraphy and geochronology of the Pannonian Stage in the Central Pannonian Basin

Magyar, Imre - immagyar@mol.hu [1],Sztanó, Orsolya - sztano.orsolya@gmail.com [2], Sebe, Krisztina - krisztina.sebe@gmail.com [3], Katona, Lajos Tamás - finci99@gmail.com [4], Csoma, Vivien - csoma.vivien7@gmail.com [2], Görög, Ágnes - gorog@ludens.elte.hu [2], Tóth, Emőke - tothemoke.pal@gmail.com [2], Šujan, Michal - miso@equis.sk [5] ,Braucher, Régis - regisbraucher@gmail.com [6], Ruszkiczay-Rüdiger, Zsófia - rrzsofi@geochem.hu [7], Koroknai, Balázs - koroknai@geomega.hu [8], Sant, Karin - karin.sant@gmail.com [9], Kelder, Nick - n.a.kelder@students.uu.nl [9], Krijgsman, Wout - W.Krijgsman@uu.nl [9]

[1]MOL Hungarian Oil and Gas Plc, Budapest
[2]Eötvös Loránd University, Budapest
[3]University of Pécs, Pécs
[4] Hungarian Natural History Museum, Zirc
[5]Comenius University of Bratislava, Bratislava
[6]CEREGE, Aix-en-Provence
[7]Hungarian Academy of Sciences, Budapest
[8]Geomega Ltd, Budapest
[9]University of Utrecht, Utrecht

Chronostratigraphic subdivision and correlation of the Upper Miocene – Pliocene deposits of Lake Pannon in the Pannonian Basin (=Pannonian Stage) is based on biochronozones defined by endemic molluscs, ostracods, and dinoflagellates, and correlated to the Global Polarity Timescale by means of magnetostratigraphy and radioisotopic dating of volcanic layers. This system has two major shortcomings. First, the biostratigraphic subdivision of the 7-4 Ma interval of the lacustrine sequence is almost entirely lacking. Second, geochronology of the younger part of the sequence (younger than 8 Ma) is poorly constrained because of the lack of radiometric ages and because of the disputable reliability of polarity measurements and magnetostratigraphic interpretations, most of which were performed in the 1980's.

A new stratigraphic standard for the Pannonian Stage is expected to emerge from the sedimentological, biostratigraphical, magnetostratigraphical, geochronological and seismic stratigraphical investigation of 6 drill cores that were drilled by Paks II Nuclear Power Plant Plc. as a preparatory step for the construction of a new power plant near the city of Paks, Central Pannonian Basin, between 2015 and 2016. The boreholes were drilled with continuous coring, and they fully penetrated the Pannonian sequence in a thickness of 390 to 675 m (the sixth drilling cored only the lowermost 80 m of the Pannonian). The cores include offshore clay marl deposited far from sediment entry points (Endrőd Fm), heterolithic clayey siltstones of a <200 m high shelf-margin slope (Algyő Fm), and several stacked deltaic deposits from prodelta silts to sandy mouth bars and channels of the delta plain (Újfalu Fm). The rich fossil record indicates the presence of the Congeria czjzeki and C. rhomboidea sublittoral mollusk zones, the Lymnocardium decorum, Prosodacnomya dainellii, and P. vutskitsi littoral mollusk zones, the Pontiadinium pecsvaradensis, Spiniferites validus and Galeacysta etrusca dinoflagellate zones, and the Hemicytheria croatica, Sinegubiella sublabiata – Amplocypris nonreticulata, and Bakunella dorsoarcuata – Thaminocypris pontica ostracod zones.

Paleomagnetic investigations showed that the natural remanent magnetization was mostly residing in greigite, and only two out of the 4 sampled cores possessed sample quality and resolution suitable for magnetostratigraphic purposes. According to the joint biochronostratigraphic and magnetostratigraphic correlations, the top of the Pannonian sequence (below the Pannonian/Pleistocene unconformity) is about 6.5-6.8 Ma, whereas the base of the Pannonian sequence is ca. 8.5 Ma in shallower and about 9.2 in deeper structural positions.

These results are well in agreement with preliminary results of authigenic 10Be/9Be age determinations from two cores suggesting that the top of the Pannonian sequence is about 6.5 Ma and its bottom is between 8.1-8.7 Ma old in shallow structural positions.

Crosschecking of biostratigraphic data, polarity zones, and Be ages between the boreholes by seismic stratigraphy is in progress; seismic interpretations revealed significant local departures from the regional NW to SE direction of progradation across the area. (NKFIH 116618 fund acknowledged.)

Overpressure and stress configuration of the North Alpine Thrust Front and Foreland Basin, SE-Germany

Michael C. Drews

Pore pressure and stresses play a key role before and while drilling, reservoir quality studies, the structural development of fold belts and sedimentary basins and ultimately in understanding basin hydraulics and petroleum migration. Despite extensively drilled in the second half of the 20th century; the origins of overpressure and configuration of the stress regime of the North Alpine thrust Front in SE-Germany are not well understood, yet, except for a few early studies (e.g. Müller et al., 1988). Thereby, the status quo assumption is that a thrust-faulting stress regime is present in the North Alpine Thrust Front, while overpressure formation in the North Alpine Thrust Front has been attributed to lateral compression (Müller et al., 1988). In contrast, there is clear consensus that disequilibrium compaction is likely the main cause of overpressure in the North Alpine Foreland Basin in SE-Germany (Drews et al., 2018; Müller et al., 1988). However, the stress regime of the North Alpine Foreland Basin in SE-Germany is still under debate and currently a strike-slip to thrust-faulting stress regime is assumed to be present in the North Alpine Foreland Basin in SE-Germany (e.g. Reinecker et al., 2010).

In this study, we analyzed and synthesized new and published results from velocity and drilling data (Drews et al., 2018) and published seismic cross-sections (Müller et al., 1988; Ortner et al., 2015) to gain an improved understanding on the pressure and stress configuration of the North Alpine Thrust Front and Foreland Basin. As a result, we demonstrate that there is clear evidence of a normal-faulting stress regime in the central part of North Alpine Foreland Basin in SE-Germany. In addition, we present evidence, that the stress regime of the North Alpine Thrust Front is likely changing across the detachment. These results are in concordance with latest numerical studies, addressing the mechanical evolution of fold-and-thrust belts (Gao et al., 2018; Obradors-Prats et al., 2017). However, our results also indicate that overpressure formation in the North Alpine Thrust Front is probably not related to lateral compression, rather than simple burial through overthrusting. The results give insights into the origin and timing of overpressure formation and therefore have great impact on future drilling campaigns and geological studies in the area (e.g. projects targeting the structural restauration of the North Alpine Thrust Front and/or modelling petroleum migration within the North Alpine Foreland Basin in SE-Germany) and in other fold-and-thrust-belt systems.

References

Drews, M.C., Bauer, W., Caracciolo, L., Stollhofen, H., 2018. Disequilibrium compaction overpressure in shales of the Bavarian Foreland Molasse Basin: Results and geographical distribution from velocity-based analyses. Mar. Pet. Geol.

Gao, B., Flemings, P.B., Nikolinakou, M.A., Saffer, D.M., Heidari, M., 2018. Mechanics of Fold-and-Thrust Belts Based on Geomechanical Modeling. Journal of Geophysical Research: Solid Earth 123, 4454-4474.

Müller, M., Nieberding, F., Wanninger, A., 1988. Tectonic style and pressure distribution at the northern margin of the Alps between Lake Constance and the River Inn. Geol. Rundsch. 77, 787-796.

Obradors-Prats, J., Rouainia, M., Aplin, A.C., Crook, A.J.L., 2017. Hydromechanical Modeling of Stress, Pore Pressure, and Porosity Evolution in Fold-and-Thrust Belt Systems. Journal of Geophysical Research: Solid Earth 122, 9383-9403.

Ortner, H., Aichholzer, S., Zerlauth, M., Pilser, R., Fügenschuh, B., 2015. Geometry, amount, and sequence of thrusting in the Subalpine Molasse of western Austria and southern Germany, European Alps. Tectonics 34, 1-30.

Reinecker, J., Tingay, M., Müller, B., Heidbach, O., 2010. Present-day stress orientation in the Molasse Basin. Tectonophysics 482, 129-138.

Stress field in the frontal part of the Eastern Alps from Image Logs

N. Levi[1], M. Habermueller[1], E. Piani[2,3], U. Exner[2], G. Wiesmayr[2], K. Holzer-Traxler[2], K. Decker[1]

[1]University of Vienna, Department of Geodynamics and Sedimentology, Althanstraße 14, 1090 Vienna, Austria
[2]RAG Exploration & Production, Schwarzenbergplatz 16, 1015 Vienna, Austria
[3]now at: RDG E& P GmbH, Schwarzenbergplatz 16, 1015 Vienna, Austria

The present day displacement of the Adriatic and European plate results in active convergence in the Eastern Alps, leading to folding and thrusting in the Southern Alps, crustal scale folding in the Tauern Window and lateral escape East of the Tauern window. Nevertheless, the tectonic regime in the frontal part of the Eastern Alps (i.e. the Molasse Basin between Salzburg and Steyr) was poorly constrained so far.

In this study, we inferred the orientation of the maximum horizontal stress (SHmax) in the frontal part of the Eastern Alps trough the analysis of the drilling induced borehole failures detected in FMI and FMS image logs of 62 wells. The use of high quality image logs delivered consistent mean in-situ stress orientations with low standard deviations (s.d.).

The results are grouped in three geographic sectors. Borehole breakouts were observed in all wells except one, whereas induced tensile fractures were detected only in four wells located in the Central sector. The mean orientation of SHmax is 002° (s.d. 11.1°) in the Western sector, 177° (s.d. 14°) in the Central sector and 174° (s.d. 12.4°) in the Eastern sector.

A moderate rotation of the SHmax orientation from N-S to NNW-SSE is observed from West to East. Drilling induced feature orientations suggest a prevailing strike slip regime for both Western and Central sectors where the SHmax is solely oriented N-S. In the Eastern sector, rotation of drilling induced features is locally observed at moderate borehole deviations, indicating a thrust regime. This finding agrees with the occurrence of Pleistocene terrasses that are reported to be offset by some major Alpine thrust faults in the Eastern sector. The onset of a thrust stress regime in the Eastern part of the study area is potentially related to the close vicinity to the Bohemian Massif spur.

Our findings not only fill a gap in the world stress map, but also provide critical information for the planning of wells in the area, both for the best suitable orientation of well paths and for wellbore stability management.

The North Alpine Foreland Basin between two thrust belts: exploration potential leftover?

Hans-Gert Linzer, hans-gert.linzer@rag-austria.at, RAG Exploration & Production GmbH

Systematic HC exploration of the North Alpine Foreland Basin (NAFB) started shortly after WW II, following earlier coincidental HC discoveries. Up to now, the NAFB is perforated by more than 1000 wells with HC targets and large parts of it have been covered by 2D and 3D seismic reflection surveys. In the last 60 years, the obvious structures have been drilled. Some potential traps have remained underexplored: stratigraphic and combined stratigraphic/ structural traps of the imbricated part of the NAFB, some areas of the south slope and deep- (>3 km) and ultra-deep (>5 km) structures below the thrust front.

The HC system consists of mixed biogenic and thermogenic gas trapped in a variety of reservoir types whereas the oil is trapped in Eocene, Cenomanian and basal Jurassic sandstones. Oligocene source rocks were redeposited by extensive submarine mass movements toward the HC kitchen below the thrust belt during Alpine collision and the formation of the foreland basin, thereby causing large additional HC potential.

One attempt in defining leftover structures consists in reevaluating the regional settings on a big scale. The basement of the NAFB was involved in the Central European Cretaceous inversion structures caused by the collision of the Iberian and European plates. Hercynian crystalline basement rocks were thrusted on their Mesozoic sedimentary cover. These basement pop-ups were peneplained in Late Cretaceous to Paleocene times. The NAFB is situated of top of this Cretaceous thick-skinned thrust belt, recently documented in deep wells and by 3D seismic.

The NAFB evolved during Tertiary (Eocene to Miocene) times during late Alpine orogeny and forms an up to 4 km thick sedimentary wedge in front of the thrust belt. The basin fill is characterized by deeper marine, west to east migrating axial channel systems. The southern margin of the NAFB was imbricated during the late stage of the Alpine orogeny. Deeper parts of the channel systems were incorporated in the foreland thrust sheets. The Neogene Alpine thrusting was strongly affected by the eastward lateral orogenic floating of the Eastern Alps. This process led to left-lateral transpressional structures within the thrust sheets and reservoir compartmentalization in field and reservoir scale which enabled gas traps in complex structural settings. Late-stage asymmetric uplift of the foreland basin probably caused a realignment of filled-to-spill structures. Underexplored stratigraphic traps occur on both, the north-slope and the imbricated south-slope, the latter showing higher sealing risks.

Although repeated reevaluations, remapping and reprocessing of seismic data indicate a substantial remaining potential in the southern part of the NAFB, the structural complexity of the foreland imbricates turns the imaging of valid structures and seal prediction into a frontier exploration challenge.

Kinematic Modelling in the Austroalpine Fold-and-Thrust Belt as a tool for de-risking in hydrocarbon exploration

Author : Habermueller, Mario - mario.habermueller@univie.ac.at – University of Vienna
Co Author : Grasemann, Bernhard - bernhard.grasemann@univie.ac.at – University of Vienna
Co Author : Exner, Ulrike - ulrike.exner@rag-austria.at – RAG Exploration & Production GmbH
Co Author : Wiesmayr, Gerhard - gerhard.wiesmayr@rag-austria.at – RAG Exploration & Production GmbH

Hydrocarbons have been successfully produced from the eastward continuation of the Northern Calcareous Alps (NCA), beneath the Neogene fill of the Vienna Basin, for several decades. In contrast, exploration in the NCA fold-and-thrust belt west of Vienna ceased in the 1990s. However, new attempts were recently made by RAG E&P to reassess the hydrocarbon potential of the Central and Eastern Zones of the NCA.
Here, we present new insights on the NCA's subsurface structure, derived from a research project based at the Alpine Front, where the leading edge of the NCA overthrusts the Penninic Flysch Zone and Alpine Foreland Basin. A structural field-study was conducted in the Ternberg- and Reichraming Nappes in Upper Austria, integrating field-mapping with 2D seismic and vintage well data. Published structural interpretations and cross-sections from this area argued for tight to isoclinal buckle folding with thickened hinge zones that were cut by relatively few thrust faults.
Our field-work detected fault-related folding rather than buckle folding, thus revealing a different structural style than previously suggested. Further, no isoclinal folds were observed; instead a high number of thrust faults were mapped; these control the geometry of the nappe stack. Thrust faulting occurred on all scales, causing upright repetitions of strata and passive rotation of structures by underlying thrust units. A consistent top-to-the-NNW shortening along the thrust faults was derived from fault-slip data, analysis of SCC'-fabrics and fold geometries. Fold axes are horizontal and trend ENE-WSW throughout the study area.
The structural interpretations are based on 2D- and 3D-kinematic forward modelling. A change in the structural style is evident across the study area: contraction was accommodated by fault-bend folding in the hinterland regions of the Reichraming Nappe, whereas fault-propagation folding, with typically steep front limbs and tipping faults, occurred in the Ternberg Nappe, at the Alpine Front. Commonly, the fault-related folds are stacked as duplexes or imbricate thrust systems as a consequence of the low thrust spacing. In particular, the frontal area, near the basal thrust of the NCA onto the foreland units, shows a marked decrease in the thrust spacing. Further complications arise from out-of-sequence kinematics along synclinal- and anticlinal breaks of folds.
The evidently high structural complexity and tectonostratigraphic evolution of the NCA pose a challenge for hydrocarbon exploration. This study highlights the benefits of structural field work for exploration purposes in an area where outcropping structures are directly related to the geometry of potential hydrocarbon reservoirs at depth. Detailed structural mapping and kinematic modelling are low-cost tools that provide indispensable information in addition to geophysical surveys (e.g. reflection seismic, gravimetric analysis), thus increasing the accuracy of structure interpretations.

Keywords: Northern Calcareous Alps, Fold-and-Thrust Belt, Kinematic Model

Structural model and hydrocarbon plays in the westernmost Polish Outer Carpathians.

Starzec Krzysztof[1], Barmuta Jan[1], Poprawa Paweł[1], Machowski Grzegorz[1]

[1]AGH – University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Krakow, Poland, e-mail: kstarzec@agh.edu.pl

Irrespective of very long oil and gas exploration and production in the Polish Outer Carpathians, until recent time little of attention has been paid to their most western part. New 2D seismic survey, as well as structural, petrophysical and geochemical analysis inspire for reevaluation of petroleum potential within this region. Based on seismic data, calibrated with wells and surface geology, we propose new interpretation of the fold-and-thrust belt structure within the area.

In contrary to previous interpretations, we suggest that the Silesian Unit terminates abruptly to the south and does not continue beneath the Magura Nappe cover. The Unit reveals relatively simple geometry with slightly deformed strata, gently dipping to the south, in which the Late Jurassic – Early Cretaceous formations built up its lowermost part. Moreover, the Menilite – Krosno formations and the Cretaceous complex present below the Magura Unit, as documented by deep wells, represent the Fore-Magura / Dukla Unit, rather than the Silesian one, and form an imbricated structure that directly overlays the basement. New evidences imply also that the basement, composed of crystalline rocks and Paleozoic sedimentary successions, may be involved in the Carpathian thrust and fold system, although seismic data are not unequivocal in this respect.

In the frame of the above structural model three different hydrocarbon plays are considered. The youngest and uppermost play can be assigned to the Dukla Unit, where the Menilite shales are the source rock and tight (fractured) Krosno sandstones reservoir, involved in the imbricated structure, can provide an adequate trap. The second play is linked with the sedimentary basement of the Outer Carpathians, in analogy to the hydrocarbon fields in the Czech Republic, where oils are accumulated in the Devonian to Carboniferous carbonates and terrigenous sediments as well as in fractured granitic rocks. The Upper Carboniferous coal seams serve there as the principal gas prone source rock. The third play refers to the unconventional potential of the Early Cretaceous (Verovice Shales) and the Lower Oligocene (Menilite) black shales of the Silesian Unit. Their high TOC content, proper maturation, considerable thickness, limited depth of burial and monoclinal geometry indicate potential for shale oil/gas exploration.

Acknowledgements. This research has been financially supported by National Centre for Research and Development grants no. BG2/ShaleCarp/14 and Statutory funds no. 11.11.140.176, Faculty of Geology, Geophysics and Environmental Protection, AGH UST.

Keywords: Outer Carpathians, fold-and-thrust belt, hydrocarbon plays

Miocene syn-rift structural evolution and sedimentation along the Kapos Line (Mid-Hungarian fault zone): implications for the convergence of ALCAPA and Tisza

Author : Musitz, Balázs – musitz.balazs@mbfsz.gov.hu; bmusitz@gmail.com – Mining and Geological Survey of Hungary, Department of Geological Research, Budapest, Hungary
Co Author : Selmeczi, Ildikó – selmeczi.ildiko@mbfsz.gov.hu – Mining and Geological Survey of Hungary, Department of Geological Research, Budapest, Hungary
Co Author : Markos, Gábor – markos.gabor@mbfsz.gov.hu – Mining and Geological Survey of Hungary, Department of Geological Research, Budapest, Hungary
Co Author : Bereczki, László – bereczki.laszlo@mbfsz.gov.hu – Mining and Geological Survey of Hungary, Department of Geological Research, Budapest, Hungary; ELTE Eötvös Loránd University, Department of Geophysics and Space Science, Budapest, Hungary
Co Author : Horváth, Ferenc† – frankh@ludens.elte.hu – ELTE Eötvös Loránd University, Department of Geophysics and Space Science, Budapest, Hungary; Geomega Ltd., Budapest, Hungary

The convergence of the ALCAPA and the Tisza micro-continental blocks into the Carpathian embayment led to the formation of the Pannonian Basin. Although this process represents one of the key issues in the evolution of the Pannonian Basin, it is not well-known in terms of associated effects on the sedimentary systems and structural evolution during syn- and post-rift basin formation. Most contact between ALCAPA and Tisza is covered by syn- and post-rift deposits (CSONTOS, NAGYMAROSY 1998; TISCHLER et al. 2007); this geological setting can be observed along the Mid-Hungarian fault zone (MHFZ), by which the micro-continents are separated along a broad zone of deformation (e.g. CSONTOS, NAGYMAROSY 1998; FODOR et al. 2005). Repeated periodical strike-slip movements took place along this fault zone from the Paleogene (KÁZMÉR, KOVÁCS 1985; FODOR et al. 1992) to the Late Miocene (BALLA 1984; BALLA et al. 1987) and significant block rotations are documented from the Paleogene to Early Miocene times (e.g. CSONTOS, VÖRÖS 2004; HORVÁTH et al. 2006). The convergence between the invading continental blocks led to thrusting of the ALCAPA onto the Tisza–Dacia (CSONTOS, NAGYMAROSY 1998). This process culminated during the Early Miocene at the Pienide nappes, Northern Romania (SĂNDULESCU et al. 1981). The main driving force of the emplacement of the invading continental blocks into the Carpathian embayment is the slab retreat at the margin of the Carpathian foreland (ROYDEN 1993).

Kapos Line represents the westernmost segment of the Mid-Hungarian Line up to the intersection with the Tamási Line. From this triple junction the line enters the Tisza unit and continues within it through the Szolnok Flysch Zone up to Maramures. The Mid Hungarian fault zone worked as a large-scale, long-life transfer zone, during the syn-rift phase, separating the invading micro-continents. The characteristics of this tectonic process led to the developing of numerous strike-slip faults with contrary or different sense at the same geological time. The object/goal of the conducted work is to provide data to understand the tectonic evolution of the Pannonian Basin. The formation of extensional sedimentary basin is influenced by a number of external and internal process, factor, and parameter. Sedimentological data on facies combined with some micropalaeontological data and 2D well calibrated seismic lines constrain the tectonic history of the contact zone between ALCAPA and Tisza. Lithofacies of the syn-rift deposits in many cases were controlled by the tectonic settings, i.e. the Tengelic wells, drilled close to each other, represent different Sarmatian successions. The lithofacies of the late syn-rift - early post-rift Sarmatian sediments depends on the local tectonic features and/or environmental effects, e. g. the cores of the neighbouring Tengelic wells represent different successions. The investigated 2D seismic sections of the Kapos Line are located in the middle part of MHFZ stretching from South Transdanubia to the Kecskemét area. Due to the absence of Paleogene–Early Miocene strata, significant tectonic constrain should be assumed for the area and by reason of the lack of borehole data the earlier story remains obscure along the lineament. This work supports the hypothesis that the southern boundary of the Mid-Hungarian fault zone, i.e. the Kapos Line cannot be considered as a unified master (border) fault. The particular section of the zone shows different tectonic style and activity

during geological times. During the syn-rift phases each observed area, the sections of the Kapos Line, developed — from a structural aspect — independently (from each other). The line gained its present shape, to develop into a strike slip zone, with the renewal the earlier variable sense structures during the late syn-rift and post-rift phases.

Keywords: faults, Pannonian Basin, plate tectonics, Mid-Hungarian fault zone

References:

BALLA, Z., 1984. The Carpathian loop and the Pannonian basin: a kinematic analysis. Geophys. Trans. 30 (4), 313–353.

BALLA, Z., 1987. Cenozoic paleomagnetic data for the Carpatho-Pannonian region in the light of Miocene rotation kinematics. Tectonophysics 139, 67–98.

CSONTOS, L., NAGYMAROSY, A., 1998. The Mid-Hungarian line: a zone of repeated tectonic inversions. Tectonophysics 297, 51–71.

CSONTOS, L., VÖRÖS, A., 2004. Mesozoic plate tectonic reconstruction of the Carpathian region. Palaeogeogr. Paleoclimatol. Palaeoecol. 210, 1–56.

FODOR, L., MAGYARI, Á., KÁZMÉR, M., FOGARASI, A., 1992. Gravity-flow dominated sedimentation on the Buda paleoslope (Hungary): record of Late Eocene continental escape of the Bakony unit. Geol. Rundsch. 81 (3), 695–716.

FODOR, L., BADA, G., CSILLAG, G., HORVÁTH, E., RUSZKICZAY-RÜDIGER, ZS., PALOTÁS, K., SÍKHEGYI, F., TIMÁR, G., CLOETINGH, S., HORVÁTH, F., 2005. An outline of neotectonic structures and morphotectonics of the western and central Pannonian Basin. Tectonophysics, 410, 15–41.

HORVÁTH, F., BADA, G., SZAFIÁN, P., TARI, G., ÁDÁM, A., & CLOETINGH, S., 2006. Formation and deformation of the Pannonian basin: constraints from observational data. In: GEE, D. G. & STEPHENSON, R. (eds) European Lithosphere Dynamics. Geological Society, London, Memoirs, 1–672.

KÁZMÉR, M., KOVÁCS, S., 1985. Permian–Paleogene paleogeography along the Eastern part of the Insubric–Periadriatic Lineament system: evidence for continental escape of the Bakony-Drauzug unit. Acta Geol. Hung. 28 (1–2), 71–84.

ROYDEN, L. H., 1993. The tectonic expression of slab pull at continental convergent boundaries. Tectonics, 12, 303–325.

SĂNDULESCU, M., KRÄUTNER, H. G., BALINTONI, I., RUSSO- SĂNDULESCU, D. & MICU, M., 1981. The Structure of the East Carpathians. (Guide Book B1), Carpatho-Balkan Geological Association 12th Congress, Bucharest.

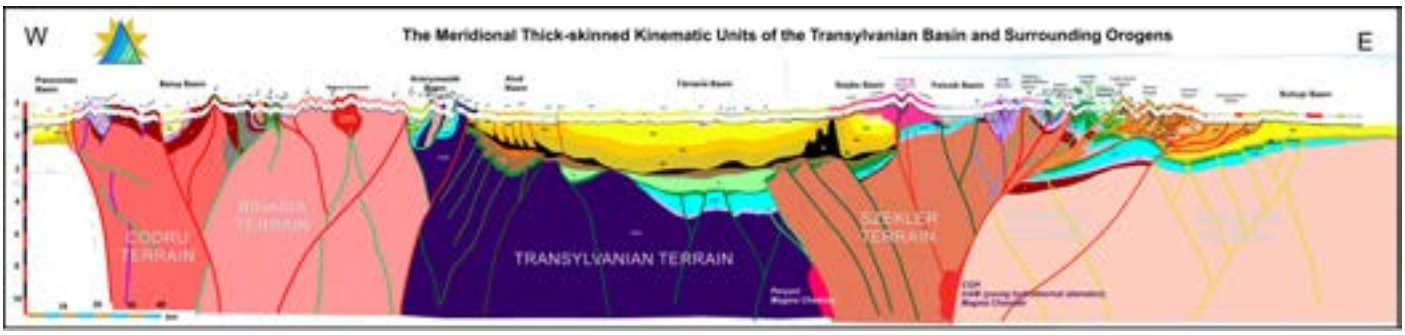
TISCHLER, M., GRÖGER, H.R., FÜGENSCHUH, B., SCHMID, S.M., 2007. Miocene tectonics of the Maramures area (Northern Romania): implications for the Mid-Hungarian fault zone. Int. J. Earth. Sci. 96, 473–496, http://dx.doi.org/10.1007/s00531-006-0110-x.

A New Thick-skinned Kinematic Model for the Transylvanian basin and Surrounding Orogens: Implications for Hydrocarbon and Ore Exploration

Szilamér J. Kovács, Szekler Resources Ltd

Both the outer and inner forelands of the Romanian Carpathians hold prolific mature oil provinces, which witnessed more than a century of oil and gas production. Carpathian ore mining was recorded on even more pages of history. Both mining sectors rely on structural geology to a great extent, thus a deep understanding of geodynamics is equally important in any frontier type exploration.
In Szeklerland, focus area of the current study, oil industry has discovered only one [subthrust] oil field (Ghelința), whilst the Ojdula gas discovery was uneconomic to develop at the time of discovery. Regarding the geological factors, one can notice that a fully representative set of seismic lines have been published recently discussing the evolution of the Transylvanian basin, and many others tackle separately the deep epicenter Vrancea seismic events. Unfortunately, all these interpretations were integrated into the three-decade old Roydenian geodynamic model, which assumes the westward subduction of the Moldavian platform, while triggering extensional basin subsidence in the "back-arc" Transylvanian basin. This geodynamic model fails to explain several long-time-known geological contradictions, one of which is the wrong location of the 'subducted slab', as noticed by Gârbacea & Frisch (1998) and others.
This work intends to give a case study presenting a new geodynamic/kinetic model for the study area in terms of Global Strike-slip Tectonics (GSST), as defined in one of our earlier works, integrating surface geology from several hundreds of observation sites, reinterpreted published seismic sections, IGR geological maps and tomographic data.
As the core part of the work, the main kinetic units of the study area have been delineated, in both, geological profiles and map view. Hence, two quasi-perpendicular strike-slip fault systems were defined: 1) a W-E oriented primary system which define the GSST micro-and nanoplate boundaries controlled by planetary asthenospheric currents, and a 2) secondary NNW-SSE system, initiated most probably by [Cretaceous] Earth axis variations of tilting, reactivated whenever microplate space problems had to be accommodated.

Restricting the area of YTF quasi-deterministic resource estimations to Szeklerland, 465mmbbl unrisked OOIP and 354bcf unrisked OGIP resources were identified in 5 Mesozoic to Neogene play types within the GSST framework, highlighting the areas for further prospective works.



Early Mesozoic tectonics of Northern Dobrogea: structural inheritance of the Black Sea Basins

Yevgeniya Sheremet[1], Marc Sosson[1], Antoneta Seghedi[2] and Mihaela C. Melinte-Dobrinescu[2]
1 University Côte d'Azur, UNS, CNRS, Obs. de la Côte d'Azur, IRD, UMR Géoazur, 06560, Valbonne, France
[2] GeoEcoMar, RO-024053 Bucharest, Romania
sheremet@geoazur.unice.fr

What is the main factor influencing the configuration of the Black Sea (BS) opening? Observing the structural patterns of European plate the NW-SE trending structures appear to be prevalent in it. Northern Dobrogea (ND) lies in the vicinity of the longest lineament of Europe the Trans European Suture Zone (TESZ), also known as TTL (Tornquist-Teisseire Lineament) which south-eastern termination extends in Dobrogea on more than 250 kilometers long before reaching the BS, framing the ND by Pecenega Camena and St Georges NW-SE Faults. However, the configuration of the Western BS sub-basin seems to be oblique to a major NW-SE trend of structures in the BS tectonic province. What if underestimation of the impact of crustal structural inheritance is this missing link in the numerous scenarios proposed to explain the BS opening, as the back-arc basin (BAB), in the geodynamic settings of the long-living subduction of the Tethys Ocean beneath Eurasia?

Outcrops of the Northern Dobrogea that include fragments of the Variscan orogenesis and of the Triassic basin allow looking deeper in the BS' past and reconsider ones again its tectonic patterns before opening. The new field observations and results of structural analysis brought new data about 1) Upper Triassic extension related, probably, to a Triassic Trough formation: upper Triassic olistostrome, slumps and normal faulting evidence about horsts and grabens that formed in, most likely, transtensional tectonic settings; 2) the time-span of compression, known as "Cimmerian orogeny", is precised as Early Jurassic of NW trend; 3) the structural data allow to define the structural connection between the ND and the Crimean Mountains during the Mesozoic.

Results of structural analysis show strong binding of further deformations to the ancient deep structures. These structures predetermined tectonic evolution of the northern BS margin, impacting the BS BAB's tectonic evolution during the Cretaceous rifting and inversion of the BS during the Cenozoic.

Alternative Structural interpretations for the Middle Miocene deformations of the Getic Basin, Romania

Schleder, Z.[1], Trandafir, G.[2], Krezsek, C.[2], Arnberger, K.[2]
[1] OMV Upstream Division, Trabrennstrasse 6-8, 1020 Vienna, Austria
[2] OMV Petrom S. A., Upstream Division, 22 Strada Coralilor, 013329 Bucharest, Romania

The Getic Basin is located to the south of the Southern Romanian Carpathians. It is a flexural basin with a width of about 50 km and an along axis length of about 130 km. The basin has evolved starting in the Cretaceous and it contains a 10 km thick pile of sediments from the Cretaceous up to the Burdigalian (Lower Miocene). The basin was inverted during the emergence of the Carpathians, in the Badenian-Mid Sarmatian (Middle Miocene). The amount of shortening increases from a few kilometres in the west to about 20 km in the east. The main detachment levels were the shale intervals in Eocene, Oligocene and the salt layer in Lower Burdigalian and Badenian. At the leading edge of the inverted basin there is a nappe unit consisting exclusively of an imbricate system of Burdigalian strata. This unit has a wedge shape in map view, hence was locally termed as the 'Burdigalian Wedge'. The wedge is narrow in the west (few km) and progressively widens to the east to a width of about 15-20 km. Wells show that this 'Burdigalian wedge' is allochtonous, and it rests entirely on a thin Badenian salt layer on the undeformed Moesian Platform. A key to understand the inversion of the Getic Basin rests in proposing a valid model to where the Burdigalian Wedge should restore back to.

One model can be that the sediments that make up the Burdigalian wedge should restore back to a sub-basin that has formed at the beginning of Burdigalian. This sub-basin was located to the south of the main Cretaceous basin. This model requires that all stratigraphic levels are shortened by roughly the same amount and implies that the trailing edge of the basin is still a sub-vertical feature. The second alternative is that the Burdigalian Wedge did not have its own separate depocenter but that it restores back onto the top of the sedimentary pile of the basin immediately to the north of the wedge. The wedge has been transported off this pile along the lower Burdigalian and Badenian salt detachment levels. Implicit in this model that the hindward thrusts and the Burdigalian Wedge is linked by the excellent detachment of the Badenian and Burdigalian salt levels which form a very long thrust flat. A third alternative solution acknowledges the fact that there are issues with the Lower vs. Miocene age dating in the foreland basins of the Romanian Carpathians and relaxes the assumption that all the Burdigalian wedge is made up of Lower Miocene age rocks. Allowing the wedge to be consisting of predominantly Middle Miocene age rocks (Badenian, Sarmatian), then all the deformation history simplifies to an inversion sequence where the deformation simply propagates into the formerly undeformed Middle Miocene foreland fill and the shortening values drop to <10km in all modelled sections. This latter solution is attractive in its simplicity but requires extensive age re-dating of key wells.

Structural evolution of the western Black Sea margin (Bulgaria)

Mélanie Louterbach, Lorenzo Cascone, Saul Subias Rodriguez, Sofía Soriano Pascual, Carlos Rosales Rodriguez, Ines Perez Baroja Verde, Laura Garcia del Olmo, Gonzalo Zamora, Hugo Matías, Ioan Munteanu and Marius Tillita.
Repsol Exploration, C/ Mendez Alvaro, 44, 28045 Madrid, Spain.

The Black Sea consists of two rift basins: the Western and the Eastern Black Sea Basins, separated by the Andrusov Ridge. The Western Black Sea Basin (WBSB) is thought to be underlain by oceanic crust in its most distal part and contains up to 18 km of sedimentary cover. Hydrocarbon discoveries in the WBSB have proven the presence of both thermogenic and biogenic petroleum systems, mainly fed by the regional Oligocene-Miocene Maykop Group. The aim of this study was to constrain the geological evolution of the area and to produce some inputs for petroleum system modeling. Two perpendicular regional structural cross-sections have been constructed, balanced and restored on the basis of 2D seismic data, well data, and regional geological knowledge. The first cross-section (a), oriented NW-SE, illustrates the structural settings of the rift basin. It is perpendicular to the global extension as it crosses over the Bulgarian shelf and ends into the center of the WBSB. The second cross-section (b), oriented SW-NE, crosses over the Balkanides fold-and-thrust belt (southern Bulgaria) and also ends into the rift basin, close to the southern Romanian margin. The aim of this section was to evaluate the effect of the Balkanides fold-and-thrust-belt in the late stage of the margin construction. Restoration of the cross sections allowed having a pseudo 3D understanding of the evolution of the NW margin of the WBSB.

Extension began with a stretching phase of the continental lithosphere, forming high angle faults and classic fault bonded rift basins during the Late Cretaceous. Progressive thinning coupled the brittle layers and large-scale detachment faults developed marking the transition to the exhumation phase. According to previous studies and gravimetric and magnetic data, continental breakup and seafloor spreading may have happened towards the SW of the WBSB. In our study area, thermal subsidence gave rise to the deposition of more than 6000 meters of sediments. Advance of the Balkanides fold-and-thrust belt from the SW during the Eocene induced the flexure of the lithosphere and the development of a foreland basin towards the Black Sea (NE). As a consequence of this event, previous extensional faults suffered mild inversion.

Consequently, structural traps such as those already drilled in the area should be considered as the consequence of both regional rifting and inversion processes.

Influence of inherited crustal faults zones on the location and inversion of the Caucasus and Black Sea basins.

Marc Sosson[1], Ara Avagyan[2], Yevgeniya Sheremet[1], Victor Alania[3], Onice Enukidze[3], Zoé Candaux[1], Lilit Sahakyan[2], Nino Sadradze[3], and Sargis Vardanyan[2].
[1] University Côte d'Azur, UNS, CNRS, Obs. de la Côte d'Azur, IRD, UMR Géoazur, Valbonne, France
[2] Institute of Geological Sciences, National Acad. of Sciences of the Rep. of Armenia, Yerevan Armenia
[3] I. Javakhishvili Tbilisi State University, Tbilisi, Georgia,
sosson@geoazur.unice.fr

All rifting periods in the Caucasus-Black Sea domains' tectonic evolution, specifically during the Jurassic (Greater Caucasus basin: GC), the Cretaceous (Black Sea basins: BS) and during the Paleocene-Eocene (Transcaucasus Adjara-Trialeti basin) and Late Eocene Lesser Caucasus post collisional basin, seem were guided by ancient structural heterogeneities within the Eurasian crust and within the Taurides-Anatolides-South Armenian Microplate (TASAM). These inherited structures defined the shapes and location of corresponding basins and predetermined propagation of the following compressional deformations during the stages of collisions (Eurasia with TASAM and then with Arabia). According to our results which have been taken into account in the new paleotectonic reconstruction of the Tethyan realm (Darius programme maps, Barrier et al., 2018) we present four keys areas allowing to demonstrate the major role of inherited fault zones during the tectonic basins evolution: 1) the NW BS, including the Crimea, 2) the northern tectonic units of the Rioni Basin (GC, Georgia), 3) the Adjara-Trialeti basin (Transcaucasus domain, Georgia) and 4) the Late Eocene basin (Lesser Caucasus, Armenia). One of those structures that influenced the BS development as a back-arc basin finds its end in the Western BS: the Trans-European Suture Zone (TESZ) (see Sheremet et al. for more explanations). This tectonic zone was active several times during Tethys' closure, impacting the inversion scenario of the BS. The GC basin's location has been controlled by structures formed within the late Paleozoic-Triassic deep basin (Dizi basin) and inversion of the GC basin occurred due to reactivation of the Jurassic structural inheritance. The inversion of Cenozoic (Paleocene-Eocene) Adjara-Trialeti basin, formed as a back-arc basin within the Transcaucasus domain of Eurasian plate, was influenced by reactivation of former normal faults of the rifting phase. And, in the Lesser Caucasus, the post collisional Late Eocene basin was also the result of reactivation of inherited Late Paleozoic faults within the TASAM of Gondwanian origin.

The results show that crustal shortening as thick and thin-skin tectonics originated the inversion of all these basins. The thin-skin deformations were released along several decollement levels as: 1) thick Triassic and Cretaceous turbidites in the North Western BS, 2) Triassic turbidites, Upper Jurassic evaporites, Cretaceous turbidites, Oligo-Miocene Maykop clays in the GC, 3) Eocene turbidites and Oligo-Miocene Maykop series in the Transcaucasus and, 4) part of obducted ophiolites (the obduction contact made of a tectonic mélange with serpentinites) in the Lesser Caucasus.

The pre-structuration of the continental crust on the modalities of its fragmentation has to be taken into account in the numerical modellings of the back-arc basins formed above of a long-lived subduction zone. Taking into account the characteristic rheological behavior of pre-structured continental upper plate will help to reconstruct domains with a long and complex tectonic evolution as it is the case for the structural pattern of BS-GC domain in the Eurasian plate representing a part of northern active margin of Tethys Ocean.

Complex shortening tectonic style in the undisturbed Alpine foreland: Example from the Geneva Basin (Switzerland) and implications for subsurface geo-fluid circulation.

Moscariello Andrea, Nicolas Clerc, Eruteya Ovie Emmanuel, Omodeo-Salé Silvia, Guglielmetti Luca
Department of Earth Sciences, University of Geneva, Switzerland
Andrea.Moscariello@unige.ch

The Swiss Alpine foreland located between the Alpine front and the folded Jura chain is described as a generally undisturbed plateau where the shortening related to the Alpine compression is accommodated mostly by deeply rooted sliding of the thick Mesozoic series over the Triassic evaporites. In addition to the basal sliding, proving the thin-skin tectonic character of the regional deformation, a series of several-km long N-S and NW-SE regional strike-slip faults formed resulting in the lateral compartmentalization of the undeformed thick succession of Mesozoic and Cenozoic sediments. The role of high-angle faults deeply rooted in the underlying Hercynian basement in the deformation of the Swiss Plateau is still under debate. However, evidence of a relationship between the occurrence of a buttress of Hercynian basement and the development of anticlinal structures in the overlying Mesozoic, targeted in the past by hydrocarbon exploration, seems to indicate the importance of these Paleozoic structures in explaining the present day deformation style of the Swiss Plateau subsurface.

The ongoing study of the Geneva Basin subsurface aims at developing a strategy for Geothermal energy exploration. In this area, the examination of vintage reprocessed and newly acquired 2-D reflection seismic lines highlights the discontinuity of the regional NW-SE strike-slip lineaments originally thought to cross the Geneva Basin. Instead, the occurrence of a higher degree of deformation at a smaller scale distributed within several stratigraphic intervals within the Mesozoic succession has been highlighted. These deformations consist of low-angle inverse faults/thrusts which root generally in shale and marly intervals. Thrust anticlines formed in the low-angle hanging wall have also been observed. These compressional features have an axis generally oriented parallel to the main deformation of the Jura domain, which displays a progressive rotation from NE-SW to NW-SE direction.

These observations indicate a higher structurally complexity than previously thought. It reflects a complex history of deformation indicating that shortening is accommodated by small low-angle inverse faults and thrusts displaying tens to few hundreds of meters of lateral displacement with a little vertical offset. Deformation is controlled by contrasting lithologies occurring within the Jurassic and lower Cretaceous (carbonates vs marls and shales). Different phases of deformation include compression, rotation and development of both transpressive and transtensional strike-slip.

In places, fault and dense fracture network associated with these deformations are connected crossing throughout the entire thickness of the Mesozoic sequence above the Triassic anhydrites showing a listric character rooted in the Lower Jurassic shale intervals (e.g. Toarcian). The latter are important structural features which can play a key role in controlling the subsurface circulations of both hydrocarbon and geothermal fluids.

The Control of Pre-Existing Faults on the Development of Thrust-Related Folds in the Kura Foreland Fold-and-Thrust Belt (Norio License Block, Onshore Georgia)

Pace, Paolo - paolo.pace@geplan.it [1] , Riva, Alberto - alberto.riva@geplan.it [1,] , Ricciato, Angelo - angelo.ricciato@geplan.it [1] Prof. Revaz Tevzadze [2], Alexander Janiashvili - alexander@noc.ge [2] , Artem Sanishvili - artem@noc.ge [2] , Victor Alania - victor.alania@tsu.ge [3], Onise Enukidze - onise.enukidze@noc.ge [3]

[1]*G.E. Plan Consulting, Petroleum Geosciences, Italy*
[2]*Georgia Oil & Gas Limited, Georgia*
[3]*M. Nodia Institute of Geophysics, Tbilisi State University, Georgia*

The Kura foreland fold-and-thrust belt defines the north-western edge of the Kura Basin that extends from central Georgia eastward to the Caspian Sea in the so-called Transcaucasian intermontane valley. It separates the Greater and Lesser Caucasus Mountain to the north and south, respectively. The compressional deformation, which is progressively increasing moving to the Greater and Lesser Caucasus, is associated to the convergence between the Arabian and Eurasian plates that is still active. Different evolutionary tectonic phases can be distinguished in the Alpine evolution of the Caucasus, with different time boundaries in the various zones. There are two main stages of evolution: pre-orogenic (Jurassic-Eocene) and orogenic (Oligocene-Quaternary). Recent works in the area reveal that the compressional deformation in the Kura foreland fold-and-thrust belt started in the Middle Miocene and compression reached its peak at the end of the Miocene. A seismic interpretation on a 2D post-stack depth migrated survey was performed in the Norio license block in order to reconstruct the subsurface thrust-related structures and assess their hydrocarbon potential. The study area is located in the interference zone between the two opposite-directed thrust systems belonging to the Greater and Lesser Caucasus. The structural interpretation revealed that there are two levels of contractional deformation: a deep-seated north-directed contractional deformation characterised by high-angle thrusts/reverse faults affecting the Cretaceous-Eocene units with remarkable thickness variations within the Eocene interval and a shallower, more complex, contractional deformation with south-directed low-angle thrusts giving rise to strong folding with overturned synclines and anticlines pairs. Based on the reconstructed structural geometries, the decoupling level is inferred to occur within the Oligocene-Lower Miocene clays. The interpretation of magnetotelluric data revealed a structural style consistent with structures identified on seismic corroborating the interpreted structural model. Moreover, a good 2D gravity data coverage allowed to compare the reconstructed structures involving the sedimentary units with the basement morphology. The consistency in trends of the basement structures and the ones involving the sedimentary cover suggest a control of the pre-exiting basement faults on the subsequent of the contractional deformation. A 2D kinematic restoration was also performed with the aim to validate the interpreted structural geometries and the lateral stratigraphic thickness variations. Three dip lines were selected from west to east. The restoration of the compressional deformation that acted from the Miocene onwards revealed the occurrence of a pre-existing normal fault system controlling an E-W oriented basin very likely developed during the Lower-Middle Eocene extensional event that is known in the region. The north-bounding normal faults of this basin were clearly reconstructed from the restoration because they undergone to simple reverse reactivation during the positive inversion. By contrast, the faults which were likely bounding the basin along the southern margin were just inferred based on the lateral thickness variations. These faults and their relationships with the basin have been totally obliterated by the north-directed thrusting along the southern margin of the extant basin. Overall, the three restored cross-sections suggest an E-W continuity this mainly Eocene extensional basin with some changes in the normal fault system as inferred along the southern margin. Presumably, some of the normal faults from the Eocene extension have locally reactivated former extensional structures developed during the Jurassic extension and rooted down to the basement.

Keywords: Kura Foreland Thrust Belt, Pre-Existing Faults, Thrust-Fold Structures

Decreasing uncertainty of MT data interpretation in shallow subsurface by using a comprehensive interpretation of independent geophysical datasets. Case study from eastern part of Polish Outer Carpathians

Authors: Jakub Ważny1 , Adam Cygal1, Michał Stefaniuk1, Piotr Hadro1*
1AGH University of Science and Technology, Poland
**jwazny@agh.edu.pl*

Resistivity models based on inversion of magnetotelluric measurements performed in eastern part of Polish Outer Carpathians are exposed to uncertainty due to the presence of static shift phenomenon. Particularly exposed to this galvanic distortion are vertically shifted amplitude curves while phase curves remain unchanged. The phenomenon is caused by the geological situation of measurement environment, characterized by fold and thrusted structure with angles of layers dipping up to 90 degrees. This implies lithological heterogeneity of the subsurface zone and a varied topography of the area. Inversion of magnetotelluric data results in large errors associated with scaling the resistivity. For this reason it is necessary to use the interpretative methodology to support MT measurements. The research was preceded by analysis of geological medium anisotropy, based on vertical electric soundings and polar diagrams of magnetotelluric data. As well, the analysis of archival geological data was of a great importance. Results of 1D and 2D magnetotelluric data inversion were compared with results of electrical resistivity tomography and seismic refraction measurements. Both these sets are less susceptible to adverse influence of distortion.

A comprehensive approach in choosing the right model allowed the selection of the best solution for magnetotelluric inversion and enabled a detailed structural interpretation of the surface structures. Based on these results, a presented geological model was created.

This paper was prepared based on results of investigations carried out in the framework of the project "Experimental, complex and multi-variant interpretation of seismic, magnetotelluric, gravity and borehole data as a tool to improve the effectiveness of structural and reservoir research" – Applied Research Program III, financed by Minister of Science and Higher Education of Poland through National Centre of Research and Development. We appreciate the support from Polish Oil and Gas Company (PGNiG SA.) to perform this study.

Keywords: magnetotellurics, geoelectrical methods, refraction tomography, comprehensive interpretation, Carpathians

Methodology for electromagnetic noise removal from magnetotelluric data using machine learning techniques as a tool for improved structural interpretation – case study from Eastern Carpathians

Authors : Piotr Hadro1, Adam Cygal1, Jakub Ważny1*
1AGH - University of Science and Technology, Poland
**hadro@agh.edu.pl*

The magnetotelluric records are affected by different types of high-amplitude, electromagnetic noise, which should be removed from all measured component, before data processing. We developed a deep learning model which allows to detect noisy intervals and replace them with low amplitude signals which are not affecting further processing. For the discrimination of the noisy intervals we utilized the machine learning by training the model on the manually analysed data.

The model was applied for test dataset and proved its robustness by removing most of the noise from the data. We compared the results of the processing before and after application of the model. Comparison shows that our solution improved the quality of the data and reduced the noise into acceptable level. We also reviewed the frequency spectrum of the signal to evaluate how our procedure affects the data in the frequency domain.
This methodology is very helpful for the data preprocessing in the Eastern Carpathians area, where our data were acquired. This region is characterized by existence of the complex tectonics and steeply dipping layers with dip angles up to 90 degree. The specific research area is located in the SE part of Poland, namely at the boundary of the Silesian and Skole Unit of the Outer Flysch Carpathians. This approach allowed to better image the near-surface and reveal the details of complicated geology in the area of research. Obtained results were compared with seismic sections for the quality control.

This paper was prepared based on results of investigations carried out in the framework of the project entitled “Experimental, complex and multi-variant interpretation of seismic, magnetotelluric, gravity and borehole data as a tool to improve the effectiveness of structural and reservoir research” – Applied Research Program III (In Polish: Program Badań Stosowanych III. We appreciate the support from Polish Oil and Gas Company (PGNiG SA.) to perform this study.

Keywords: Eastern Carpathians, magnetotelluric, EM noise, machine learning, geological imaging.

Petroleum system analysis of small scale Miocene troughs in the Pannonian basin, results of a 3D basin modeling case study from southern Hungary

Viktor Lemberkovics (1), Edina Kissné Pável (1), Balázs Badics (2), Katalin Lőrincz dr. (3)
1 O&GD Central Kft., Budapest, Hungary, lemberkovics36@outlook.hu, 2 DEA Norway, Stavanger, Norway., 3 RAG Hungary Kft., Budapest, Hungary

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 describes 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 modelling 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.

Keywords: Pannonian Basin, small scale Miocene grabens, petroleum system, basin subsidence, 3D basin modelling

3D Petroleum System Model of Southeastern Part of Pannonian basin

Bogicevic, Goran - goran.bogicevic@nis.eu – Science & Technology center NIS- Naftagas LLC
Dulic, Ivan - ivan.dulic@nis.eu – Science & Technology center NIS- Naftagas LLC
Sovilj, Janko - janko.sovilj@nis.eu – Science & Technology center NIS- Naftagas LLC

Regional 3D Petroleum System Model of Pannonian Basin were done in southeastern part of Pannonian basin, with the aim of more efficient planning of the future exploration works and exploration risk and uncertainty reduction. Investigated area encompasses 92.290 km2, which is covered with 5.681 2D seismic lines (with total 81.582 km) and 58 3D seismic cubes (covering 15.697 km2), and it includes parts of Serbia, Hungary, Romania, Bosnia and Herzegovina and Croatia. Modelling process was carried out using SLB PetroMod software.
Regional 3D petroleum system model was constructed with 500x500 m grid cell, using 8 initial regional structural maps, which were split into 46 layers/sublayers to achieve better vertical model resolution. During preparation of structural framework for 3D modeling, 28 regional 2D models, with total length of over 6600 km, were created and calibrated. Modeling these master sections enabled better understanding of basin dynamics through time, as a key factor of migration routes in 3D. In addition, modeling results from 28 2D models, allow us to create 107 PSE input maps (lithofacies, total organic carbon, hydrogen index, source rocks thickness, heat flow, erosion estimation, paleo water depth etc), necessary for 3D modeling.

Based on over 8000 Rock-Eval analysis from 869 wells, and public available data, six major source rocks are determined. Distribution and areal characteristics changes of basic parameters (kerogen type, original hydrogen index, original total organic carbon, reaction kinetics and net thickness) were specify for each source rock, and derived distribution maps were used as 3D modeling input.

During 3D modeling process, more than 1.000 wells were used for the calibration of basic physical parameters: 932 wells with temperature data, 162 wells with pore pressure data, 214 wells with effective porosity, 103 wells with vitrinite reflection data and 409 for lithofacies analysis. Also, for calibration of petroleum phase definition, data from 293 oil and gas fields with geological reserves totalling 1.080 mil. TOE were used, representing more than 80% of previously discovered reserves in this part of Pannonian Basin.

Based on the results of 3D modeling and distribution of the discovered fields, 14 petroleum systems were determined. The amount of already discovered reserves of oil and gas and the remaining yet-to-be-found resources were defined for the whole basin and for each system. During the construction of geological model, more than 300 structures were defined and for each of them was done calculation of already discovered and still undiscovered accumulations of hydrocarbons. All remaining accumulations are risked out based on index of probability of model accuracy, depending on quantity of the available data. It is defined separately for each petroleum system, and ranging between 0.46-0.83. In addition, based on modeling results, chance of success maps for this part of Pannonian basin were constructed.

Keywords: Pannonian basin, petroleum system modeling, geology

Petroleum systems analysis based on simulation results of a 2D numerical model, eastern Pannonian Basin

Harold, Zsófia - haroldzsofia@gmail.com - Department of Physical and Applied Geology, Eötvös Loránd University, Budapest, Hungary
Bartha, Attila - abartha@slb.com - Schlumberger, Software Integrated Solutions (SIS), Aachen, Germany
Csizmeg, János - jcsizmeg@vermilionenergy.com - Vermilion Energy, Budapest, Hungary
Sztanó, Orsolya - sztano@caesar.elte.hu - Department of Physical and Applied Geology, Eötvös Loránd University, Budapest, Hungary

Two-dimensional basin and petroleum system modelling was carried out in the eastern part of the Pannonian Basin to analyse the burial, thermal and maturity history, and the petroleum system elements and processes. Furthermore, the impact of uncertainties in the key input parameters on simulation results were also examined.

The area of interest included two Neogene depressions – the Derecske Trough and the Tiszapalkonya Depocenter – and the Ebes-Hajdúszoboszló Structural High between them. The tectono-sedimentary evolutionary model constrained by seismic and well data integrated the spatial and chronological variations of depositional, non-depositional and erosional events, as well as the progradation of the shelf-margin slope. The impact of its load on the mechanical compaction of sediments, pore pressure development, thermal history, maturation of effective source rocks, and hydrocarbon charge were also analysed.

Different maturation and petroleum generation reaction kinetics were tested, and their impact on thermal and maturation histories, and hydrocarbon charge were examined. The selection of proper vitrinite reflectance model had a key impact on the calibration of thermal history and timing of hydrocarbon generation. The use of different kinetic models resulted in slightly different hydrocarbon phases, compositions and volumes of predicted petroleum accumulations, as the transformation of organic matter took place at different temperatures.

Besides the thermogenic hydrocarbons, the generation of biogenic gases associated with the deposition of the sedimentary succession in the study area was also considered. Despite it was almost continuous during the depositional history, the preservation of gases was limited in time and space.

Due to the complex lithology and facies distribution predominant in Pannonian basin several migration methods were tested. The application of the Darcy Flow coupled with Invasion Percolation provided the best migration results, since it handled the lateral and vertical facies changes and the presence of stratigraphic traps in a realistic way.

By means of modifying the input data and optimizing the lithological and kinetic parameters, a model close to geological reality was created, in which the pore pressures and compaction trends were adjusted to the conditions prevailing in the basin, the thermal and maturity histories to measured thermal indicators, and the modelled petroleum accumulations to the known Ebes and Sáránd fields.

Keywords: Basin and petroleum system modelling, PetroMod, Derecske Trough, Jászság Basin

Palaeoenvironmental analysis and hydrocarbon source rock potential of Permo-Carboniferous shales below the Eastern Molasse Basin, Austria

Author : Jäger, Hartmut - jaeger@georesources.de – GeoResources STC, Leimen, Germany
Co Author : Reutner, Thomas - reutner@georesources.de – GeoResources STC, Leimen, Germany
Co Author : Wiesmayr, Gerhard - Gerhard.Wiesmayr@rag-austria.at – RAG Exploration & Production GmbH, Vienna, Austria

The Molasse Basin is the Northern Alpine Foreland Basin, developed during the final stage of the Alpine Orogeny. Its complex basin fill is made of Cenozoic, Mesozoic and Palaeozoic sediments on a basement of crystalline rocks of the Bohemian Massif. Below the Tertiary and Mesozoic basin fill locally restricted Permo-Carboniferous rift basins along E-W trending Variscan wrench faults are observed, filled with siliciclastic sediments. These sediments are rarely recorded in wells and little is known about the sedimentary systems and palaeoenvironmental conditions, but also about the hydrocarbon source rock potential and its possible contribution to the hydrocarbon plays of the Molasse Basin.

The current study is focused on optical kerogen analysis of the Permo-Carboniferous strata of the Austrian Molasse Basin in Upper Austria, providing new data on palaeoenvironments and the associated hydrocarbon source rock potential. Optical kerogen analysis studies composition and preservation of organic matter. Beside palaeoenvironmental analysis it provides the specific hydrocarbon generating potential for oil and gas, just as kerogen transformation in the actual setting. Three wells were studied: Well A (unfolded autochthonous Molasse), Well B (marginal imbricated, allochthonous Molasse) and Well C (imbricated, allochthonous Molasse).

Optical Kerogen Analysis showed totally terrestrial dominated organic matter, mainly plant debris, for all Palaeozoic samples. It indicates strongly terrestrial influenced environments, as typical in lacustrine to deltaic settings. No clear indicator for marine input is observed. Regarding the hydrocarbon potential most samples are dominated by unproductive kerogen type IV, followed by gas-prone kerogen type III. Oil-prone kerogen type I & II are only of minor importance. Samples from well A and one sample from well B show much less kerogen type IV, but strongly increased oil-prone kerogen type I & II. Most kerogen (types I - III) is poorly preserved, suggesting intense alteration during transport and deposition. Significant kerogen transformation due to hydrocarbon generation is not observed.

TOC values show a wide range from very poor to very good, but poor TOC content is most common. Due to the high amount of unproductive kerogen type IV in most samples the productive kerogen (net-TOC) is much lower than the measured TOC. The net-TOC gas is poor in most samples, rarely fair to good. The net-TOC oil is poor for all samples, mostly very poor, indicating poor to no oil potential in all samples. Due to the basal to lower gas window maturation in all 3 wells, only the oil-prone part of the kerogen could have produced hydrocarbons, indicating a very poor potential for generating hydrocarbons (oil) in the Palaeozoic of the studied wells.

Keywords: Molasse Basin, kerogen analysis, palaeoenvironment, hydrocarbon source rock potential

Early-Middle Jurassic Sedimentary Basins in the Southern Part of the Moesian Platform - Development and Hydrocarbon Favours

Georgi Georgiev[1], Assya Ilieva[2], Eva Marinovska[2], Juliya Stefanova[2]
[1] Department of Geology, Sofia University, 15 Tsar Osvoboditel Blvd., 1504 Sofia, Bulgaria, gigeor@abv.bg
[2] Exploration Department, Oil and Gas E&P Plc., Bulgaria

After 1975, when were discovered in Bulgaria the first two economic oil-gas fields (named Dolni Lukovit and Burdarski Geran) in the Lower Jurassic basal terrigenous sediments, the exploration strategy in the country has been changed to these basal clastics, presented by Batchiishtene & Kostina Formations. However, in spite of the large volume exploration (seismic and drilling), only few smaller oil and gas-condensate fields of this type have been found.

The main obstacle during the exploration has been the unpredicted irregularity in the spreading of the Lower Jurassic basal clastic sediments. Often, they pinch out quickly, or became predominantly shally, or manifest serious compaction changes.

However, a large volume seismic and drilling data has been received. Their integrate and precise analyses and interpretation during the years, especially in recent time, allow to decipher a complicate system of Lower-Middle Jurassic sedimentary basins, developed in the southern part of the Moesian Platform.

Our main aim study is to localize and describe this complicated system of small and deeper sedimentary basins, which development is controlled often by reverse faults, as well to clarify their subsidence history and depositional environment. Also, our important goal is to assess the main hydrocarbon features and to define the exploration prospects and most promising directions.

The study is based on all available data from seismic acquisition, drilled deep wells and literature.

The hydrocarbon favours of ticker Lower-Middle Jurassic sediments are related with their source potential and presence of good to very good reservoirs.

Very good genetic correlation has been established between discovered hydrocarbon fields in central part of Northern Bulgaria and some source intervals in Lower-Middle Jurassic sedimentary succession, presented mainly by shall intervals in lower-middle part of Ozirovo Formation (Dolni Lukovit and Bukurovo members) and lower part of Etropole Formation (Stefanets member) (Georgiev, 1997, 2000; Georgiev and Ilieva, 2007).

The irregular spreading of Lower Jurassic basal clastic deposits, which usual thickness is no more 30-50 m, has been studied by seismic facial and paleo-geomorphological analysis and interpretations with well control. These deposits are the main exploration target.

References

Georgiev, G., Dabovski, Ch. 1997. Alpine structure and Petroleum geology of Bulgaria. Geology and Mineral resources, 8-9, 3-7.
Georgiev G. 2000. Oil-oil and oil-source correlation for the major crude oils in Bulgaria. Annuaire de l'Universite de Sofia "St. Kl. Ohridski", Fac. de Geologie et Geographie, 1 - Geologie, 92, 39-60.
Georgiev, G., Ilieva, A. 2007. Selanovtsi oil accumulation – geological and genetic model. Annuaire de l'Universite de Sofia "St. Kl. Ohridski", Fac. de Geologie et Geographie, 1 - Geologie, 100, 67-96.

Geochemical conditions of Maikop (Oligocene-lower Miocene) sediment accumulation in the eastern Caucasian Basin, NE Paratethys

Gavrilov Yuriy, Geological Institute RAS (GIN RAS), Moscow, Russia, yugavrilov@gmail.com
Nedumov Rostislav, GIN RAS, rostislavn@yandex.ru
Shcherbinina Ekaterina, GIN RAS, katuniash@gmail.com

The Cenozoic sediments exposed in the valley of Sulak R., Dagestan, eastern Caucasus provide the most complete information about the specificity of evolution of paleobasins of NE Paratethys. The first detailed study and lithological division of sediments incorporated into Maikop Group was made by N.S. Shatsky in 1926 and remains relevant to the present. The Rupelian Khadum Fm., Chattian Miatly, Lower Clayey, Mutsidakal and Riki Fms. and lower Miocene Zuramakent Fm. are assigned in this thick succession. The sediments of Maikop Group are mainly dark thinly laminated clays; sandstones are present sporadically in Miatly and Mutsidakal Fms. The highest CaCO3 content is found in the lower part of Khadum Fm. (up to 60% in few isolated marly layers). In the rest of Maikop Group, CaCO3 content is negligible.

The oppressed benthic fauna and behavior of redox-sensitive elements (Mn, Mo, U, S, a.o.) evidence mainly anoxic bottom conditions. However, bottom anoxia was not consistent and its intensity varied in time (e.g., Nedumov, 1998).
The organic matter (TOC) is unevenly concentrated in the Maikop sediments. The highest TOC concentration (1-4%) is found in Khadum Fm. A set of indications suggests anoxic environment during this time with the only exception for the short time span just preceeded and during accumulation of Ostracoda Bed. In the middle part of Maikop Group, TOC concentration mainly does not exceed 1% and increases up to 2% at individual levels only. The same trend is documented for Mo and some other redox-sensitive elements. These indicate the inconsistency of anoxia during Miatly-Mutsidakal time.

The environmental turnover occurred during accumulation of Riki Fm.: TOC content increases (1-2.5%) in parallel with the increased concentrations of Mo, S, U, Zn, Ni, Co, As, a.o., while Mn concentration remains very low. Geochemical features indicate much more stable anoxia in this time. Contrarily, the transition to the younger Zuramakent Fm. of Maikop basin corresponds to the occurrence of oxic conditions in the water column. This caused accumulation of Mn concentrated earlier in the water of anoxic Riki basin.

The succession of geochemically different sedimentary environments reveals Khadum-Mutsidakal and Riki-Zuramakend sedimentary cycles in the Oligocene-early Miocene basin. The initial stages of these major cycles were characterized by anoxic conditions, which weakened, became unstable and/or gave way to oxic environments at the later stages.

The sediments of Maikop Group are overlying by the middle Miocene Tarkhan and Chokrak Fms. (up to 500 m thick) with sharp contact. The lower parts of these formations are built up of thinly laminated sediments lack in borrows and rich in TOC (up to 4%). This succession represents sedimentary cycle similar by its structure to sedimentary succession of Maikop Group. Similar sedimentary cycle is composed by underlying the Maikop Group Kuma (Bartonian) and Belaya Glina (Priabonian) Fms. accumulated under anoxic and oxic conditions, respectively.
(Projects GIN RAS nos. 0135-2016-0004 and 0135-2016-0051)

Nedumov R.I. 1998. Variation in hydrogen sulfide contamination of the bottom water of the Maikop basin. Lithology and Mineral Resources. Vol. 33. No 4. P. 327-339.
Key words: oxic, anoxic environment, redox-sensitive elements, sedimentary cycles

The hydrocarbon potential of Miocene rocks in Azerbaijan

(Maikop Group, Diatom Suite)
Vusala Aghayeva - v.agayeva@geo.science.az -Institute of Geography, ANAS Baku, Azerbaijan
Reinhard F. Sachsenhofer – reinhard.sachsenhofer@unileoben.ac.at- Montanuniversität Leoben, Austria
Magdalena Pupp -magdalena.pupp@unileoben.ac.at- Montanuniversität Leoben, Austria
Shiyanova, Natalya – shnwpo@bp.com – BP-Azerbaijan, Xazar Center, Baku, Azerbaijan
Van Baak, Christiaan G.C. – Chris.vanBaak@casp.cam.ac.uk – CASP, Cambridge, UK
Vincent, Stephen J. – Stephen.Vincent@casp.cam.ac.uk – CASP, Cambridge, UK

Despite a wealth of previous investigations, the hydrocarbon potential and related ages of Miocene rocks in the Lower Kura Basin of Azerbaijan are still a matter of debate. Therefore, an approximately 800 m thick succession has been logged in detail at the Islamdag section in the northern part of the Gobustan region. This section provides a very complete Miocene record of fine-grained deposits, and offers a unique opportunity to study their hydrocarbon potential in high detail. As part of a larger integrated multi-proxy stratigraphic study, over 500 samples have been taken for biostratigraphic, magnetostratigraphic and geochemical analysis. Here we report bulk geochemical data (total organic carbon [TOC] and sulphur [S] contents, calcite equivalent percentages, Rock Eval data).

The studied section comprises from base to top the upper (Lower Miocene) part of the Maikop Group, Tarkhanian and Chokrakian (Middle Miocene) sediments and rocks attributed to the Diatom Suite (Karaganian to ?Bessarabian). The uppermost (Maeotian) part of the Diatom Suite is likely missing in the Islamdag section.

The studied interval of the Maikop Group is about 370 m thick. Lithologically it is predominantly comprised of non-calcareous mudstones, which contain strong yellow weathering colours indicating an abundance of sulphur in the sediments. Based on bulk parameters, this part of the section can be subdivided into two units. The lower unit, 330 m thick, is characterized by high amounts of organic matter (average TOC: 1.7 %) with low HI values (av.: 129 mgHC/gTOC) indicating the prevalence of type III kerogen. Very low TOC/S ratios (av.: 1.2) suggest anoxic conditions during deposition. The upper unit, about 70 m thick, contains three distinct layers. Whereas the lower and upper layers contain abundant organic matter (2.2 and 1.6 %TOC, respectively), TOC contents are low (0.7%) in the middle layer. High TOC/S ratios (av.: 6.4) may indicate deposition in a brackish environment. Type III kerogen prevails in all units, but some samples from the uppermost 25 m of the Maikop Group contain type II kerogen.

Tarkhanian and Chokrakian sediments are about 100 m thick. They contain calcareous mudstones with low TOC contents. Planktonic microgastropods occur throughout this unit.

Although the top part of the Diatom Suite is not preserved in the Islamdag section, its thickness exceeds 280 m thick. The lower and upper parts of the Diatom Suite contain low amounts of organic matter (av.: 0.5 and 0.8 %TOC). In stark contrast, a 58-m-thick unit of paper shales with high TOC contents (av.: 4.5 %) and a type II kerogen (av.: HI: 468 mgHC/gTOC) dominates the middle part of the Diatom Suite. Relatively high TOC/S ratios (av.: 6.4) may indicate a brackish depositional environment during deposition of the paper shales.

Estimates of the Source Potential Index (according to Demaison & Huizinga, 1994) show that the exposed Upper Maikop sediments may generate about 2 tons of hydrocarbons per square meter (tHC/m²), when mature. The paper shales in the Diatom Suite can generate more than 3 tHC/m². The prevailing kerogen types suggest that the Maikop Group will generate mainly condensate and gas, whereas the paper shales are highly oil prone.

Diamondoids reveal one of the world's deepest petroleum systems, South Caspian Basin, Azerbaijan

Author : Goodwin, Nick – nick.goodwin@uk.bp.com – BP Exploration Operating Company
Co Author : Volk, Herbert - herbert.volk@uk.bp.com – BP Exploration Operating Company
Co Author: Abdullayev, Nazim – nazim.abdullayev@bp.com – BP Exploration (Caspian Sea) Limited
Co Author: Riley, Greg – gregory.riley@bp.com – BP Exploration (Caspian Sea) Limited

The South Caspian basin (SCB) contains the most prolific petroleum province along the ancient Paratethys Sea. Despite the large number of petroleum discoveries, which span over the past century, the source rock sequence for these discoveries is unpenetrated by the drill-bit in the offshore basin and therefore remains poorly defined. Historically an oil province, exploration of the deeper waters in the past two decades has resulted in the discovery of large gas-condensate accumulations such as Shah Deniz. Uplift of the Caucasus mountains has exposed the source rock bearing Cenozoic section in outcrops onshore, towards the basin margins. However, in the more distal offshore basin, the geochemistry and volumetrics of discovered petroleum fluids provide the most valuable insight into the source rocks. We have used geochemistry and high-level estimates of in-place volumes of petroleum fluids, together with onshore outcrop data and basin modelling to constrain the source rock model offshore.

Diamondoids are a group of hydrocarbons that occur naturally in petroleum with carbon atoms arranged in a chair configuration like in diamond. As a result of this structure, diamondoids are the most thermally stable hydrocarbon compounds in petroleum, persisting at high degrees of thermal stress when most biomarkers have been degraded. Diamondoids have been measured in high concentrations (up to 160 ppm 3- + 4-methyldiamantanes) in condensate from the giant Shah Deniz gas field, indicating significant oil to gas cracking, which must have taken place much deeper than the present day Productive Series reservoirs of the palaeo-Volga. Both gas isotope compositions (δ13C1 - δ13C3) and diamondoid concentrations indicate the presence of a source rock at high levels of thermal maturity (1.5 – 2.0% Ro equivalent), which given the cool geothermal gradients of the South Caspian basin (16 – 17 °C/km at Shah Deniz) and relatively high temperatures required for maturation due to rapid, relatively recent burial and heating, must be buried to depths in excess of 13 km in the Shah Deniz drainage area. Of the world's prolific petroleum producing basins, only in the deep-water Gulf of Mexico are actively generating source rocks buried to similar depths.

Keywords: diamondoids, basin modelling, petroleum systems, South Caspian Basin, Maykop

Features of the geological setting and development of Maikop deposits of Eastern Paratethys in connection with oil and gas occurrence

Vasili Kalabin, LUKE OIL

"…none of the formations of those constituting the Caucasus section is an object of such multi-ple interpretations and none of the formations was a reason for such number of disputes and diver-gence of views, as the Maikop formation" V.V. Belousov, "The Greater Caucasus", 1940

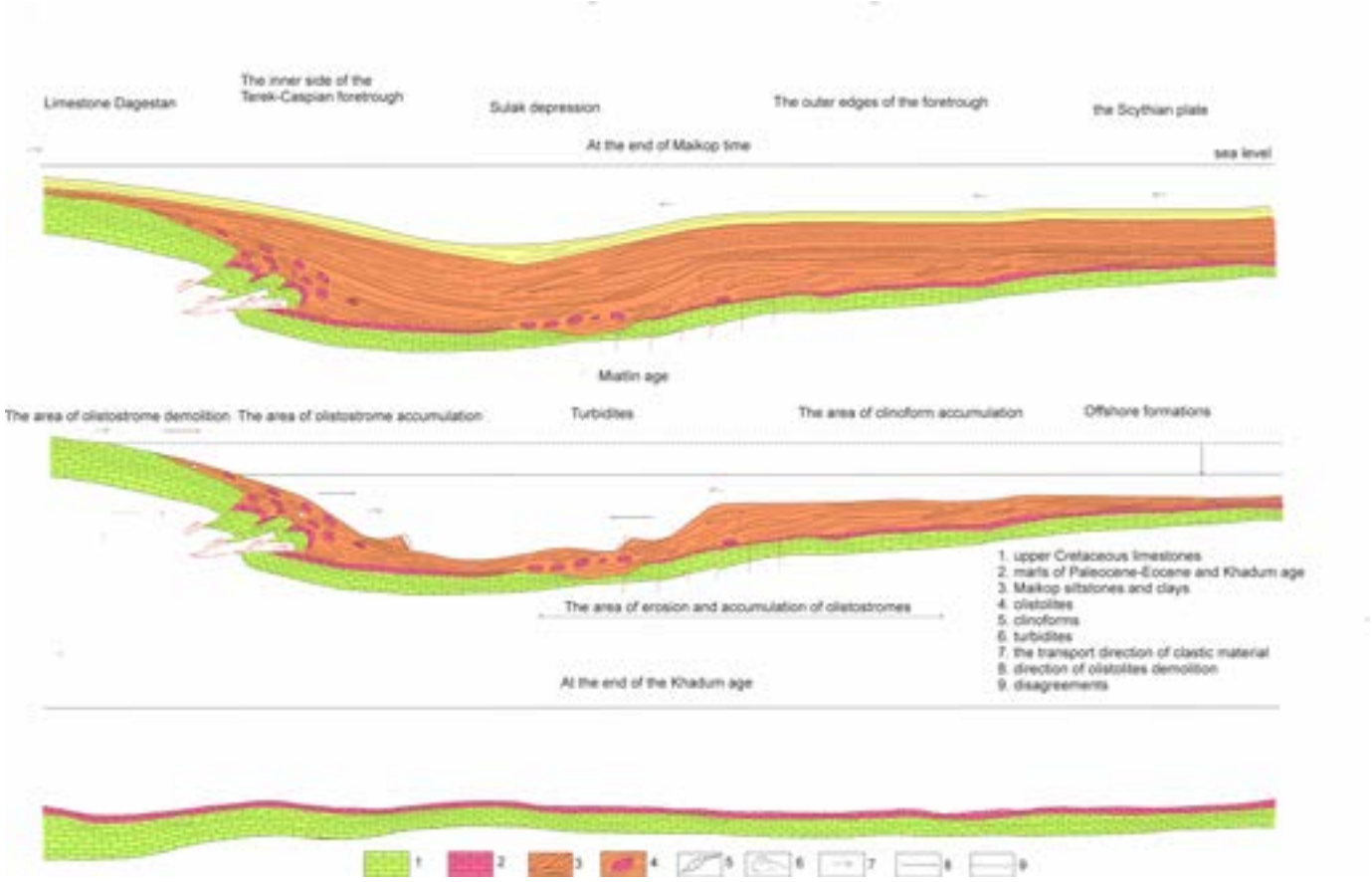
Identification of simultaneous occurrence and interrelation of the geological events of the Caucasian-Kopet Dagh segment of the Alpine-Asian fold belt is caused by the necessity to accurate-ly reconstruct the development of the Estern Paratethys during Maikop times. Following a multi-dimensional analysis of geological events, certain regularities and uniformity of the tectonic devel-opment at the interregional level were observed, thus allowing us to apply significant corrections to the conventional patterns of paleogeological development during Maikop time.

The stratigraphic scheme of the Maikop sediments is detailed and the separation of the Kha-dum horizon from their composition into an independent stratigraphic subdivision is justified. A re-gional unconformity between the Khadum horizon and the Maikop series was identified.

During Early Maikop (Later Khadum) times, the Caucasus and the Kopet Dagh were exposed to an early orogenic orte-tectonic stage of tectogenesis and some foretroughs were generated along their northern front (Indolo-Kuban, Tersko-Caspian, Kusaro-Divichinsky and Pre-Kopet Dagh). The compression with generation of thrusts occurred not along the entire length of internal edges of the troughs, but rather was associated with Akhtyrsky upthrust, as well as to the thrusts of Dagestan cline, Pre-Caspian monocline and Kopet Dagh thrust. It determined the specific development of the Maikop sedimentary basin. The sedimentation rates at this time were much higher compared with the Foraminifera and Khadum age. Under the conditions of regressive sedimentation regime, lateral sedimentation phenomena sharply increased, manifesting themselves as clinoforms and slop gravita-tional processes (olistostromes) (Fig. 1). The migration source of the terrigenous material was the southern edge of the Russian Plate (clinoforms of the edge of platform of Pre-Caucasian throughs) and emerging structures of the Caucasus and Kopet Dagh (olistostromes).

Based on the analysis of the sedimentation regularities and modern tectonic structure, a set of criteria was established to substantiate the hydrocarbon potential of Khadum and Maikop deposits and identify oil and gas accumulation zones. Areas connected with unconventional traps represent areas with high potential for the prospecting of HC accumulations: catagenetic type in Khadum de-posits, as well as clinoform and olistostrome types in Lower Maikop deposits.

ABSTRACTS


Limestone Dagestan
The inner side of the Terek-Caspian foretrough
Sulak depression
The outer edges of the foretrough
the Scythian plate
At the end of Maikop time
sea level
Maikop age
The area of olistostrome demolition
The area of olistostrome accumulation
Turbidites
The area of clinoform accumulation
Offshore formations
The area of erosion and accumulation of olistostromes
At the end of the Khadum age
1. upper Cretaceous limestones
2. marls of Paleocene-Eocene and Khadum age
3. Maikop siltstones and clays
4. olistolites
5. clinoforms
6. turbidites
7. the transport direction of clastic material
8. direction of olistolites demolition
9. disagreements

The Eastern Black Sea: The next Oil Super-basin in Paratethys

Neil Hodgson[1] and Karyna Rodriguez[1]
[1] Spectrum Geo Ltd, Woking, Surrey, UK

The deliberate and desperate search for new oil basins in the world starts at the same place; the identification of a rich oil prone source rock. The identification of reservoirs, seals and traps that are effective during the generation and migration of oil can follow as more subsurface data becomes available. Whilst the lack of drilling that defines most unexplored basins new basins, the Miocene Maykop Formation in the unexplored East Black Sea is singularly different as, deposited in the extensive central Paratethys, the Maykop is already well known to be a major regional source rock. Located by successful drilling in offset basins such as the Southern Caspian Sea, and Western Black Sea (Tari and Simmons 2018), the Maykop is also well studies in outcrop, around the basin and particularly as exposed in the collisional Pontides/Caucuses. Petroleum system modelling of the Maykop in the East Black Sea demonstrates that the Maykop is currently in the oil window under geotherm scenarios controlled by available well data (Minshull, 2010), which is consistent with the observation of numerous repeating natural oil slicks in the basin as detected on satellite data.

Having identified that source presence and effectiveness were the lowest exploration key risk factors for any of the poorly or undrilled basins being evaluated globally, in 2018 Spectrum collected new long streamer 2D data in the Turkish sector of the East Black Sea Basin, to investigate the additional key risk factors in this basin that are required for oil exploration plays – reservoir and trap. Only three wells have been drilled in the offshore; Sinop-1 that targeted a carbonate build up play, Hopa-1 that targeted shallow Pliocene clastics in a compressive structural trap, and Surmene-1 testing a deeper section in this play. The Pliocene and Upper Miocene clastics tested by Hopa-1 and Surmene-1 wells were provenance from the Rioni Delta in Georgia. These sediments are rich in volcanoclastics and though oil stained in both wells, the poor quality clastics were deemed to be tight.

However, as the Maykop distribution shows, the Maykop and pre Maykop sequences were deposited before the collision of the Pontides and Caucuses, i.e. before the Rioni delta existed. Sands within the Maykop and below the Maykop are likely to have been derived from the north where clastic sediments have a higher quartz grain component (Vincent et al. 2013), of from a paleo Dnieper/Volga fluvial system. The Shatsky ridge that lies between these sediment provenances and the East Black sea can be shown to be a late feature developed after the Early Miocene clastics had been deposited as deep water basin floor fans within and just on top of the Maykop source rock sequence.

The new 2D data acquired by Spectrum will be used to demonstrate the seismic characteristics of the Maykop source rock, to investigate and mitigate the Sinop-1, Hopa-1 and Surmene-1 well results and clarify the presence of stratigraphic and structural plays above, within and below the Maykop formation offshore Turkey and Georgia.

References

G.C. Tari and M.D. Simmons. (2018). History of deepwater exploration in the black sea and an overview of deepwater petroleum play types.
Geological Society, London, Special Publications, 464, 4 May 2018, https://doi.org/10.1144/SP464.16

T. Minshull and K.A. Aaaron 2010 Measuring the geotherm with gas hydrate bottom-simulating reflectors: a novel approach using three-dimensional seismic data from the eastern Black Sea Terra Nova, 22 (2), 131-136. (doi:10.1111/j.1365-3121.2010.00926.x).

S.J. Vincent, F. Hyden and W. Braham (2013). Along-strike variations in the composition of sandstones derived from the uplifting western Greater Caucasus: causes and implications for reservoir quality prediction in the Eastern Black Sea. Geological Society, London, Special Publications, 386, 111-127, 17 September 2013, https://doi.org/10.1144/SP386.15

Mapping depositional systems from the East Balkan thrust belt to the southwest Black Sea – provenance and reservoir quality implications at the transition between Peri- and Para-Tethys

Vincent, Stephen J. – stephen.vincent@casp.cam.ac.uk - CASP, Cambridge, UK
Vangelov, Dian - Sofia University, Bulgaria
Törő, Balázs - CASP, Cambridge, UK
Morton, Andrew C. - CASP, Cambridge, UK / HM Associates, St Ishmaels, UK
Hyden, Fiona - Oil Quest Ltd., Cerne Abbas, UK
Pointon, Michael A. - CASP, Cambridge, UK
Shiers, Michelle N. - CASP, Cambridge, UK
Frei, Dirk - University of the Western Cape, Bellville, South Africa

The East Balkan thrust belt is a north vergent retro-arc belt that formed during the closure of the Vardar Ocean and subsequent post-collisional convergence. Compressional deformation began in the late Campanian as earlier half-grabens were inverted. Thrust propagation resulted in the progressive cannibalisation and northward migration of the foreland, and thrust-sheet-basin development. Siliciclastic depositional systems were shed northward and then eastward from the active thrust belt into the southwest Black Sea. A coarsening-upward progression from thin-bedded, low-density turbidite to thick-bedded to massive, high-density turbidite and mass flow deposition, along with a northward migration of siliciclastic facies, is evident at outcrop. Carbonate deposition, along with quartz-rich siliciclastic deposition during low stands, characterised the more northerly, passive, Moesian Platform stratigraphy. Petrographic and provenance data including detrital zircon U-Pb dating, can clearly discriminate between these two systems and validate our outcrop observations.
Late Middle to Late Eocene half-graben formation and the shallowing upward of the foreland basin succession signals the beginning of orogenic collapsed and rebound in the East Balkans. This, when combined with drops in base-level, culminated in a major mid Oligocene to Early Miocene hiatus onshore, and canyon formation and large-scale turbidite progradation offshore. These turbidite systems form actual and potential reservoir targets in the southwest Black Sea. Basal canyon fill facies comprise thick, structureless, pebbly sandstones and interbedded sandstones, siltstones and mudstones, which are interpreted as high-density turbidites and debrites, and canyon levee or intra channel low-density turbidites, respectively. Compositional data demonstrate a clear link between well sample material and onshore depositional analogues. Furthermore, the compilation of a circum-Black Sea basement and detrital zircon U-Pb age database has enabled us to highlight specific source regions likely to fall within the catchment of these depositional systems. Very limited porosity data from offshore Oligocene sandstones suggest that they have good reservoir quality.

Evaluation of heterolithic thinbeds and impact to oil in place in OMV Petrom offshore field Sinoe

Bieg, Ulrich(1), Hausberger, Oliver (1)
(1) OMV Petrom S.A., Coralilor Street No. 22, Sector 1, 013329 Bucharest

OMV Petrom brown-fields, in particular offshore, often comprise of a fast succession of sand-silt-(clay) heterolithic layers in mm, cm and dm-scale thickness. These thin layers are easily omitted from HC volume in place due to the limited vertical log resolution (i.e. neutron-density, GR, resistivity), however contributing significantly to hydrocarbon production with stable, low decline over several years.

A methodology based on high resolution drill-core sampling and petrophysical interpretation was developed to evaluate bypassed pay.

Detailed sampling of lithofacies types, core plug and high resolution mini-permeameter measurements were utilized to derive an understanding of pay thickness and the depositional model. Core lithofacies types show a consistent number of classes distributed over the whole stratigraphic column. However, stacking pattern and overall changes in single bed thickness change. A distal delta front environment translating into a more down-slope basinal environment was inferred.

Due to typical log resolution (neutron log ~12 inch) thin bedded layers are often overlooked in a conventional petrophysical evaluation. Thin bed analysis using cross plots techniques like Thomas-Stieber allowed resolving the challenges of highly laminated formations.

By selecting sand and shale endpoints one is able to partition the formation in up to four different sand-shale distributions and evaluate their fractions. One of these configurations is the laminated sequence consisting of two distinct rock types, namely clean, shale-free sands and pure shale. Due to their character these clean sands even as thin beds exhibit high porosities and permeabilities and are therefore significantly contributing to hydrocarbon volumes and production. In addition high resolution image logs were utilized to adapt and validate the required input parameters.

The above described workflow enabled us to demonstrate, that a factor of 1.5 to 2 of laminated pay was bypassed so far.

Evolution and petroleum potential of the Meso-Cenozoic basins of the Crimean-Caucasus region and the surrounding waters of the Black and Azov Seas

Kruglyakova Maria - kruglyakovamari@gmail.com – JSC "Yuzhmorgeologiya"
Levitskaya Maria – levitskaya.mari@gmail.com – JSC "Yuzhmorgeologiya"
Levitsky A.A. – levitsky91@gmail.com – JSC "Yuzhmorgeologiya".

Presently consumption and interest in oil production is growing every year. Therefore, the question of new prospects in the oil and gas industry is actual now. The Crimean-Caucasus region and the surrounding waters of the Black and Azov Seas are one of the oldest Russian petroleum region. There, the main prospects of oil and gas are associated with Cenozoic petroleum systems. Howewer, analysis of the history of development this region shows a high probability of the prospects of Mesozoic petroleum systems. To make this analysis, it is necessary to consider the entire evolution of basins, starting with the Mesozoic.

There are some of the theses in this article:

- Within the study area, petroleum systems are distinguished in the Mesozoic and Cenozoic parts of the sedimentary section.

- Reasoning from sedimentation environments, Middle Jurassic, Lower and Upper Cretaceous, and Maikopian clayish deposits accumulated in the deep-water environments of the outer shelf and continental slopes of age-appropriate paleobasins, may have oil and gas source rock properties.

-The paleo reconstructions of basins were produced for the main stages of the region's development (Middle Jurassic, Late Jurassic, Early and Late Cretaceous, Paleocene-Eocene, Maikop, Sarmatian, Meotis) to clarify the peculiarities of the development of the elements of petroleum systems (source rock and reservoirs). Reservoirs may be represented by Upper Jurassic shelf carbonate deposits, Lower Cretaceous clayish carbonate deposits, Upper Cretaceous carbonate deposits, Maikopian and Middle-Upper Miocene coastal or deep-water (turbidite) terrigenous deposits.

As a result of research, distribution areas of source rocks and resevoirs were determined. With this information, it is possible to make a suggestion about distribution areas of petroleum systems in eastern Black sea aquatorium and adjacent land. Next step of research is basin modelling of this region. It can predict some oil and gas plays, which were unknown today.

Identification of electrical and petrophysical rock types based on core and well logs: utilizing the results to delineate prolific zones in a deep water sandy package, South Caspian Sea basin

Najmeh Jafarzadeh[1], Farid Taati[2], Ali Kadkhodaie[3]
[1] School of Geology, University College of Science, University of Tehran
[2] Caspian Petroleum Company, Tehran, Iran
[3] Earth Sciences Department, Faculty of Natural Sciences, University of Tabriz, Tabriz, Iran

The characterization of reservoir rocks in terms of their depositional and diagenetic properties plays a significant role in reservoir studies. The main properties are usually defined by descriptive macroscopic and microscopic studies on core intervals (lithofacies) and thin sections (petrofacies/microfacies) respectively. Considering that the core data is not found in all the wells, the main focus is on well log data which exists in all the wells continuously. In the current study, with focus on sandy reservoir deposits of a field in the southern area of the Caspian Sea, reservoir rocks were characterized based on the integration of the results from core description, thin section studies and petrophysical well logs analysis. In this respect, the well logs responses were analyzed through the electrofacies concept on the basis of the Multi Regression Graph Base Clustering (MRGC). This process has eventually led to the identification of four facies. The best facies, determined with the help of correlating between the three methods of acquiring facies, is a facies with high production potential. Facies Code One has been assessed as the best facies on the basis of reservoir quality which has a good compatibility with the best rock facies of PFI. Eventually, the best facies in terms of reservoir quality has been identified as the Facies Code One which has the most extensiveness in the Fasila reservoir zone. Finally the best production zone can be assessed on the basis of Fasila B reservoir quality zone.

Keywords:Petrofacies, Electrofacies, Multi Regression Graph Base Clustering (MRGC), South Caspian

On the arrival and evolution of the Danube in the Dacian Basin, Romania

Author: Krézsek, Csaba - csaba.krezsek@petrom.com - OMV Petrom, Bucharest, Romania
Co-Author: Olariu, Cornel - cornelo@jsg.utexas.edu - The University of Texas at Austin, Austin, TX, USA

The Danube is one of the largest continental-scale rivers of Europe. It originates in the Bavarian foreland and flows across the Vienna, Pannonian and Dacian basins before enters into the Black Sea and forms the Danube Delta.

The post Late Miocene sedimentary fill of the basins located along the Danube course and upstream of the Dacian Basin is strongly related to the evolution of the Danube itself. In contrast, the arrival of the Danube into the Dacian basin, its role in the basin fill, and its entry into the Black Sea remains debated.

Our scope is to revisit the stratigraphy of the Dacian Basin searching for the evidences for the Danube. We argue the Dacian Basin in fact comprises two different sub-basins (Western and Eastern) with different sedimentary evolution. These two sub-basins were often connected across a shallow gateway located in the area of the Intra-Moesian fault zone.

The Eastern Dacian Basin was controlled by a river system (Paleo-Prut?) prograding from north to south along the foreland of the Eastern Carpathians. In turn, the Western Dacian Basin has been predominantly filled from east to west by a different river system that originated in the central Southern Carpathians (Paleo-Olt?).

The first clear evidences of the Danube in the Western Dacian Basin are the Pliocene aged thick fluvial sequences with coal. By that time, the Western Dacian Basin has been already filled up by the “Paleo-Olt” and the Eastern Dacian Basin by the “Paleo-Prut”. Therefore, the Danube likely zipped through relatively fast across the entire Dacian Basin and then joined the “Paleo-Prut”, which by that time had a well-established sediment delivery route into the Black Sea through the Galati Gateway.

As a conclusion, the Danube in the Dacian Basin comprises Pliocene-aged and mostly alluvial deposits. In addition, deltaic to shallow marine deposits locally could be present in the Eastern Dacian Basin, related to marine incursions from the Black Sea through the Galati Gateway.

Keywords: Paratethys, Dacian Basin, Danube

Biostratigraphy and depositional environments of Late Miocene to Early Pliocene rocks in the Dacian Basin (SE Romania)

Manuel Casas-Gallego[1], Irene Perez-Rodriguez[1], James P.G. Fenton[1], Andreea Marza[2], Eugen Tudor[2]
1 CGG Robertson, Llandudno, North Wales LL30 1SA, United Kingdom
2 Hunt Oil Company of Romania, Banease Business Center, Sector 1, 013694 Bucharest, Romania

The Dacian Basin (eastern Paratethys region) experienced a progressive isolation from the Mediterranean and the neighbouring Pannonian and Euxinian basins during the Late Miocene. This general trend resulted in the establishment of gradually shallower depositional settings and the development of distinctive, often endemic, floral and faunal communities. Major palaeoenvironmental changes and the fossil assemblages associated with them are the main features used to define the limits between the regional Paratethys chronostratigraphic stages. Despite more than 50 years of oil exploration in the Dacian Basin, understanding of its complex stratigraphy and the fossil assemblages is still far from being complete. This presentation aims to give an overview of the biostratigraphic work carried out in the Dacian Basin based on the study of five recently drilled wells in the central-eastern part of the basin. We focus on Late Miocene to Early Pliocene sedimentary successions from SE Romania, where no previous biostratigraphic data are available, to provide a palaeoenvironmental depositional model covering the Sarmatian, Meotian, Pontian and Dacian regional stages. Additionally, a biostratigraphic zonation scheme with emphasis on palynology is proposed, as a complement to the ostracod and mollusc-based biostratigraphy traditionally used for age determination in the Neogene of the Dacian Basin.

Two major marine incursions into the basin are represented by influxes of the benthonic foraminifer Ammonia beccarii and used to define the Sarmatian - Meotian and the Meotian - Pontian boundaries. Between these two transgressions, the Meotian is interpreted as a period with at least a certain degree of marine influence. The occurrence of dinocyst taxa usually found in Mediterranean and Atlantic sedimentary records suggests a connection between Paratethys and the Mediterranean, which probably occurred via the Black Sea. The Meotian-Pontian marine flooding event led to a short re-connection of the Pannonian and Dacian Basins, resulting in the migration of a diverse, endemic microflora and fauna from the former to the latter. Thus, in the Pontian section we record the first occurrence of a diverse, endemic dinocyst assemblage that evolved under isolated and low salinity conditions in the Pannonian Basin. The signature of a reduction in water level due to the Messinian Salinity Crisis within the study area is interpreted to be represented in the successions by an interval dominated by distinctive sand units. For the late Pontian, a consistent change in the gamma ray log response, identified in the five studied wells, is interpreted as representing increased water level of the Dacian Basin due to a positive hydrological balance, previously recognised in the northern part of the basin. During the Dacian stage (Early Pliocene), the occurrence of coal layers reflects a transition from brackish to freshwater depositional setting is inferred, as indicated by the abundance of non-marine molluscs and miospore assemblages produced by a diverse hygrophytic flora.

Sedimentary architecture and depositional controls of a Pliocene river-dominated delta in the semi-isolated Dacian Basin

Author : Jorissen, Elisabeth L. - e.l.jorissen@uu.nl - Palaeomagnetic Laboratory 'Fort Hoofddijk', Faculty of Geosciences, Utrecht University, Budapestlaan 17, 3584 CD, Utrecht, The Netherlands
Co Author : de Leeuw, Arjan - arjan.de-leeuw@univ-grenoble-alpes.fr - Université Grenoble Alpes, Institut des Sciences de la Terre, 38000 Grenoble, France; van Baak, Christiaan G.C - cv336@cam.ac.uk - CASP, West Building, Madingley Rise, Madingley Road, Cambridge, CB3 0UD, United Kingdom; Mandic, Oleg - oleg.mandic@NHM-WIEN.AC.AT - Geological-palaeontological Department, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria; Stoica, Marius - marius.stoica@g.unibuc.ro - Department of Palaeontology, Faculty of Geology and Geophysics, University of Bucharest, Bălcescu Bd. 1, 010041, Romania; Abels, Hemmo A. - H.A.Abels@tudelft.nl - Department of Geosciences and Engineering, Delft University of Technology, Stevinweg 1, 2628 CN, Delft, The Netherlands; Krijgsman, Wout - W.Krijgsman@uu.nl - Palaeomagnetic Laboratory 'Fort Hoofddijk', Faculty of Geosciences, Utrecht University, Budapestlaan 17, 3584 CD, Utrecht, The Netherlands

Sedimentological facies models for (semi-)isolated basins are less well developed than those for marine environments, but are critical for our understanding of both present-day and ancient deltaic sediment records in restricted environments. Restricted basins form unusual depositional settings, where depositional forcing mechanisms often differ from the open ocean. Outcrops of deltaic deposits that accumulated in (semi-)isolated basins are relatively rare, but can provide wider spatial and temporal insights into drivers of sedimentary facies and fauna distributions.
This study considers an 835m-thick sedimentary succession of mid-Pliocene age (Dacian regional stage), which accumulated in the Dacian Basin, a former embayment of the Black Sea. Sediments were deposited along the northern margin of the basin, in the SE Carpathians foredeep. Detailed sedimentological and palaeontological analyses reveal a regression from distal prodelta deposits with brackish water faunas to delta-top deposits with freshwater faunas. Deltaic progradation created thin, sharply-based sand bodies formed by multiple terminal distributary channels, covering a wide depositional area. The system experienced frequent delta-lobe switching, resulting in numerous thin parasequences. Parasequences are overlain by erosive oxidized shell beds, formed under sediment starvation on top of abandoned delta lobes after a flooding event. A robust magnetostratigraphic time frame allows for comparison between the observed sedimentary cyclicity and the amplitude and frequency of astronomical forcing cycles. Our results indicate that parasequence frequencies are significantly higher than the number of time equivalent astronomical cycles. This suggests that delta-lobe switching was due to autogenic processes.
We consider the observed facies architecture typical for a delta prograding on a low-gradient slope into a shallow, brackish, protected, semi isolated basin. Furthermore, in the absence of significant wave and tidal influence, sediment progradation in such a protected depositional setting shaped a strongly river-dominated delta. Facies models developed in this paper may form good analogues for more poorly exposed or subsurface deltaic successions in (semi-)isolated basins.

Keywords: Paratethys, isolated basin, river-dominated delta, regressive parasequences, autogenic forcing, flooding surface

Sand injectite occurrence in the Western Black Sea

Author : OTELEANU Alexandra - EugeniaAlexandra.Oteleanu@petrom.com– OMV Petrom

While sand injectites are a relatively common feature of deep-water clastic systems, their existence and importance is routinely overlooked in most basins. This is certainly also the case in most of the Paratethys basin and notably in the Black Sea area.

Injected bodies due to post depositional sand remobilisation are well documented in the Paleogene of the North Sea basin. Their importance and recognition started growing after technology advances (such as an increase in 3D seismic resolution) and subsequent discoveries or reinterpretation of large scale oil bearing injected sands (Briedis et al., 2007; de Boer et al., 2007).

In the Western Black Sea, courtesy of a new large coverage high quality 3D seismic data set several features can be mapped with distinctive, sand injection features (Figure 1). Large scale, isolated or connected winglike discordant seismic anomalies can be described, both in in cross section or map view.

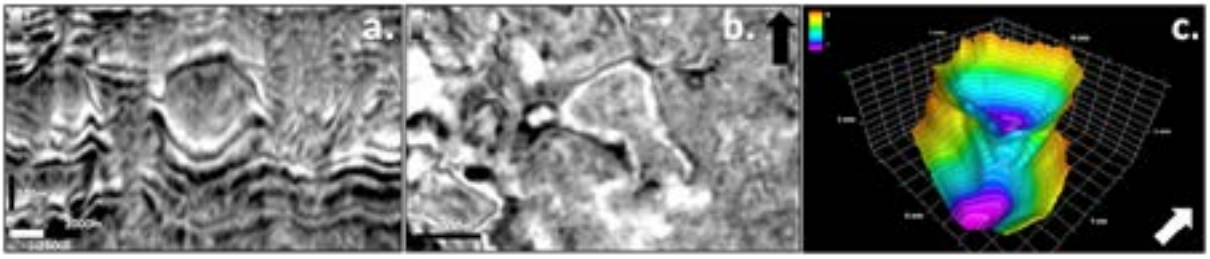


Figure 1: Seismic examples of a sand injectite body in the Western Black Sea. (a) Discordant winglike reflections crosscutting up to 200m upward. (b) Depth slice through the structure described at (a) showing the extent of the winglike reflection and oval pattern. (c) 3D visualisation of the structure map of the event, showing a characteristic saucer shape. The seismic volume was acquired by CGG, with PSDM processing by WesternGeco for an ExxonMobil/OMV Petrom joint venture.

The features bear a distinct difference to potentially similar blocks inside mass transport complex (MTCs) that are also common in the data set. No flow direction can be inferred in map view and the mapped geometries are consistent with the ones previously published (Huuse et al., 2007), such as oval shapes and the steep flanks of the mounds compared with the angular and elongated MTC blocks.

Injected sand is usually well sorted sand with good reservoir quality and good to very good communication that can work as a hydrocarbon migration pathway or as individual traps (Briedis et al., 2007; Hurst et al., 2003b). Following the North Sea example, sand injection presence can change the process of hydrocarbon exploration in a basin.

The features are not fully visible on vintage data sets and have been systematically overlooked or mistaken for MTCs. This paper is planning to describe the features, comparing them with outcrop and seismic analogues and to support the case of the existence of large scaled sand injectite bodies in the Western Black Sea basin.

Keywords: Sand, Injectite, WBS, Western, Black, Sea, play

References:

Briedis, N. A., D. Bergslien, A. Hjellbakk, R. E. Hill, and G. J. Moir, 2007, Recognition criteria, significance to field performance,

and reservoir modeling of sand injections in the Balder field, North Sea, in A. Hurst and J. Cartwright, eds., Sand injectites: Implications for hydrocarbon exploration and production: AAPG Memoir 87, p. 91–102.
de Boer, W., P. B. Rawlinson, and A. Hurst, 2007, Successful exploration of a sand injectite complex: Hamsun Prospect, Norway Block 24/9, in A. Hurst and J. Cartwright, eds., Sand injectites: Implications for hydrocarbon exploration and production: AAPGMemoir 87, p. 65–68.
Hurst, A., J. A. Cartwright, M. Huuse, R. Jonk, A. Schwab, D. Duranti, and B. T. Cronin, 2003, Significance of large-scale sand injectites as long-term fluid conduits: Evidence from seismic data: Geofluids, v. 3, p. 263–274
Huuse, M.J., Cartwright, J.A., Hurst, A., Steinsland, N., 2007. Seismic characterization of large-scale sandstone intrusions. In: Hurst, A., Cartwright, J. (Eds.), Sand Injectites: Implications for Hydrocarbon Exploration and Production: American Association of Petroleum Geologists Memoir, Tulsa, pp. 21–35.

Karaburun (NW Turkey): A Key Oligocene Section on the Margins of Paratethys

M.D. Simmons[1], M.D. Bidgood[2], S. Ćorić[3], A.I. Okay[4], D. Shaw[5], E. Tulan[6], J. Mayer[7] & G.C. Tari[8]*
1 - Halliburton, 97 Jubilee Avenue, Milton Park, Abingdon, OX14 4RW, UK & The Natural History Museum, Cromwell Road, London, SW7 5BD, UK (mike.simmons@halliburton.com)
2 – GSS (Geoscience) Ltd, 2 Meadows Drive, Oldmeldrum, Inverurie AB51 0GA, UK
3 – Geological Survey of Austria, Neulinggasse 38, 1030 Vienna, Austria
4 - Eurasia Institute of Earth Sciences, İstanbul Technical University, 34469 Maslak, İstanbul, Turkey
5 – Biostratigraphic Associates (UK) Ltd, 17 Woodland Avenue, Stoke On Trent, ST6 8NE, UK
6 - Montanuniversitaet Leoben, Peter Tunner Strasse 5, 8700 Leoben, Austria
7 – OMV New Zealand Ltd, The Majestic Centre, 100 Ellis Street, 6011 Wellington, New Zealand
8 - OMV Exploration & Production GmbH, Trabrennstrasse 6-8, A-1020 Vienna, Austria

Oligocene strata of the İhsaniye Formation crop out at Karaburun located on the Black Sea Coast of Turkey approximately 60 km northwest of Istanbul. This is primarily a succession of marls (in part rich in organic carbon), although coarser units are present in parts of the succession. The precise age and depositional environment of this succession has been the subject of some discussion in the literature; consequently, we have used well-preserved assemblages of calcareous nannoplankton, foraminifera, and palynomorphs present to determine the detailed biostratigraphy, age calibration, and palaeoenvironments of the section. The succession is significant to petroleum geologists because it represents a lateral equivalent to Oligocene-aged source rocks in the Black Sea Basin that are variously attributed to the Maykop Suite and Ruslar Formation. Age-equivalent source rocks also occur in the Thrace Basin. Interpretation of the succession is therefore useful for providing insight into regional palaeogeography and relative sea-level change, both of which have a bearing on the regional distribution of petroleum play elements within this sector of Paratethys.

The outcrop represents a complex story of onlap against an Eocene reefal limestone high, with an active fault partly controlling deposition. Nonetheless, all three biostratigraphic disciplines used suggest that the studied section can be biostratigraphically calibrated to the Early Oligocene (Early Rupelian). Biozonal subdivision and detailed correlation is possible within this age bracket.

Deposition occurred dominantly in outer neritic (shelf) – bathyal (slope) depositional settings. It is notable that the İhsaniye Formation at Karaburun is mostly marly (as opposed to purely siliciclastic) and contains a fully open marine diverse fauna with no evidence for restriction and/or only limited evidence for bottom-water anoxia within its lower part. This may reflect a proximity to a Tethyan marine connection to the south by means of the Thrace Basin. The restriction (semi-marine isolation) noted in age equivalent strata in other parts of the Black Sea Basin was not observed at Karaburun.

Sediment volumes and sedimentation rates in the South Caspian Basin: distribution, sources and age constraints

Nazim Abdullayev, BP

Landlocked South Caspian Basin (SCB) is characterized by unusually high mass accumulation and sedimentation rates in Pliocene and Pleistocene. These rates are in order of magnitudes larger than most sedimentation rates in Asia. The solid sedimentary mass in SCB accumulated during last 5Ma is second only to the coeval sediments of the Bay of Bengal – one of the world's thickest accumulation of sediments. More than 1.6 million cubic meters of net rock volume (or a solid sediment mass of 4.42*10^18 kg) have accumulated in the basin since its inception; of which 492 thousand km3 was in Pliocene and 282 thousand km3 in Pleistocene. This mass-age distribution of sediments in the basin slowly rose through to Miocene when SCB was part of Paratethys, and increased drastically at Miocene-Pliocene boundary. More than 40% of sediments in the Caspian were accumulated after this time.

Using combination of radiometric U/Pb, He-Th and magnetostratigraphy dating within Pliocene Productive Series (PS) allowed to better understand sedimentation rates within the basin. The average sedimentation rates across the basin rose dramatically from 182 m/Ma in Miocene to 1289 m/Mya in Pliocene-age Lower PS and then to maximum of 2400 m/Mya during Middle PS. During Akchagyil sediment accumulation rates decreased to 200 m/Mya, but then rose to 800 m/ Mya.

The Pliocene age PS, represents significant increase in sedimentary volume after large scale Miocene-Pliocene base level that initiated short period of deposition between 5.3Ma and 2.71Ma. We interpret the increase in the sedimentation rates at Miocene-Pliocene boundary as related to erosion of geographically large hinterland areas of Eastern European craton by Paleo-Volga system, interior Central Asia, Pamirs and possibly West Siberia by Paleo-Amudarya system and Caucasus by Paleo-Kura system.

Two large integrated drainage network systems, the Paleo-Amudarya river drainage system and Paleo-Volga drainage system, played the dominant role in filling the basin with sediments. The role these two river systems played in supplying the basin with sediment mass also seemed to have changed over time. Thus, during Pliocene Paleo-Volga supplied about 37% of all sediment mass, its influence waning through Pliocene. Paleo-Amudarya, on the other hand brought increasing amounts of sediments into the Caspian through to Pleistocene comprising 73% of all sediment volume coming from Paleo-Amudarya in Pleistocene (during last 2.4Myr). During Akchagyl period between 2.71 and 1.8Ma more than 40 thousand km3 was accumulated in the basin, all of it supplied from the east via the Paleo-Amudary entry point. It is speculated that rush of water brought into the Caspian from the Arctic ocean via the Amu-Darya kept the sedimentation rates high through to modern day despite less water input from Paleo-Volga.

Increase in sediment volume and sedimentation rates this period are coeval to the increase in sedimentation rates recorded last 2 to 4 million years around a globe in a variety of settings, implying increasing erosional rates related to a change from a period of climatic stability to a more variable period of frequent an abrupt changes in climate. This apparent increase in sedimentation rate during the Neogene and Quaternary is linked to alteration of the weathering-erosion-sedimentation system of which phenomenon the SCB plays an important role.

Establishing a stratigraphic reference section for the Middle Miocene marine deposits of Azerbaijan

Van Baak, Christiaan G.C. – Chris.vanBaak@casp.cam.ac.uk – CASP, Cambridge, UK
Vincent, Stephen J. – Stephen.Vincent@casp.cam.ac.uk – CASP, Cambridge, UK
Shiyanova, Natalya – shnwpo@bp.com – BP-Azerbaijan, Xazar Center, Baku, Azerbaijan
Richards, Keith – kr@paly.co.uk – KrA Stratigraphic, Deganwy, UK
Aghayeva, Vusala – vagayeva1@GMail.com – Geography Institute, Baku, Azerbaijan
Krijgsman, Wout – W.Krijgsman@uu.nl – Utrecht University, The Netherlands
Santos, Carlos – Carlos.Santos@uk.bp.com – BP, Sunbury, UK

Given the semi-isolated nature of the Eastern Paratethys Sea, key markers used in global biostratigraphic schemes are barely recognised. Instead, the biostratigraphic subdivisions of the Paratethyan sedimentary succession is based on faunal response to regional paleoenvironmental changes. While this macrofossil-based biostratigraphy does potentially allow for high-resolution subdivision, the use of macrofossils such as molluscs in the subsurface is hard to apply.

In recent years, significant progress has been made in understanding the Middle Miocene to Recent Paratethys stratigraphy by creating high-resolution, absolute age-dated multiproxy stratigraphic records. In these studies, the focus has predominantly been on marginal, shallow-water environments in which the Paratethys regional stages were originally defined. With this framework now in place, can we apply this knowledge to deep-water, fine-grained sediment successions in the region?

The Gobustan region of Azerbaijan has one of the most continuous outcrop records of Early Cenozoic deep-water sediments in the Eastern Paratethys region. We analysed the classic and widely studied Islamdag section. Contradictory age interpretations have been published by different authors, with some intervals assigned to either the Late Eocene or the Late Miocene. This obvious mismatch highlights the importance of establishing detailed biostratigraphic reference localities in Eastern Paratethys deep-water deposits.

During fieldworks in 2016-2017, we logged 450 m of section at cm-scale, trenching through up to 1 m of weathered material to collect ~ 300 samples. A subset of around 65 samples have been analysed to develop a multidisciplinary biostratigraphic scheme. In the field, we referred back to stratigraphic subdivisions of the Gobustan area in Russian lithostratigraphic works dating from the 1920's and 1930's. While these subdivisions and reference levels allow for straightforward correlation between outcrops, their significance on a regional scale remains poorly understood.

Here, we aim to establish a high-resolution, quantitative and multiproxy, age-dated stratigraphic framework for these fine-grained marine sediments. The biostratigraphic dataset is predominantly based on palynology (dinoflagellate cysts, acritarchs, green algae, pollen and spores). Additional insights come from sedimentological observations and microfossils. We will propose a high-resolution age model based on magnetostratigraphy and absolute age-dating techniques such as 40Ar/39Ar dating of volcanic ash layers. Using these constraints, we will propose a correlation both to global records and to previously published biostratigraphic records in other regions in the Eastern Paratethys, including the Taman Peninsula (Southern Russia) on the shore of the Black Sea, to highlight the importance of these results in a Paratethys-wide context.

Keywords: Middle Miocene, deep-water, biostratigraphy, Azerbaijan

Understanding the Akchagyl and Apsheron in the Greater Caspian Sea Region: new biostratigraphic insights

Richards, Keith - kr@paly.co.uk – KrA Stratigraphic, Deganwy, UK & University of Amsterdam
Van Baak, Christiaan G.C. - Chris.vanBaak@casp.cam.ac.uk – CASP, Cambridge, UK
Hoyle, Thomas M. - t.m.hoyle@uu.nl – Utrecht University, The Netherlands
Naidina, Olga D. - onaidina@gmail.com – Russian Academy of Sciences, Moscow, Russia

The Akchagylian (Akchagyl) and Apsheronian (Apsheron) Regional Stages are well known stratigraphic intervals that were widely deposited in and around the Greater Caspian Sea Region during the latest Pliocene and early Pleistocene. Both these stratigraphic units were deposited as a result of water levels in the Caspian Sea that were significantly higher than at the present time. The Akchagyl is important as it provides the regional seal overlying the oil and gas bearing Productive Series, whereas the Apsheron forms a major portion of the 'overburden' sediments in this over-pressured petroleum system. Detailed biostratigraphic investigations reveal that both the Akchagyl and Apsheron units were deposited primarily under brackish rather than fully marine conditions. However, marine influences are widely evident in the lower part of the Akchagyl, marked by the presence of dinoflagellate cysts and small cassidulinid foraminifera which typically occur in deep and/or cold marine waters. The marine microfossils are likely to have originated from the Arctic Ocean, and not the Black Sea or Mediterranean Sea as is widely believed. Microfossils with affinity to Central Paratethys (Pannonian and Dacian basins) occur sporadically in the Akchagyl and frequently in the Apsheron intervals. Accurate dating and subdivision of the Akchagyl and Apsheron units is possible using a combination of Ar/Ar dating of ash layers, magnetostratigraphy and biostratigraphy. This is demonstrated in outcrop, core and well studies from Azerbaijan and Russia.

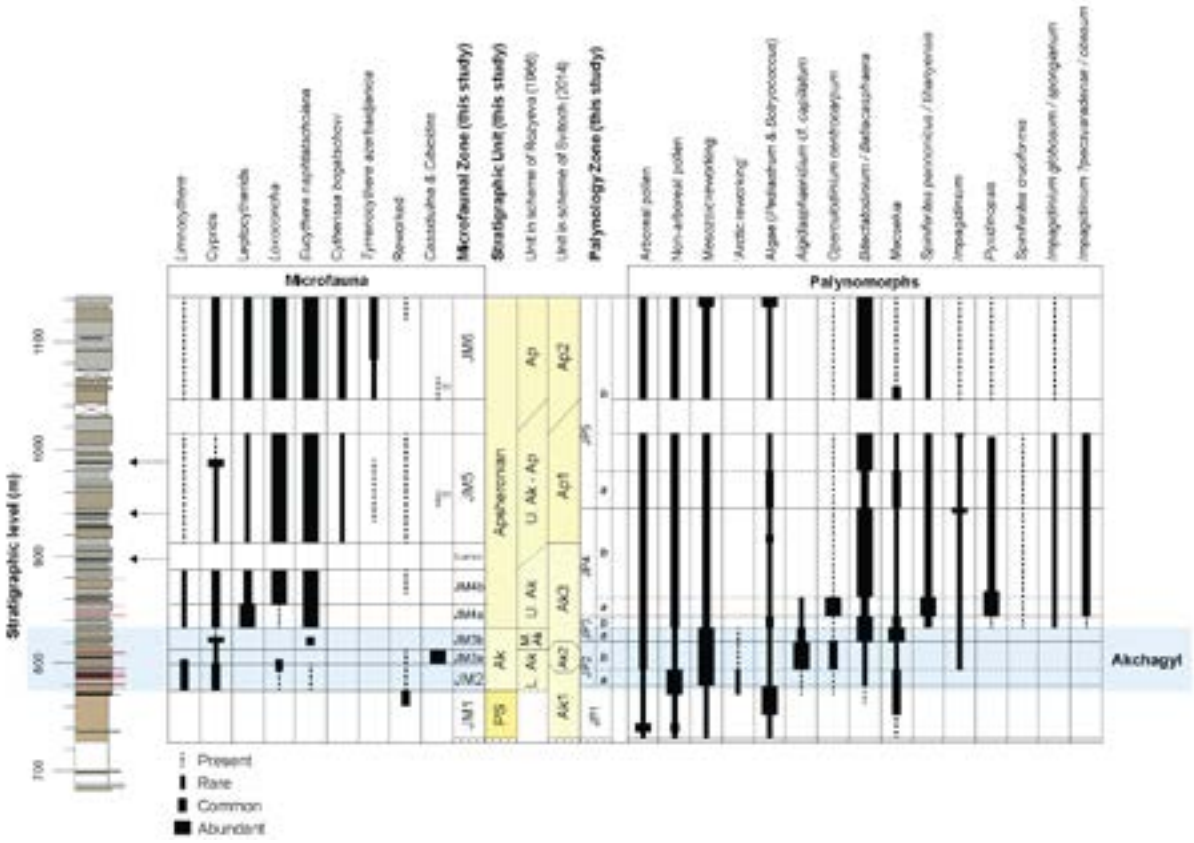


Figure 1: Stratigraphic summary showing relative abundances of microfauna (ostracods and foraminifera) and palynomorphs in outcrop at Jeirankechmez, Azerbaijan. Source: Richards, Van Baak et al. (2018) Palaeogeography, Palaeoclimatology, Palaeoecology 511, 119-143.

Keywords: palynology, ostracods, foraminifera, magnetostratigraphy, Caspian Sea, Paratethys, Azerbaijan, Russia

The Eastern Paratethys during the Messinian Salinity Crisis

Rostovtseva Yuliana, rostovtseva@list.ru, Lomonosov Moscow State University
Rybkina Alena, a.rybkina@gcras.ru, Geophysical centre of the Russian Academy of Sciences

The Messinian Salinity Crisis (MSC) of the Mediterranean is the greatest event in the Miocene related to dramatic palaeoenvironmental changes and deposition of evaporites. This unusual event, driven by tectonic reorganization and gradual climatic deterioration, influenced the sedimentary setting in the Paratethys, including the Black Sea region (Earthen Paratethys). The interpretation of individual MSC steps in the Miocene record of the Black Sea is open to debate. Most researchers assume that the Black Sea Pontian partially or entirely corresponds to the MSC interval.

This study presents data on the orbitally calibrated Maeotian/Pontian and Pontian record of the Black Sea Basin obtained by time-series analysis of magnetic susceptibility (MS) data from relatively deep-water Upper Miocene sediments exposed in Taman Peninsula (Russia). In the studied Black Sea Pontian sequence, spectral analysis revealed statistically significant signals with 6.1–8.2 m and 3.0–4.0 m wavelength. These signals correspond to the obliquity and precession cycles, respectively.

Astronomical tuning of the Maeotian/Pontian transition and the Pontian sedimentary record at Taman region (Black Sea Basin) confirms that the Pontian began at ~6.1 Ma. The Maeotian/Pontian beds with Actinocyclus octonarius were deposited from ~6.3 to 6.1 Ma. The Novorossian sediments extending from the base “stagnation horizon” to the Novorossian/Portaferian boundary correspond to the first MCS step (5.97–5.6 Ma). The TG 22 (5.79 Ma) and TG 20 (5.75 Ma) glacial events are reflected in the uppermost Novorossian record with extraordinarily high values of MS. In the Novorossian, the final phase of marine invasion occurred no later than ~5.88 Ma. The estimated ages of base and the top of Taman Portaferian are ~5.65 Ma and ~5.45 Ma, respectively. These beds include detrital shell limestone, clay breccia, a paleosol horizon, and sandy clay. The Portaferian corresponds to the second MSC step, which is marked by development of the Messinian Erosional Surface (MES). The Novorossian/Portaferian boundary is marked by a hiatus of ~150–160 kyr that agrees well with the presence of re-sedimented deposits and erosional boundaries in Portaferian sedimentary sequence and the concept of intra-Pontian unconformity. It is known that the Pontian petroleum system is defined in the Western Black Sea Basin. The intra-Pontian (Messinian) sea-level drop caused the gravitational slumping and erosion within Romanian shelf (Istria Trough).

The Bosphorian that corresponds to the transgressive phase in Black Sea Basin is analogous to the re-flooding of the Mediterranean and the third Lago Mare episode, both of which were caused by a high sea-level connection between the Mediterranean and Eastern Paratethys. The top of the Bosphorian dates at ~5.27 Ma. The length of the Pontian stage is at least ~830 kyr (from 6.1 to 5.27 Ma), taking into account integrated biostratigraphic, paleomagnetic, sedimentological and astronomical cyclicity data.

This work was financially supported by the RFBR (№17-05-01085).

Keywords: Messinian Salinity Crisis, Earthen Paratethys, intra-Pontian erosional surface

The South Caspian Basin subsidence and its bearing on depositional environment of Upper Barremian-Lower Aptian successions (Tirgan Formation), Western Koppet-Dagh (NE Iran)

Behrooz Ariafar[1], Mohsen Yazdi-Moghadam[2]
1-(Email:geoariaf@yahoo.com): Correspondent outhor
2- (Email:Mohsen.moghadam@gmail.com)
N.I.O.C. Exploration Directorate, 1st Dead End, Seoul St., NE Sheikh Bahaei Sq. P.O. Box 19395-6669, Tehran-IRAN

The carbonates of the Upper Barremian – Lower Aptian (Tirgan Formation) is one of the most important petroleum reservoir in the west of Kopet- Dagh basin in northeast of Iran. The objectives of this study are to facies analysis, depositional environments, sequence stratigraphy and paleogeography of the sedimentary successions in order to recognize the sea-level change and subsidence affected by extension of the South Caspian Basin (SCB) on the sedimentary system in the study area. This study is based on datas adopted from six outcrop sections have been measured in terms of stratigarphy and sedimentology ahd one exploration well (well A). We have also compared our results with two outcrop sections (Keldzhe and Tekedzhic) in the south of Krasnovodsk in Turkmenistan.

The Tirgan Formation shows the first transgressive phase in the Lower Cretaceous in Koppet- Dagh basin and was in general deposited in a ramp setting in the Late Barremian and shelf setting in the Early Aptian. There are significant changes in thicknesses and lateral variations of facies between the north (Maraveh Tapeh Graben (MTG)) and south parts of the study area during the Late Barremian- Early Aptian. These observations are supposed to have originated from local differences in subsidence affected also by local tectonics (extension of the Caspian Sea and W-E faults activities).

Based on lateral facies changes, the region can be divided into two major sedimentary zones. These zones are located at southern and northern parts of the Takal Kuh Fault (TKF). The south and east part of the TKF (sedimentary zone) is characterized by shallow marine (tidal-flat, lagoon and barrier) with low subsidence. Whereas during the same time, the northwestern part of the TKF (MTG) is marked by high subsidence and sedimentations in slope and basin environments (deeper conditions).

The MTG located in the north of TKF and south of Ashkabat Fault Zone (AF) in Turkmenistan. This fault (AF) forms the northeastern boundary of the South Caspian Microplate (SCM) (V.G. Kazmin, 2009).

The MTG and western Turkmenistan are characterized by northwest – southeast axial trends with high sedimentation rates and deeper conditions from middle Jurassic to Neogene. The eastern limitation of the spreading zone in the SCB has not been detected clearly yet, but in the Lower Barremian – Early Aptian it might be terminates to the east of MTG.

Keywords: Tirgan, Kopet Dagh, Late Barremian-Early Aptian, Marave Tapeh, Facies, South caspian

Further 2D seismic reflection evidence for a Messinian-style drawdown in the Black Sea at the end Eocene

Gabor Tari[1], Cameron Sheya[1], Luis Calle-Bennavides[2], Carlos Rosales[3], Ian Mallinson[1] and Tom Eder[1]
[1] OMV, Vienna, Austria.
[2] TOTAL, Paris, France
[3] REPSOL, Madrid, Spain

A prominent erosional unconformity between the Eocene and Oligocene strata has been described from various parts of the Black Sea. Based on well and outcrop data around the basin margin, the typical facies of the Eocene strata underlying the unconformity indicates deposition in shallow water (e.g. neritic limestones) whereas the Oligocene overlying the unconformity with shales and marls deposited in a deeper water environment, i.e. in a deep shelf or slope setting. Based on regional 2D and also on prospect-scale 3D seismic reflection data in the NW Black Sea, the "end Eocene" (or "base Oligocene") unconformity can be followed from the shelfal regions to the deepwater realm of the basin. The erosion associated with this unconformity is particularly pronounced is in the Histria Trough, offshore Romania, and in the Kaliakra Canyon, offshore Bulgaria. In these canyons the pronounced truncation of the strata underlying the unconformity can be mapped without doubts beyond the paleo-shelf break into the basin. The seismic geometry of the unconformity suggests its erosional character in a paleo-deepwater depth more than 1000 m.

In the deepwater part of the Bulgarian Black Sea, small-scale (40–80 m) clinoforms were observed at the base of the Maykop Group on a single, long-offset 2D seismic section a few years ago. The reflectors downlapping onto the top Eocene unconformity could not be seen on earlier vintage seismic data sets due to their very deep position, close to the basin center. Due to their characteristic seismic pattern, these clinoforms were interpreted as part of a shallow-water delta during the earliest Oligocene.

Recently reprocessed 2D seismic reflection data revealed the very same distinct seismic package on many other profiles in the same area. Despite the spacing of the seismic profiles clinoforms were correlated along strike and defined, for the first time, the map view extent of this Maykop delta sequence prograding to the east and southeast. The above observations reinforce the validity of the interpretation of a huge base-level drop (2000+ m!) in the Black Sea Basin at the end of the Eocene, possibly still during the Priabonian.

Key-words: Black-Sea, Eocene, Oligocene, Maykop, Messinian-style, sea-level drop, drawdown

What triggered 20 million years of anoxia in central Eurasia?

van Baak, Christiaan G.C. - Chris.vanBaak@casp.cam.ac.uk - CASP, Cambridge, UK
Simon, Dirk - Simon.Dirk@outlook.com - CPPC, Cambridge, UK

Organic-rich sediments may form in response to (1) increased preservation during periods of stratification of the water column, and/or (2) enhanced biological productivity. In marginal basins like the Paratethys, both of these effects are typically linked to drivers such as increased river runoff, for example due to short-term increases in precipitation across drainage basins, or a change in the ocean gateway dynamics caused by either sea-level fluctuations or tectonics.

During the Oligocene and Early Miocene, the Paratethys Sea experienced long-term anoxic conditions lasting for 20 million years. The sediments deposited at this time, typically referred to as the Maykop Formation, provide an important hydrocarbon source for both the Black Sea and Caspian Sea areas. Due to its substantial time span the Maykop Formation cannot be interpreted as the effect of a short-term disturbance in water circulation and/or biological productivity. Instead, a mechanism needs to be found which may explain the establishment of long-term anoxia in the basin.

A link between the hydrological budget of an enclosed basin, the sea surface area, and water stratification has previously been established for several other geological events of regional importance; for example: (1) the Caspian Sea desiccation during the Pliocene Productive Series, (2) the Messinian Salinity Crisis in the Mediterranean Sea, and (3) the Middle Miocene Badenian-Sarmatian Extinction Event. Here we investigate what role the Paratethys hydrological budget may play in causing long-term anoxic conditions in the Oligocene and Early Miocene. For this, we focus on one of the obvious changes over the past 40 million years in the Paratethys region, the progressive decrease in sea surface area. Based on paleogeographic reconstructions and paleoclimate models we test the sensitivity of the Maykop basin's hydrologic budget to this change in sea surface area. Our calculations of the hydrologic budget include past and present values for river runoff in various parts of the Paratethys region, and precipitation and evaporation over the Paratethys surface area. We use this quantitative analysis as a basis to explore the potential forcing mechanisms for this long-lasting period of oceanic anoxia in the middle of the Eurasian continent. Moreover, from a general point of view the mechanism we will propose may play an important role in establishing and maintaining anoxia in other epicontinental and/or semi-restricted basin settings.

Keywords: Eastern Paratethys, Maykop Formation, anoxia, hydrological budget calculation

Black Sea eustatic variation through time to assess the impact of the sedimentary load in order to refine the timing for hydrocarbon accumulation

Luis CALLE-BENAVIDES[1], Nicolas DELCOURT[1], François COURTEIX[1], Gabor TARI[2], Saul SUBIAS[3]
[1] TOTAL, Exploration & Production, Paris - France
[2] OMV, Vienna, Austria.
[3] REPSOL, Madrid, Spain.

Sea-level variations through time impact sedimentation and therefore reservoir/sealing efficiency (capacity and integrity) of offshore petroleum systems. For an oil bearing reservoir (open system), major regressions can deplete reservoir pressure and consequently a drop of pressure below the bubble point can occur. In such cases, the additional buoyancy pressure created by the newly formed gas cap might be enough to initiate hydraulic fracturing. This paper aims to address the impact of sedimentary loading and major regressions of the Black Sea on the sealing efficiency of reservoir Y (Field X), located deep-offshore Bulgaria.

The sea-level curve of the Black Sea was refined based on the literature. Major regressions were identified within the Miocene – Pliocene transition and correlated to the seismic data using a sequence stratigraphy approach. Mass Transport Complexes (MTCs) were used for the interpretation as they are typically formed during lowstand deposits when sea-level falls. In addition, those MTCs were correlated with the Romanian shelf margin's unconformities. The Messinian Salinity Crisis (MSC) (5.96-5.33 Ma) was the largest sea-level fall (-600 m) in the Black Sea over the last 30 Ma and was used to study its impact on the sealing efficiency of reservoir Y.

A 600 m sea-level fall resulted in the depletion of 58.8 bars of reservoir pressure, passing below the bubble point and creating a gas column (gas cap). Assuming no overpressure, the additional buoyancy pressure created due to the gas cap would not be enough to frack the seal in the studied case. A 1600 m sea-level drop is also unable to reach the fracture gradient. Sensitivity tests on overpressure suggest that a minimum of 7 MPa and 5 MPa overpressure are required to frack the seal when sea-level drop of 600 m and 1600 m occur respectively.

This study highlighted that the MSC has no impact on the sealing capacity of reservoir Y. However, potential overpressure due to Miocene MTCs is a major uncertainty that could severely impact the reservoir and potentially the sealing integrity

Key-words: Eustasy, Black-Sea, Seal/Reservoir integrity, pore pressure, Hydraulic fracturing

A potential connection between the Mediterranean and the Black Sea during the Messinian Salinity Crisis: the Sakarya Bosporus

Tari, G.[1], Sipahioglu, Ö. N. [2], Bati, Z. [2] and Fallah, M.[3]
1 OMV, Vienna, Austria
2 Turkish Petroleum, Ankara, Turkey
3 OMV Petrom, Bucharest, Romania

There are two existing models for the physical connection between the Black Sea and the Mediterranean during the Messinian Salinity Crisis (MSC). One marine gateway has been proposed to be located some 50 km to the west of the Bosporus in the area of the Strandja Sill. Recent studies have found no evidence for the provisionally suggested "Karacaköy-Karadeniz" passage across the Strandja Sill during the MSC. Therefore, an alternative connection was proposed across the Balkans, some 100 km to the west of the Bosporus, following the Vardar Zone and reaching Carpathian foredeep basin during the MSC.

We propose yet another potential marine gateway, but to the east of the Bosporus. The Sakarya River reaches the Black Sea shorline some 100 km to the east from the Bosporus. Max Pfannenstiel has already coined the term of Sakarya Bosporus in the 1940s envisioning a marine connection in the Sakarya River valley during the Quaternary, connecting the Black Sea/Lake through the Sakarya river valley across the Sapanca Lake to the eastern arm of the Izmit Gulf. From there the marine connection to the Mediterranean was the Sea of Marmara to the Aegean Sea.

Indeed, various studies documented a prominent Quaternary submarine canyon extending almost to the coastline, including two canyon heads, in front of the Sakarya Delta. The overall canyon extends across the shelf to 1500–2000 m water depth. Previous studies based on high-resolution academic seismic reflection data sets suggested either a very young age of the Sakarya Canyon or, alternatively, its formation by the gradual landward extension of an older canyon.

Our 2D industry seismic data sets show that the modern Sakarya submarine canyon is indeed underlain by a much older canyon filled by thick Pliocene sediments prograding into the paleo-canyon from its both sides. The exact age of these sediments cannot be determined due to a lack of well data penetrating this succession in the vicinity of the Sakarya Canyon. However, regional-scale correlation of deepwater seismic reflection horizons in the western Black Sea, associated with the MSC, shows that the paleo-canyon could have initiated during the Messinian (or Pontian in Paratethyan terms).

Discovery of a deep-basin fluvial system documents drawdown during the Messinian salinity crisis

Andrew S. Madof1
Claudia Bertoni2
Johanna Lofi3
1Chevron Energy Technology Company, Houston, Texas, 77002-7308, USA
2University of Oxford, Department of Earth Sciences, Oxford, OX1 3AN, UK
3 Université de Montpellier, Géosciences Montpellier, Montpellier, 34095, France

Until recently, proprietary seismic data have not been made readily accessible for areas in the eastern Mediterranean; in the absence of such data, solving questions related to petroleum systems, sediment sources and sinks, and the region's geologic evolution remain particularly problematic. Here, we present previously unpublished 2D and 3D seismic data from offshore Cyprus, Syria, Lebanon, and Israel, and introduce a formerly unidentified basin-scale fluvial accumulation. The deep-basin supra-evaporitic deposit has an areal extent approximately equal to the late Miocene Nile River and a volume of more than 4,150 km3, making it one of the largest known riverine accumulations associated with the Messinian Salinity Crisis. From its seismic stratigraphy and morphology, the deposit consists of axial and transverse accumulations, with the former trending south to southwest and the latter oriented radially into the Levant Basin. Based on its seismic architecture and position above evaporites, we interpret the axial and transverse fluvial systems to have flowed into a partially desiccated Levant Basin.

From marked onshore incision and basinward thinning trends, we interpret the fluvial deposit's main sediment source to be a formerly unidentified drainage basin in western Syria and southern Turkey. From this location, the fluvial accumulation expands more than 500 km to the southwest, where it terminates in the western Levant Basin (south of the Eratosthenes seamount) at six well-developed lobate deposits. Based on the presence of backstepping lobes (outboard) and inverted topography (inboard), we interpret the deposit to have accumulated during increased discharge and basinward tilting. Such deformation necessitates structural rotation around a tectonic hinge, which we presume to have been in the modern offshore Levant Basin.

Our identification of a previously unknown fluvial deposit has led to the recognition of a new sediment transport direction and drainage basin, which has significant implications for future source-to-sink studies. Knowledge of such a vast accumulation may provide further insight into the stratigraphic and structural evolution of the eastern Mediterranean, which is of fundamental importance for a complete understanding of the Levant Basin petroleum system.

Unconventional shale exploration challenges, Pannonian Basin, Hungary

Author:
Dr. Anita Éva, Csoma[1] - AnCsoma@MOL.hu
Co Authors:
Réka, Bottyán[1] - RBottyan@MOL.hu, Dr. Balázs, Kiss[1] - BaKiss@mol.hu, Zsolt, Nagy[1] – ZsNagy2@MOL.hu, Jenifer, Sarrang[1] - JSarrang@MOL.hu, Viktor, Volford[1] - VVolford@MOL.hu
1: MOL Group Exploration and Production, Budapest, Hungary

The North American unconventional revolution is the biggest technological success of the oil and gas industry of this century. This technology has spread to other continents, such as South America, Asia, Australia, yet to be successful in Europe.

In general, economic shale oil and gas plays have higher than 2% TOC and higher than 1.1 Ro values, usually have kerogen type I, II, or IIs. Porosities of these shales are generally higher than 5% and net thickness larger than 15m. These plays extend over large distance without structural complexity allowing for exploitation of these plays with long-length laterals (up to 3000m).

There are several proven hydrocarbon systems in the Pannonian Basin in Hungary feeding several conventional structural and stratigraphic traps, such as the Miocene Tótkomlós Marl of East Hungary and the Triassic Kössen Marl of West Hungary. These oil shales today can be found in horsts and grabens as a result of structural complexity and also in areas where stress regimes are highly variable. Thus, the lack of lateral continuity may be a challenge to develop these unconventional shales with long laterals. In addition, design of the direction of horizontal wells and completions will have to be based on well-defined log and core data sets in order to determine stress directions.

Volume, maturity, TOC content of these Hungarian plays are highly heterogeneous, varies with depth, depositional environment, stratigraphy, and diagenesis. Based on existing stimulation data, the Tótkomlós Marl around 2500 m depth can be successfully fracture-stimulated and existing production data suggest that this shale is a strong candidate for unconventional exploration. The Kössen Marl, interbedded with dolomite and carbonate layers might be a good candidate to explore is as a hybrid shale oil play. This talk will compare and contrast the characteristics of the Tótkomlós and Kössen Plays focusing on materiality, fracability, and mobility of these plays.

The question however will remain: Can advanced infrastructure and drilling costs offset the geological challenges of the shale oil plays of the Pannonian Basin making these plays successful?

Keywords: unconventional, shale, exploration, Pannonian Basin

Pore imaging of Late Miocene calcareous marl from the Pannonian Basin (Tótkomlós Member, Endrőd Formation) and comparison with North America productive calcareous marls

G. Mallarino[1], A. É. Csoma[2], K. Milota[2], A. Sóron[2] and Á. Szabó[3]

1: Department of Geology, Eötvös Loránd University, Budapest, Hungary
2: MOL Group Exploration and Production, Budapest, Hungary
3: Lithosphere Fluid Research Laboratory, Eötvös Loránd University, Budapest, Hungary

The Tótkomlós Member of the Endrőd Formation, in the subsurface of the central Pannonian Basin (Hungary), consists of hemipelagic calcareous marls deposited in the early Late Miocene in structurally-controlled sub-basins. TOC values ranging from 0.5 to 3 wt% make it a potential target for unconventional hydrocarbon exploration. Here we describe the pore systems of this calcareous marl and compare it with similar rocks from the productive Eagle Ford and Niobrara unconventional plays (USA).

Microfacies of the Tótkomlós Member consists of calcareous mudstone with detrital quartz, mica, few bioclasts, and dispersed pyrite. No pore space is visible in thin sections. FIB-SEM imaging reveals that the carbonate matrix is mostly made of coccoliths with calcite overgrowths. At high magnifications (10.000× and above) the pore system is clearly visible. Pore types are interparticle (i.e. mineral pores) and associated with organic-matter (OM). Interparticle pores occur either between coccoliths or authigenic clay platelets and their size ranges from 100 nm to 1 µm. Pores associated with OM are smaller and range from 20 nm to 500 nm. Generally OM surrounds euhedral crystal terminations indicating that it moved into an open interparticle-pore space after the crystal growth. This suggests that the OM was originally a mobile hydrocarbon phase. Subsequent thermal cracking of this early hydrocarbon phase likely generated the present-day pore space associated with it. Detrital OM is also present but much less abundant and mostly pore free.

Both in the Upper Eagle Ford (UEF) and the Niobrara-B Chalk (NBC) TOC spans from 1 to 5 wt%. Pore types are similar to what described in the Tótkomlós Member. In the UEF mineral-pore size ranges from 100 nm to 4 µm and OM pores from 10 nm to 2 µm. In the NBC mineral-pore size ranges from 50 nm to 2.5 µm and OM pores from 10 nm to 1 µm. Similarly to the Tótkomlós Member, in both North America calcareous marls the majority of OM pores are associated with residual hydrocarbon that seems to have originally filled the interparticle mineral pores.

Tight and shale unconventional reservoirs in the Outer Carpathians (Poland, Ukraine, Czech Republic)

Paweł Poprawa[1], Grzegorz Machowski[1], Yuri Koltun[2], Paweł Kosakowski[1], Bartosz Papiernik[1], Juraj Franců[3], Andrzej Maksym[4]

(1) AGH University of Science and Technology, Cracow, Poland
(2) Institute of Geology and Geochemistry of Fossil Fuels, Ukrainian Academy of Sciences, Lviv, Ukraine
(3) Czech Geological Survey, Branch Brno, Czech Republic
(4) Polish Oil and Gas Company, Warsaw, Poland

Western Outer Carpathian (WOC) fold-and-thrust belt is located within North Carpathian petroleum province. The WOC, producing oil and gas since the mid of XIX century, is presently very mature with exploration and production. More than 4200 oil and gas related wells were drilled in the Polish part of the WOC up to date, and conventional reserves in there are nearly depleted. Significant scale of HC production is still sustained in the Ukrainian part of the WOC.

However, at present shale oil/gas potential is identified in the Menilite Shale (Lower Oligocene), and to the lesser degree also in the Lower Cretaceous shale. The Menilite Shale is characterized by very high average TOC (often 4-10 %), high original Hydrogen Index, and dominance of II type of kerogen. In the Polish part of the WOC gross thickness of the Menilite Shale if often ~100 m or more, and commonly is inter-bedded with the Krosno-type sandstone, thus the whole complex often have a hybride reservoir character. Both average TOC contents and thickness of the Menilite Shale increases towards the east significantly. Thermal maturity varies both laterally and, due to tectonic multiplication, also vertically, increasing southward and downward from immature, through oil and wet gas window, to dry gas window. Oil and gas saturation of the shale is confirmed by common HC shows, as well as the results of hydraulic fracturing in two exploration wells.

The Lower Cretaceous shale is the best developed in the western part of the WOC. Their thickness in there typically ranges between 50-150 m, while thermal maturity at the surface condition is 0.7-1 % Ro, i.e. oil to wet gas window, and further increases downwards within the accretionary prism. The TOC contents of this shale complex is, however, lean and most measurements falls into range of 1.5-2.0 % TOC. Another limitation for the shale oil/gas potential of the Lower Cretaceous shale is mixed type of kerogen with significant contribution of the III, humic one. The other new unconventional play in the North Carpathian petroleum province is a tight gas/oil in Cretaceous and Paleogene sandstone reservoir. Tight petrophysical characteristics of these reservoirs is commonly observed at burial depths higher than ~2000 m, were permeability typically is lower than 0.1 mD, while porosity is same cases is preserved at the level of 4-5 % or higher. The both above mentioned shale complexes are the source rocks for tight oil/gas. Concept of tight gas/oil was tested in 3 exploration wells in Polish part of the WOC, and so far in one case hydraulic fracturing allowed for commercial gas flow.

Commercial potential of every very unconventional play in the WOC is to some extend limited by very complex tectonic structure of the orogen. Resources of these new petroleum plays remains not quantified yet.

This research was financially supported by National Centre for Research and Development grant no. BG2/ShaleFore/14 and Statutory Funds of Department of Fossil Fuels no. 11.11.140.176, Faculty of Geology, Geophysics and Environmental Protection, AGH UST.

Sub-conventional petroleum play related to the mudstone-dominated heterolithic reservoirs of the Miocene Outer Carpathian Foredeep Basin (SE Poland)

Paweł Poprawa[1], Bartosz Papiernik[1], Grzegorz Machowski[1], Mariusz Słyś[2], Andrzej Maksym[2], Magdalena Krzysztofik[1], Paweł Kosakowski[1], Szczepan Porębski[1]
(1) AGH University of Science and Technology, Cracow, Poland;
(2) Polish Oil and Gas Company, Warsaw, Poland

The Miocene Foredeep (MF) of the Outer Carpathians is a petroleum basin producing gas since 40'ties of XX century. High quality of biogenic gas (> 95 % Methane) and very low burial depth, allowing for low drilling costs, make together gas production in the MF economically prolific. However, current gas production from 81 fields is at a level of 1.3 Bcm/y, and since 2009 decreased by 35 %. Contingent resources and reserves are equal to 28.8 Bcm (~17.5 % initial contingent resources) and 7.5 Bcm, respectively. During the last decade the previous ones declined by ~20 %, while the later one by ~50 %. Roughly 4000 gas and oil related wells, as well as significant decline of production and reserves, define the basin as a very mature as for conventional exploration and production. Nonetheless, present new unconventional concepts upscale potential of yet-to-find resources significantly.

The sedimentary fill of the MFB is predominantly fine-grained, therefore conventional sandstone reservoir are uncommon in the basin. At present, however, a new exploration approach is applied to the MF, aiming to produce gas from shallow mudstone-dominated heterolithic reservoir. Within this interval the mudstone is characterized by porosity in a range of 9-12 %, domination of nanopores, and low, unconventional permeability equal to 0.05-0.15 mD (Machowski et al., 2017). This dominating type of lithology could be regarded as unconventional tight reservoir. However, thin laminas of siltstone or fine-grained sandstone perform as a conventional component of the reservoir system. Their porosity typically is 8-21 %, and is related mainly to macropores and mesopores, while permeability is 3-30 mD (Machowski et al., 2017). The siltstone and sandstone component increases cumulative lateral permeability of mainly unconventional reservoir, therefore we propose to classify the discussed accumulations as a hybride or sub-conventional one.

Low burial (1500-2000 m) implies low consolidation of unconventional reservoir. Moreover high clay content is typically observed (30-60 % for mudstone, 15-40 % for sandstone). Therefore, hydraulic fracturing would not be effective, and gas is produced with deviated wells drilled to the reservoir interval, being 100-200 m thick, without stimulation. In the southern part of the MFB, buried beneath Carpathian overthrust to higher depth (3000-3500 m), the Miocene sandstones become consolidated and fracturing stimulation of tight reservoir is applied. The both above technological approaches give commercial gas flows – among 32 wells drilled so far 27 were commercially positive, and only 5 were sub-commercial. Initial gas flows from individual wells are usually at the level of 40-80 Mcm/d, with the best wells reaching 80-140 Mcm/d. The new sub-conventional play in the MF has a regional extend. Its contingent gas resources are estimated for at least 450 Bcm.

Machowski G., Pstrucha A., Krzyżak A.T., 2017. Petrophysical characterization of the pore space in gas-bearing Miocene rocks from the Siedleczka area (the Carpathian Foredeep, Poland). 17th Int. Multidisc. Sci. Geoconf. & Expo SGEM, Albena, Bulgaria, 17: 789-796.

This research was financially supported by National Centre for Research and Development grant no. BG2/ShaleFore/14 and Statutory Funds of Department of Fossil Fuels no. 11.11.140.176, Faculty of Geology, Geophysics and Environmental Protection, AGH UST.

An unconventional shale-oil source rock in eastern Paratethyan realm: Lower Oligocene Mezardere Formation, Thrace Basin, NW Turkey

Kadir Gürgey – kadir.gurgey@neu.edu.tr Department of Petroleum and Natural Gas Engineering, Near East University, Nicosia, Mersin 10, Turkey

The Thrace Basin of NW Turkey having Early/Middle Eocene through Pleistocene age 9000 m thick sediments in its depocenter covers an area of 22,238 km2. Within this basin, the Mezardere Formation (MF) was deposited from the Early Oligocene (33.9 m.y.) through the Middle Oligocene (28.1 m.y). The MF sediments are characterized by thick brackish-prodelta organic rich shales, marls and sandstones. Furthermore, in our previous study of geochemical and palynological data, it was reported that the MF informally subdivided into the Pshekhian Lower MF (LMF) and the Solenovian Upper MF (UMF). This subdivision is consistent as is the case for many source rocks of the Central and Eastern Paratethys (e.g. the Maikop Group, the Menilite Formation, the Ruslar Formation, and the Tard Clay etc. In essence, these findings may suggest that the Lower Oligocene MF of the Thrace Basin may indeed belong to the Eastern Paratethyan realm.

The conventional oil, condensate and wet-gas discoveries in the various reservoirs of the Thrace Basin and their positive geochemical correlation with the MF extracts gives us a confidence that the MF may still keep in its unmigrated retained hydrocarbons or unconventional oil. In order to realize this hypothesis, in this study, already available Rock-Eval data set belonging to the 407 Mezardere Shale cuttings and core samples collected from the 47 Thrace Basin boreholes are evaluated to estimate the amount of retained oil in-place (OIP) resource volume in bbl.

Results showed that The MF contains a mixture of type II/III kerogen (HI= 3-744 mg HC/g TOC) and sufficient organic richness (TOC= 0.08-3.39 wt%) and has favorable thermal maturity (%VRm= 0.35–1.20). It was realized that only the five out of 47 wells show relatively continuous “Oil Saturation Index”, OSI= (S1/TOC)*100 values (e.g. Only the sample intervals showing OSI > 100 are taken into account). It is crucial to note that measured S1 and therefore calculated OSI values are corrected against the evaporation loss that could be resulted from the sample handling and the timing of sampling. Corrections are applied for the retained oil density ranges of 35, 40, and 45 API gravities which are assumed to be the density ranges of retained oil in the MF. OIP resource estimations are conducted for each of the five wells as well as for the core area (e.g. 1000 km2 in the northwestern Thrace Basin). An average Mean Swanson's value of OIP's of the five wells is estimated to be approximately 405 M bbl. The core area shows an average Mean Swanson's value of OIP as 325 MM bbl.

It is concluded that the MF could be a significant shale-oil play in the Paratethyan realm.

Keywords: Thrace Basin, Oligocene Mezardere Formation, Eastern Paratethys, unconventional shale-oil geochemistry

Compressibility of reservoir and seal of a petroleum system from the Molasse basin: Porolasticity as a useful indicator for material fatigue of an underground gas storage

Dietl, Carlo - dietl@gesteinslabor.de – Gesteinslabor Dr. Eberhard Jahns
Szech, Jennifer - szech@gesteinslabor.de – Gesteinslabor Dr. Eberhard Jahns
Baumgartner, Hansjörg - baumgartner@gesteinslabor.de – Gesteinslabor Dr. Eberhard Jahns
Jahns, Eberhard - jahns@gesteinslabor.de – Gesteinslabor Dr. Eberhard Jahns

Underground gas storages (UGS) play an important role in today's gas supply. Typical UGS sites are salt caverns, aquifers and former natural gas and oil reservoirs. The latter represent pore space gas storages. We studied a potential UGS in the Molasse basin, southern Bavaria (Germany), consisting of a fine-grained reservoir sandstone underneath a marlstone seal.

UGS will have particular significance on "power to gas" projects, where wind or solar power is transduced to synthetical CH4. “Power to gas” usage of UGSs will lead to a higher frequency in depletion and refilling cycles and possibly faster material fatigue as is the case nowadays. Consequently, material fatigue of the UGS rocks is an issue of paramount importance for gas storage operators. We present here results of cyclic compressibility tests which are aimed to find out if and how the poroelastic parameters change with ongoing cyclic deformation.

We carried out a sequence of hydrostatic CPV tests (CPV = compressibility of pore volume) alternating with an aging procedure and. The modelled aging of the reservoir sandstone and its seal in the range of 18 years (seal) to 21 years (reservoir) was achieved by cyclic pore pressure increase and decrease – simulating the depletion and refilling of the UGS. The important determined poroelastic parameters are the bulk compressibility and the compaction coefficient. Bulk compressibility data for the reservoir sandstone before and after both aging procedures are very much alike. Obviously full elasticity is preserved over the simulated time of storage use. Bulk compressibility of the seal marlstone is about half a magnitude lower than for the reservoir sandstone. Simultaneously, the seal experiences double the volume strain during CPV01 and only 25% of it during CPV02 compared to the reservoir sandstone. Nevertheless, the bulk compressibility is almost unaffected by the change in volume strain and it seems that elasticity prevails also within the seal of the UGS. The compaction coefficient of the seal marlstone is up to two magnitudes higher than the compaction coefficient of the reservoir sandstone. This behavior may be the result of the swellability of the marlstone. Coevally, the compaction coefficients do not change a lot for both lithologies: this is another hint for ubiquity of elasticity over the entire testing process.

Compressibility tests as those presented here are an invaluable tool for the determination of the poroelasticity of a UGS. Although different in compressibility and compaction, the sandstone and the marlstone have one thing in common: a high reproducibility of the data which points to the prevalence of elasticity during the entire deformation and aging process. Nevertheless, further tests are necessary to verify our so far observations before they may be applied to the entire investigated reservoir-seal system or even transferred to other UGSs.

Keywords: pore space gas storage, reservoir, seal, compressibility, poroelasticity

An evaluation of petroleum system elements in the Zagros Belt, Kurdistan, Northern Iraq using carbonate hosted seeps, petroleum-biomarkers and surface enhanced Raman scattering

Ayad Edilbi[1,3], Majaz Maleko[1], Bahroz Abdullah[2], David K. Muirhead[3], Alabi Oluwarutimi[4], Colin Taylor[3], Matt Kaye[5], John Parnell[3], Muhamed Abdalla[3] and Stephen A. Bowden[3]
1 Department of Petroleum Geosciences, Soran University, Soran, Kurdistan Region, Iraq,
2 Department of Geology, University of Salahaddin, Erbil, Kurdistan Region, Iraq,
3 School of Geosciences, University of Aberdeen, Aberdeen, AB24 3UE, Scotland, UK,
4 RAB Microfluidics Research and Development Company Ltd., Aberdeen, AB24 3UE,
5 Matt Kaye, OceanGrove Geoscience Ltd., Aberdeen, AB21 0GP, Scotland, UK,

The Gara Anticline, Duhok province, and the Akre area 100 km north of Erbil, both contain numerous petroleum seeps and formations apparently charged with bitumen. Biomarker characteristics suggest genetic links between Jurassic and Lower Cretaceous source rocks (Sargelu, Naokelekan and Chia Gara) and bitumen-occurrences in Jurassic, Cretaceous and Tertiary formations. Biomarker data does not suggest a link with the Triassic Baluti shale, despite the latter often being favourably positioned with respect to its ability to charge bitumen-bearing limestones. Interestingly, there are notably strong links between bitumen-seep samples from the Lower Jurassic Sehkaniyan Formation and Middle and Upper Jurassic source rocks. This migration would require lateral and or stratigraphically downward movement from Jurassic source rocks such as the Sargelu (Middle Jurassic). At the Gara Anticline biomarker data also rule out a genetic link between bitumen occurrences in the Upper Triassic Kurra Chine Formation and younger source rocks, thus this bitumen family may be evidence of an older source rock and different petroleum play. Surface enhanced Raman scattering (SERS) data measured on polar fractions offered a reasonable characterization of both source rock bitumen and seep-bitumen thermal maturity. This suggests that SERS could be used for geochemical prospecting and thermal maturity determination, as it could distinguish pre-oil window from oil window samples.

Reconstructing the depositional environment of Upper Eocene reservoir sandstones in eastern Upper Austria

Scheucher, L.(1), Bieg, U.(1), Troiss, W.(1)
(1) RAG Exploration & Production, Schwarzenbergplatz 16, 1015 Wien
(2) OMV Petrom S.A., 22, Coralilor street, sector 1, 013329, Bucharest

Upper Eocene Sandstones form the most important oil (and thermal gas) reservoirs within the Upper Austrian part of the North Alpine Foreland Basin. Although regional facies maps exist for Upper Eocene sandstones, they have not been updated since the 1990s. Additionally, recent drilling activities have been located outside of the area covered by those facies maps and drilling results have shown that a refinement of the facies distribution and depositional environment is necessary. For successful field development activities detailed geological and sedimentological models, and therefore the understanding of stacking patterns and lateral extent of Upper Eocene sand bodies, are crucial. Drill cores from 20 wells were logged and petrographical, palaentological, image log and seismic data were included for interpretation of the depositional environment.

Lithofacies Associations and their lateral and vertical distribution show that two main depositional environments are present in the study area. A large, flood-dominated river delta covered most of the study area and transgressive beach deposits occur to the northeast of the delta system. The palaeo-shoreline was reconstructed to be NW-SE striking, with a shift to the NE during late Upper Eocene. Within the delta system, reservoir properties are best in unsorted, coarse to very coarse, pebbly sandstones of the distributary mouth bar (DMB) and in well sorted, massive and ripple-bedded fine to medium sandstones of the reworked delta front. The transgressive beach deposits generally exhibit excellent reservoir properties.

On the basis of vertical facies successions, four phases (I to IV) throughout the Upper Eocene can be defined. Phase I represents the basal deposits and is interpreted as initial fill of palaeo-topography with unsorted, coarse to very coarse sandstones. Deposition likely occurred in confined pathways, yielding to highly amalgamated sequences of delta front (DMB) and delta plain (distributary channel) sandstones. Due to the virtual absence of silt-/claystones, net to gross (N/G) ratios are generally very high for this phase. Phase II is characterised by an alternation of reservoir DMB-sandstones with siltstones of interdistributary siltflats. Correspondingly, N/G ratios are low. At the top of this phase colour-mottled siltstones occur frequently, representing occasional sub-aerial exposures of interdistributary siltflats. Flow was likely unconfined during this phase and thus, sheet-like deposition of reservoir sandstones occurred. We assume that flash flood events in a semi-arid climate were the main trigger for deposition of the unsorted, pebbly, coarse sandstones. After deposition of phase II a rise in sea-level occurred and a more differentiated depositional environment developed (phase III). Lagoonal deposits, as well as thick, tidal-reworked delta front sandstones, are additionally present within this phase. Also, deposition of the transgressive beach deposits northeast of the delta started with this phase. In general, N/G ratios are highly variable, with highest ratios present in areas with frequent tidal reworking. N/G ratios close to 1 are characteristic for the transgressive beach deposits. Phase VI is characterised by the presence of fossiliferous, pebbly coarse sandstones with frequent occurrence of coralline red algae components (“Lithothamnion sandstones”) and marks the transition to a fully marine environment. Due to intensive carbonate cementation, those sandstones are generally non-productive.

Keywords: Upper Eocene, NAFB, flood-dominated river delta, transgressive beach deposits

Exploring for a Missing Play, a close 3D Look on the Mesozoic below the Western Austrian Molasse

Sperl, H., Geologic Advisor
RAG Exploration and Production, Schwarzenbergplatz 16, 1015 Wien

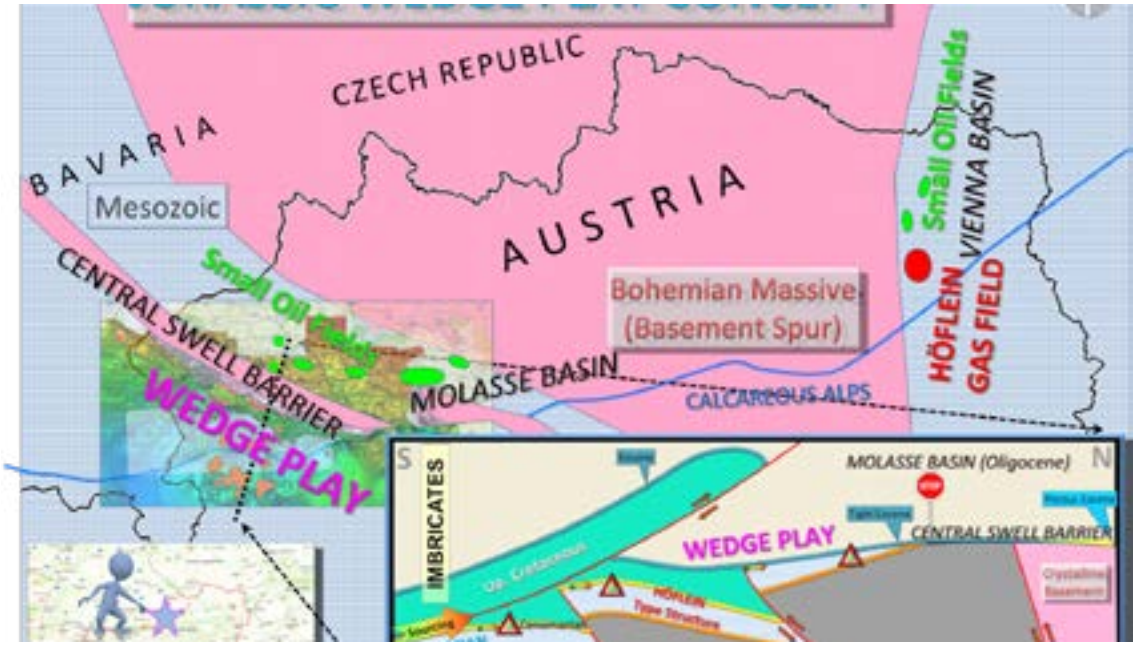
In Austria the Mesozoic base of the Tertiary Molasse still remains virtually free of large HC reservoirs. The only one major exception is the OMV-field Höflein in the East in Lower Austria (>10x109 m³ [~350 BCF] gas reserves). This is stunning, as one would expect to have more at least smaller fields to fulfill a normal statistical distribution.

In Austrias West, RAGs exploration drilling was focused on gas within the Oligocene deep marine Puchkirchen Formation and on oil within the Eocene shallow marine sandstones. Below these Tertiary sediments, the Cenomanian sandstone (shelf) play was established with some economic success. Three smaller fields were discovered yet. The largest Mesozoic oil-reserves are in the Eocene structure of the Voitsdorf field (2117 M tonnes or 14,5 MMbbl). The largest field independent from Eocene structures is Trattnach with ~2.2 MMbll (321 M tonnes) UR.

Regional 3D seismic surveys were acquired by RAG, targeting the Tertiary and the alpine thrust-belt. As an additional bonus of this 3D dataset, more information on the Mesozoic Basement and its structures was revealed.

The existing data strongly favor the importance of pre-Eocene strike-slip tectonics in conjunction with thrusting and folding paralleling the Central (Landshut) Swell of the molasse base. This leads to a new view of the Mesozoic play setting as well as to new undrilled structures.

Especially south of the Central Swell the top seal of the Mesozoic wedge-out onto the high zones is possible. This is in contrast to the Northern areas, where any contact with the erosive Eocene sandstone drains every Mesozoic trap. In the south, higher shale content in the more open marine facies of the Eocene (Discocycline-marl) could result in a valid top-seal above the truncational Mesozoic wedge play. This play is virtually unexplored and examples of new prospects will demonstrate the high potential of the Mesozoic Basement. The overall potential resources could be well above 50 MMBOE (or 360 BCF) unrisked.



Keywords: Base Molasse, Cenomanian, Malmian, Landshut Central Swell Zone

Petroleum Systems and Reservoir Distribution Laws in the Pannonian Basin - Romanian sector

Author: Cristea Dragos - dragos.cristea89@icloud.com – Oil and Gas University of Ploiesti, Romania
Co-author: Dumitru Georgiana Andreea - Oil and Gas University of Ploiesti, Romania

The petroleum systems in the Pannonian Basin contain liquid and gaseous hydrocarbons trapped in the fractured, weathered crystalline basement and in clastic or carbonatic sediments (of Mesozoic, Neogene or Pliocene age) with reservoir properties. The tectonic evolution of the Pannonian Basin includes three main stages: a prerift phase, a sinrift phase and a postrift phase; who played a crucial role in assuring the necessary conditions for the generation and trapping of the hydrocarbons.

Several total petroleum systems have been defined in the Pannonian Basin system. These TPSs are composite and have various source rocks ranging in age from Mesozoic to Neogene. The petroleum systems show evidence of vertical migration and mixing, with different hydrocarbons in associated reservoirs and with mixed oils within individual reservoirs. Sometimes, the petroleum sys¬tems are not isolated to individual subbasins.

For these and other reasons we tried to find a way to understand how the distribution of oil was produced, which were the directions of migration in this area.
We can define areas of interest and establish future exploration and the most adequate seismic investigation methodology (seismic signal parameters, recording template for the best vertical and horizontal resolution) of one specific objective (consistent with the expected reservoir depth).

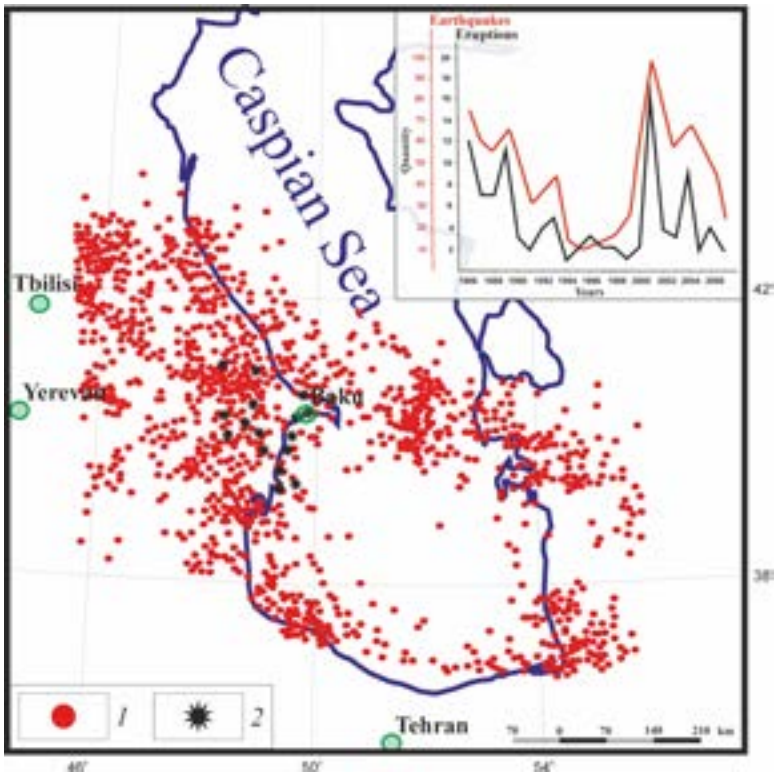
Five steps are necessary to achieve this goal: clarifying the stratigraphic and structural features at a regional scale; defining Petroleum systems; analysis of existing fields; interpretation of active hydrocarbon reservoirs distribution laws in area; establish the best investigation methodology for the next exploration.
An important benefit is reducing geological and economical risk by accurately establishing the objective depth and by choosing an exploration program perfectly adapted to the structural-stratigraphic conditions.

Based on the data from existing of productive fields (age and depth of the reservoir trap type), we applied this approach to the Romanian part of Pannonian Basin. We established for every subbasin the most suitable areas to be considered, their depth and lithology.
We can choose the prospecting method with the highest resolution focused on the reservoir depth. This is very important for future exploration because we can also know the area without perspective.
This kind of analysis may also be affixed in other petroleum provinces, in their development exploration stage.

Active hydrocarbon systems of the Black and Caspian Sea basins

I.S. Guliyev[1], V.Yu. Kerimov[2], R.N. Mustaev[2], U.S. Serikova[2]
1 Azerbaijan National Academy of Sciences,
2 Russian State Geological Prospecting University

Active hydrocarbon systems are widely distributed in various regions of Paratethys. It is characterized by high sedimentation rates, a contrasting mode of modern vertical and horizontal movements, crustal and small-focus seismicity, intense diapirism, and mud volcanism. An analysis of a combination of factors indicates the active nature of the hydrocarbon systems of the Black Sea-Caspian region. Studies of active hydrocarbon systems in the Black Sea-Caspian region are based on the analysis of the following factors: hydrocarbon degassing of the earth; mud volcanism and seismicity; features of the evolution of sedimentary basins; characteristics of geoteperature and geobaric fields; foci of excitation (generation of hydrocarbons); HC migration. The main features of active hydrocarbon systems are: present-day generation, migration and accumulation of hydrocarbons, manifested in the periodic release of hydrocarbons on mud volcanoes, the presence on the surface and bottom of the sea numerous oil and gas outcrops, the formation and decomposition of gas hydrates. In active HC systems, the process of decomposition of sedimentary rocks is widely developed, which is fixed in numerous subvertical and subhorizontal geological bodies. The intensity of fluid dynamics is determined on the basis of a study of the intensity of the manifestation of fluids on the surface, geochemical and temperature anomalies. The manifestations of geodynamic activity are associated with various types of discharge of fluid-dynamic intensity of the subsoil, first of all, intensive ascending discharge of various mobile components — oil and gas, clay flows, etc.



Map of the location of mud volcanoes and epicenters of earthquakes in the Caspian Sea and the dependence of eruptions of mud volcanoes on earthquakes. The degree of the regional fluid dynamic activity can be estimated by the frequency of eruption of mud volcanoes.
Legend: 1 - earthquake epicenters, 2 - mud volcanoes.

Depositional conditions of organic matter in the Miocene strata - a biomarkers approach (Polish Carpathian Foredeep)

Kosakowski Paweł[1], Zakrzewski Adam[1], Machowski Grzegorz[1], Poprawa Paweł[1], Kowalski Adam[1], Koltun V. Yuriy [2] , Sowizdżał Anna[1]*
1 AGH University of Science and Technology, Cracow, Poland
2 Ukrainian Academy of Sciences, L'viv, Ukraine

The Carpathian Foredeep, one of the largest foredeep basins in Europe, developed during the early and middle Miocene as a peripheral flexural foreland basin in front of the advancing Outer Carpathians. The Carpathian Foredeep is a petroleum basin of significnat importance, being the largest natural gas production zone within North Carpathian petroleum province.

The results of Rock-Eval pyrolysis of the Miocene organic matter (OM) in the Polish part of the Carpathian Foredeep shows large variation in both the organic carbon and the hydrocarbon contents, although their low values predominate. In the Badenian and Sarmatian strata, the TOC contents vary from 0.1 to about 1.4 wt.%, with the median of 0.66 and 0.70 wt.%, respectively. The results reveal poor to fair source rock potential.

The results of n-alkanes show that the source of OM was differentiated. In most of the samples are characterized by the domination of long-chain n-alkanes, with the highest abundance of n-C27 and n-C29. This type of distribution pointing that the OM has mostly terrestrial source, but the part of samples are characterized by the domination of short-chain n-alkanes with the highest abundance of n-C17 and n-C15 or bimodal distribution of n-alkanes with the highest abundance of n-C20 and n-C31. This distribution suggests that the marine or mixed (terrestrial/marine) origin of organic matter. According to regular steranes distribution, organic matter preserved in the Miocene rocks comes mostly from plankton origin with algal and bacterial addition, and from land plants. The mixed bacteria and algae origin of OM is also confirmed by tricyclic terpanes, hopanes and steranes content.

The palaeoenvironment redox conditions, based on pristane/phytane (Pr/Ph) ratio, suggest precipitation in sub-oxic conditions. The palaeoenvironment redox conditions defined by homohopanes distribution, C27Dia/(Dia+Reg) ratio and C35HS/C34HS index indicates that the Miocene rocks were deposited in suboxic/anoxic redox conditions. Relatively high amount of C34 and C35 homohopanes, confirm such an interpretation. The diasteranes/steranes ratio shows low values of C27Dia/(Dia+Reg) ratio, which indicates that sampled sediments were deposited in high pH and low Eh palaeoenvironment.

The thermal maturity of the Miocene OM, based on Rock-Eval Tmax temperatures and biomarkers indices, is low. In general, Tmax values are below 435oC. The Carbon Preference Index, based on n-alkanes abundance, pointed out that OM is immature/early-mature. The correlating of C2920S/(S+R) and C29ββαα steranes ratio prove that the samples are early-mature.

The presence of immature, gas-prone Type III kerogen, and presence of sufficiently high TOC contents throughout the study area, indicate a potential for the biogenic gas generation, which is confirmed by the existence of numerous biogenic gas fields in the Carpathian Foredeep.

Acknowledgments: This research has been financially supported by National Centre for Research and Development grant no. BG2/ShaleFore/14 and Statutory funds no. 11.11.140.626, 11.11.140.176 Faculty of Geology, Geophysics and Environmental Protection, AGH UST

Miocene hydrocarbon system offshore the Romanian Black Sea

Author : Naumova Maria - Maria.Naumova@lukoil.com – LUKOIL-Engineering
Co Authors : Nadezhkin Dmitry - Dmitry.Nadezhkin@lukoil.com – LUKOIL-Engineering
Koloskov Vasily - Vasily.Koloskov@lukoil.com - LUKOIL-Engineering
Pinous Oleg - OPinous@slb.com - Schlumberger

Integrated study of 3D seismic data and post-drilling data allowed to reveal the trends of Miocene hydrocarbon system development and predict the hydrocarbon composition in the Romanian offshore sector of the Black Sea. New actual data obtained as a result of geological exploration operations within the area of LUKOIL license blocks provided the basis for this study.

Reservoir rocks. The deposition of sediments in Miocene occurred in the discharge zone of large fluvial systems of paleo-Danube, paleo-Dnieper and paleo-Dnestr. At the same time, the main mass of terrigenous material moved by these rivers accumulated in the slope area of the Black Sea and near the bottom of the slope. Based on the well drilling data, as well as based on the results of sequence stratigraphical, seismo-facial and dynamic analysis of seismic data, we managed to identify complexes of submarine fans, in which we determined main types of deposits which are connected with the reservoir rock development: 1) channel-levee complex; 2) distribution lobes. The highest potential of presence of large sand bodies with high reservoir properties is expected in the deposits of channels and proximal parts of the distribution lobes.

Seals. The Miocene clayey deposits containing sand layers of submarine fans are characterized by good trapping properties which are confirmed by similar adjacent fields (fields Lira, Domino, etc).

Traps. The generation of traps in Miocene is a result of combination of lithological heterogeneity of the submarine fans and structure-forming gravitational processes. Therefore, in the rear and front parts of the gravitational gliding complex, the zones with higher potential are associated with combined traps. In the zones unaffected by gravitational processes, the potential of discovering HC deposits is associated with lithological traps.

Source rocks and type of fluid. According to the results of 3D basin modeling, in Miocene complex we expect discoveries of biogenic methane deposits which are sourced by Miocene oil and gas source rocks with poor thermal conversion. The biogenic nature of Miocene hydrocarbon gases was confirmed on the basis of the results of methane carbon/hydrogen isotope study (δ13C and δH/D of methane vary from -69.7 to -65.2 ‰ and from -235 to -221 ‰, accordingly). The analysis of geochemical studies of HC gases in the wells, gases and organic matter in the near-bottom samples, as well as the results of basin modeling, demonstrate that the Miocene HC system is isolated from the more mature HC systems. It allows us to predict the presence of only biogenic gas deposits in Miocene.

Keywords: Miocene deposits, Black Sea, submarine fans, combined traps, stratigraphic traps, biogenic gas.

Hydrocarbon potential of the Oligocene – Lower Miocene Menilite Formation and the Cretaceous Shypot Formation in the Ukrainian Outer Carpathians

Rauball, Johannes F.a,, Sachsenhofer, Reinhard F.a, Bechtel, Achima, Coric, Stepanb, Gratzer, Reinharda,*

The Ukrainian Carpathians belong to one of the oldest petroleum provinces in the world. The aim of the present study is to characterize the hydrocarbon potential of the Lower Oligocene – Lower Miocene Menilite Formation and the Lower Cretaceous Shypot Formation in Ukraine. 233 Lower Oligocene – Lower Miocene samples and 94 Lower Cretaceous samples were collected from the Chechva profile in the Skyba nappe and west of Bystrets, Ivano-Frankivsk Oblast, in the Chornogora nappe, respectively.

In Ukraine, the Menilite Formation is regarded as the main source rock interval of the region. The Formation can be subdivided into Lower (Lower Oligocene), Middle (Upper Oligocene) and Upper (Lower Miocene) Menilite members. The Lower Menilite Member is approximately 330 m thick and contains a high number of chert beds and turbiditic sandstones in its lower part. The TOC content of pelitic rocks frequently exceeds 20 wt.% and averages 9.76 wt.%. HI values typically range between 600 and 300 mgHC/gTOC (max. 800 mgHC/gTOC). The middle member contains only thin black shale layers and was not studied in detail. The Upper Menilite Member is about 1300 m thick and TOC content averages 5.17 wt.%. Both successions are thermally immature. Biomarker and maceral data reflect a dominance of marine organic matter mixed with varying amounts of landplants and argue for varying redox and salinity conditions.

The Lower Cretaceous Shypot Formation should be regarded as a potentially important source rock interval of the Ukrainian Carpathians. In the Chornogora nappe, the Shypot Formation is approximately 350 – 400 m thick and consists primarily of organic rich black shales with minor sandstone and siltstone beds. Pelitic rocks are mature (average 456°C Tmax) and TOC content averages 2.83 wt.% (max. 9.39 wt.%). Typically HI values of the Shypot Formation HI are in the order of 100 to 200 mgHC/gTOC. In the studied section, HI values are generally low (average 88 mgHC/gTOC) due to advanced maturity.

The Source Potential Index for the Menilite Formation in the Skyba nappe shows that 74.5 tons of hydrocarbons per m² can be generated. This classifies the Chechva profile as a world-class source rock containing a significantly higher source potential than any other profile in the Paratethys realm. It further explains that a relatively small area in Ukraine hosts about 70% of the known hydrocarbon reserves in the northern and eastern Carpathian fold-thrust belt.

New insights into the petroleum systems in the Tbilisi area, Kura Basin, Georgia

Pupp, M.1), Sachsenhofer, R.F.1), Bechtel, A. 1), Enukidze, O.2), Gratzer, R.1), Janiashvili, A.3), Tevzadze, N.3), Yukler, M.A.3)
1) Chair Petroleum Geology, Montanuniversitaet Leoben, 8700 Leoben, Austria
2) Institute of Geophysics, I. Javakhishvili Tbilisi State University, Tbilisi, Georgia
3) Georgia Oil & Gas Limited, 4A Freedom Square, Tbilisi 0105, Georgia

Georgia looks back on nearly a century of oil production. During Soviet times, the major focus was placed on Russian oil, whereas oil production in Georgia was limited. As a result, the country is currently reconsidering its hydrocarbon potential and investing in exploration. Georgia is divided into three major tectonic units: the Greater Caucasus in the north, the Lesser Caucasus in the south and the Transcaucasian Massif in-between. The latter includes two Neogene foreland basins: the Rioni Basin in the west, dipping towards the Black Sea and the Kura Basin in the east, which opens towards the Caspian Sea.

Traditionally, the Oligo-/Miocene Maikop Group is considered the most important source rock in the Caucasus region. The Maikop Group in the Rioni Basin indeed proved to be a prolific oil-prone source. Together with the Middle Eocene Kuma Formation it charged some oil accumulations (Mayer et al., 2018; Pupp et al., 2018). Previous investigations showed that the Maikop Group in the Kura Basin is a poor (to fair) source rock. Hence 130 cuttings samples from three boreholes (incl. Kumisi-2) and 32 outcrop samples representing Oligo-/Miocene and Eocene sediments have been analysed for their bulk organic parameters, biomarker composition and compound-specific isotopy. In addition eight oil samples have been examined for their biomarker and isotopic composition.

The new results confirm the poor to fair source rock potential of the Maikopian sediments in the Kura Basin (TOC ~1.0 wt.%) with land plant dominated, gas-prone type III kerogen. The (Middle to) Upper Eocene shaly Navtlugi Formation is about 100 m thick and directly overlies Middle Eocene volcanoclastics in the Kura Basin, which are the main reservoir rocks in the region. In Kumisi-2 the Navtlugi Formation holds a “fair” hydrocarbon potential, which increases from top to base. Samples in the lower part of the formation contain type II (to III) kerogen. In contrast, the petroleum potential of the Navtlugi Formation in neighbouring boreholes is poor, reflecting lateral variations of the formation. The best source rocks were found in an Upper Eocene succession north of Tbilisi (2.5-5.5 %TOC; HI up to 300 mgHC/gTOC). However their thickness and lateral continuity are still under investigation.

Irrespective of the source potential of the Eocene source rocks, biomarker and isotope ratios suggest that their contribution to the accumulated oils in the Tbilisi area is minor. Hence, it is likely that the accumulated oils represent mixtures of oils generated from different Eocene and Oligocene organic-rich units.

Petroleum System Elements in Carpathians Foredeep Molasse (Romania)

Constantin Pene, Bogdan-Mihai Niculescu, Gina Andrei, Alina Floroiu, Călin Marius

The molasse deposits of Carpathians Foredeep consist of two regions. The inner part, very intensely folded, that is known as the Carpathians Foredeep (sensu strictu) or the Subcarpathian Nappe. It extends from the South Carpathians in Romania to the Western Carpathians in Poland and its internal part is underthrusted beneath the Moldavide nappes. The outer part is very weakly folded and overthrusts the Moldavian Platform, Scythian Platform and the Moesian Platform along the Pericarpathian Fault. The subsidence in the basin has been continuous from Eocene to Mio-Pliocene, with a depocenter steadily migrating outward, towards the foreland. The Carpathians Foredeep Molasse consists of two large piles of sediments: Lower Molasse (LM) and Upper Molasse (UM) that are separated during the Moldavian tectogenesis in Volhinian. The molasse deposits have a great thickness (frequently more than 8000 m), with a maximum of more than 14 km in Focşani Depresion.

The Lower Molasse (LM) consists of Upper Eocene (Bisericani beds and Lucăceşti sandstones), Oligocene (Lower and Upper Disodiles and Menilites, White Bituminous Marls and Kliwa sandstones), Lower – Middle Miocene (Burdigalian with the Lower Saliferous Formation, shales and sandstones, Badenian with the Upper Saliferous Formation and Slănic Tuffs, shales and sandstones and Lower Sarmatian with shales and sandstones). The Upper Molasse (UM) consists of Upper Sarmatian deposits comprising shales and sandstones. This lithostratigraphic constitution is encountered in Moldova region, between the northern border with Ukraine and Buzău river and in southern part (between Buzău river and Jiu river) the Upper Molasse is more complete, with Upper Sarmatian and Pliocene deposits (shales and sandstones). In these molasse deposits almost 90 oil and gas fields have been discovered: 6 oil and gas fields in the area located north of Buzău river and 84 oil and gas fields between Buzău and Jiu rivers. The hydrocarbons are reservoired in Eocene-Oligocene, Burdigalian, Badenian, Sarmatian and Pliocene sandstones, microconglomerates and sands. The traps are of stratigraphic and tectonic type, as a result of especially Burdigalian and Badenian salt diapirism. The hydrocarbon source rocks consist of the Eocene Bisericani beds, the Oligocene Lower and Upper Disodiles and Menilites, White Bituminous Marls and Bituminous Shales (in Moldova region – the Kliwa facies and in Muntenia region – the Pucioasa facies). The pyrolysis analyses yield the following average results: TOC ranges from 0.8 to 4.11%, HI is 250 – 675 mg HC/g TOC, Tmax between 417 and 448 °C. The kerogen is mixed (type II+III) and R0 ranges from 0.45 % (the source rocks are immature) to more than 2.1 % in Focşani Depression, where the source rocks of Lower Molasse are supermatured. The time of oil and gas generation, migration and accumulation is different for every area, but the differences are small. To evaluate the petroleum system elements in this large Carpathians Foredeep, we constructed event charts for the following areas (from north to south): Frasin, Târgu Neamt,, Tescani, Focşani, Berca, Țintea-Băicoi, Moreni, Târgovişte, Țicleni. This study suggests that in Câmpeni – Piatra Neamț – Târgu Neamț, Focşani the Diapiric Folds Zones and the Vâlcele areas there might be new prospects with potential for oil and gas-condensate accumulations.

Organic matter dispersed in Menilite Beds from Silesian Nappe – hydrocarbon evidence (Outer Carpathians - Poland) - preliminary results

Marta Waliczek1, Magdalena Krzysztofik1, Grzegorz Machowski1, Gabriel Ząbek1
1AGH University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Department of Fossil Fuels, al. Mickiewicza 30, 30-059 Cracow, Poland; e-mail: waliczek@agh.edu.pl

The Lower Oligocene Menilite Shale from the Outer Carpathian are often described as an excellent source rocks for the conventional hydrocarbon reservoirs and perspective for unconventional ones. The Menilite Shale with oil-prone Type II kerogen is dominated by alginite organic matter. The aim of the presented study was to characterize and classify organic matter components and evaluate thermal maturity of huminite particles using microscopical investigation. Menilite Shale samples (22) were collected from outcrops in the eastern part of Silesian Nappe in Outer Carpathians (SE Poland) and were analyzed in reflected white and blue light. To determine the stage of maturation the huminite reflectance (Ro) was measured.

The analyzed samples are abundant in organic matter. The predominant is liptinite group occurring mostly as an alginite and bituminite. Alginite macerals are represented as lamalginite and telalginite. Bituminite observed in analyzed samples is presumably degradation product of alginite macerals. It appears as dark brown streaks and unstructured groundmass with dark brown fluorescence colour. Liptinite group is also represented in smaller amounts by macerals such as cutinite, sporinite, resinite, suberinite and liptodetrinite. In several samples oil generation from bituminite was noticed. Macerals from the huminite group are relatively rare and the inertinite group is even less frequent. Huminite often shows brown fluorescence, which makes it difficult to distinguish from bituminite. Microscopic investigation indicates that predominant type of organic matter dispersed in analyzed samples is represented by kerogen II and mixed kerogen II/III.

Reflectance values of huminite range from 0.25 to 0.49% Ro showing these samples to be pre-generative. Despite this, in a few samples with higher reflectance of about 0.48% Ro evidences of small portion of hydrocarbons were noticed. This may suggest that oil generation from bituminite in analyzed Menilite Shale starts at a huminite/vitrinite reflectance even lower than 0.50% Ro.

Acknowledgements. This research has been financially supported by statutory funds no. 15.11.140.196 and 11.11.140.176, Faculty of Geology, Geophysics and Environmental Protection, AGH UST.

Comparison of isotopic composition and origin of natural gases in the Miocene strata of the two selected zones of the Polish Carpathian Foredeep

Maciej J. Kotarba - kotarba@agh.edu.pl - AGH University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Krakow, Poland

We compare isotopic composition and origin of natural gas in the autochthonous Miocene strata of the Polish Carpathian Foredeep (CF) in two selected zones: (i) the western part of CF between Cieszyn and Czechowice-Dziedzice and (ii) the eastern part of CF between Sędziszów Małopolski and Przemyśl. Three gas fields and 70 gas deposits have been discovered in the western zone since 1945 and in eastern zone since the middle 1960s, respectively. There were collected four natural gas samples from Miocene reservoirs in the western study area, and additional seven samples from the Pennsylvanian coal bearing strata, as a reference. In the eastern study zone fourteen natural gas samples were collected from the Miocene sandstone reservoirs and two samples from Upper Jurassic carbonate reservoirs, as a reference. Molecular and isotopic (δ13C in CH4, C2H6, C3H8, i-C4H10, n-C4H10, and CO2, δ2H in CH4, C2H6 and C3H8, and δ15N in N2) compositions of natural gases were analysed.

WESTERN ZONE. The analysed hydrocarbon gases accumulated in the sandstone reservoirs of Miocene (Lower Badenian) strata of the western zone, lying on Pennsylvanian coal-bearing strata of the Upper Silesian Coal Basin (USCB), insignificantly vary both in their molecular and isotopic compositions. Methane is isotopically light (δ13C from -66.6 to -65.7‰). Molecular indices and δ13C of methane, ethane and propane and δ2H values of methane suggest that these gases migrated from the Serpukhovian and Pennsylvanian coal-bearing strata of the USCB. Moreover, at least part of natural gas was probably generated from dispersed organic matter within claystone/mudstone series of the Lower Badenian strata of western part of the CF. The majority of analysed coalbed gases from USCB contains both thermogenic and microbial carbon dioxide. Only methane (δ13C-CH4 -45.3‰) and carbon dioxide (δ13C-CO2 9.4‰) from "Pniówek" Mine in primary, indigenous accumulation zone originated during thermogenic, coalification processes. Molecular nitrogen of the analysed gases can be produced as a result of various biogenic and abiogenic processes. N2 from USCB and CF gases was mainly generated during thermogenic processes of a breakup of nitrogen-components of kerogen. Beside organic thermogenic component it may contain a component released from NH4-rich illites.

EASTERN ZONE. Methane concentrations in natural gas exceed 95 vol%. Methane of this zone is isotopically light (δ13C from -71.4 to -64.0‰, only in Miocene reservoir of Góra Ropczycka deposit -48.1‰). Isotopic studies reveal that methane and partly ethane and even propane accumulated within the autochthonous Miocene strata were generated by microbial reduction of carbon dioxide in marine depositional environments, mainly during sedimentation of the Miocene clays and muds. Generation and accumulation of microbial methane, ethane and propane, and the formation and the loading of multiply stacked Miocene sandstone reservoirs and claystone source rocks were facilitated by rhythmic and cyclic deposition of clays, muds and sands at very high sedimentation rates. The higher light hydrocarbons (butanes and pentanes, and partly ethane and propane) were originated during diagenesis and at the initial stage of the low-temperature thermogenic processes. Carbon dioxide and molecular nitrogen were generated by both microbial and early thermogenic processes. Thermogenic gas occurs only in lowest Miocene horizon of the Góra Ropczycka deposit which migrated from the Upper Jurassic strata (δ13C-CH4 -45.6‰) of the Palaeozoic-Mesozoic basement.

Keywords: microbial gases, thermogenic gases, Pennsylvanian coal-bed gases, stable carbon, hydrogen and nitrogen isotopes, Polish Carpathian Foredeep, autochthonous Miocene sandstone reservoirs, Pennsylvanian coal-bearing strata, Upper Jurassic reservoir

Hydrocarbon generation potential of Paleogene sediments in the Hungarian Paleogene Basin

Körmös, Sándor1, Fekete, József2, Milota, Katalin3 and Schubert, Félix1
1University of Szeged, Department of Mineralogy, Geochemistry and Petrology
2Institute for Geological and Geochemical Research, RCAES, HAS
3MOL Plc.

During the last few decades several hydrocarbon reservoirs were explored in the Hungarian Paleogene Basin (HPB). There are few boreholes at the central part of HPB, which were penetrated Eocene to Oligocene pelitic rocks, containing significant amount of organic matter (OM). The general lithostratigraphic setting of research area is made by the followings. The Paleogene sediments unconformable overlie the Mesozoic basement. The starting Eocene Kosd Formation (KF) (E2-3) is set up by two parts, the lower one contains terrigenous, while the upper one consists of shallow marine, lagoonal sediments. It is followed by shallow marine platform, biogenic Szépvölgy Limestone (E3), the deep-sea sediment Buda Marl (BM) (E3–Ol1), the deep bathyal Tard Clay (TC) (Ol1) and the shallow bathyal Kiscell Clay (KC) (Ol1). The Oligocene sequence is terminated by siliciclastic and carbonate platform sediments, and covered by thick Neogene.

In the current research Rock Eval pyrolysis were carried out on drill cuttings, moreover, rock extracts were prepared and gas chromatography of saturated hydrocarbons were performed on drill cuttings and core samples from KF, BM, TC and KC.

The Total Organic Carbon (TOC) contents of analysed samples are between 0.1–20.5 wt%. The amount of TOC at KC are not more than 0.5 wt%, at the TC and BM are about 1.0–2.0 wt%. Furthermore, the TOC values of KF can reach a maximum of 20.5 wt%. Hydrogen Index (HI) values vary on a wide range, 63–282 mg HC/g TOC for KC, 189–478 mg HC/g TOC for TC, 50–258 mg HC/g TOC for BM and of 50–348 mg HC/g TOC for KF. The generally low HI values (≤ 150 mg HC/g TOC) indicate high contribution of humic material from land plants, Type III kerogen. However, the higher HI values (≥ 200 mg HC/g TOC) suggest the presence of OM from algal and/or microbial lifeform, Type II kerogen. The general HI trend is slightly affected by mineral matrix effect. The values of Tmax are between 419–451 °C. Those are consistent with immature and low mature character (Ro% ≤ 0.6%) in KC, and with mature character (0.6% ≤ Ro% ≤ 1.3%) in TC, BM and KF. The kerogen at TC, BM and KF are hydrocarbon generative. The n-alkane envelope of KC sample is characterized by a maximum at n-C22–25 and shows a symmetrical distribution around its maximum. The n-alkane envelope of TC and BM are characterized by a maximum at n-C15–16 and n-C16, respectively. The gas chromatogram of BM shows a wide plateau in the range of n-C15–27, then a decreasing trend appears towards the n-alkanes with higher carbon numbers, just as well as for TC. Furthermore, duplets of peaks appear at the end of chromatogram (> n-C29) of TC. The gas chromatogram of KF shows a bimodal distribution, the n-alkane envelope is characterized by maximum at n-C16 and n-C18–24, then a slowly decreasing trend appears towards the n-alkanes with higher carbon numbers. The proportion of low (n-C15–19), intermediate (n-C21–25) and high (n-C27–31) molecular weight n-alkanes relative to total n-alkanes are 14%, 29%, 27% at KC, 36%, 28% 11% at TC, 28%, 27%, 21% at BM, and 28%, 29%, 20% at KF, respectively. The Carbon Preference Index on the range of n-C24–34 are about 1 and of n-C17–22 are about 1 in each case, except of KC, where it is 0.8. The n-alkane distribution patterns show a mixture of algal and microbial origin contributed by high amount of terrestrial OM.

Keywords: Hungarian Paleogene Basin, Rock Eval pyrolysis, gas chromatography

Hydrocarbon source rock potential of the Lower Oligocene İhsaniye Formation (Karaburun, Turkey)

Tulan E.1), Sachsenhofer R.F.1), Tari G.2), Pupp M.1)

1)Montanuniversitaet Leoben, Peter Tunner Strasse 5, 8700 Leoben, Austria
2)OMV Exploration & Production GmbH, Trabrennstrasse 6-8, A-1020 Vienna, Austria

The İhsaniye Formation is exposed near Karaburun (Turkey) along the Black Sea shore in 50 m high cliffs. The Lower Oligocene sediments are a time equivalent of the lower part of the "Maykop" source rocks and provide insights into the hydrocarbon potential of the southwestern part of the Black Sea. The present study is based on geochemical parameters and mineralogy of 78 fine-grained samples, representing a 70-m-thick succession, which is composed of light grey marl, carbonate-rich siltstone and sandstone as well as tuffaceous beds.

The İhsaniye Formation overlies Eocene limestones with an erosional unconformity. Abundant foraminifera indicate a fully marine depositional environment, which is also supported by TOC/S ratios below 2.8. Based on lithology and bulk geochemical data, the studied succession can be subdivided into three units.

The lower unit, about 20 m thick, it contains marlstones with moderately high total organic content (TOC) (average: 1.45 wt.%; max. 2.04 wt.%). Hydrogen Index (HI) values (max. 252 mg HC/g TOC) reveal the presence of type III-II kerogen. The predominance of land plants is also supported by biomarker data. Very low pristane/phytane ratios indicate oxygen-depleted conditions.

The amount of detrital land plants decreases upwards within the middle unit (20-43 m) together with the ratio between detrital minerals (quartz) and clay minerals. Hence, the middle unit probably represents a transgression. TOC contents remain low (average: 0.3%) in the upper unit (43-68 m), whereas quartz/clay mineral ratios show a subtle upward increase. A prominent tuff layer occurs between 56.8 m and 58.0 m. The top of the upper unit is formed by coarse-grained debris flow sediments.

The İhsaniye Formation is thermally immature. If mature, the lower part of the formation may generate only 0.14 t HC/m². Based on microfossils, the upper part of the studied section has been dated into nannoplankton zone 23. Therefore, the absence of any indications of the brackish-water "Solenovian Event" (lower part of NP23), which is often associated with oil-prone source rocks, is intriguing. We speculate that this is because of a marine connection with the Mediterranean Sea (e.g. through the Thrace Basin). Alternatively, the "Solenovian Event" may be hidden by the debris flow sediments.

Hydrocarbon source rock potential of Oligocene to Lower Miocene diatomaceous rocks in Sibiciu de Sus, Romania

Tulan E.1), Sachsenhofer R.F.1), Horvat A.2), Tari G.3), Olaru-Florea R.F.4)
1) Montanuniversitaet Leoben, Peter Tunner Strasse 5, 8700 Leoben, Austria
2) Institute of Paleontology, Research Centre of the Slovenian Academy of Sciences and Arts Novi trg 2, SI-1000 Ljubljana, Slovenia
3) OMV Exploration & Production GmbH, Trabrennstrasse 6-8, A-1020 Vienna, Austria
4) OMV Petrom S.A., Strada Coralilor 22, sector 1, 013329 Bucharest, Romania

The Oligocene to Lower Miocene Menilite Formation, one of the most important hydrocarbon source rocks in the Carpathians, contains siliceous rocks in different stratigraphic levels. Often these rocks contain diatom frustules. In the Tarcău Nappe of the Romanian Carpathians, an approximately 100 m thick succession of diatomaceous rock has been deposited. These rocks are exposed in an abandoned quarry near Sibiciu de Sus, which is split into two levels. The upper level shows the core of an anticline and is represented by Kliwa Sandstone alternating with Upper Dysodiles, followed by cherts, white and black alternation of diatomites and cream-white diatomites. The lower level exposes dark grey diatomite. Because of strong tectonism, it is very difficult to correlate the different layers. For this study, 22 samples have been analysed with respect to their organic matter content and kerogen type. Selected samples were used to quantify the content of biogenic opal using atomic absorption spectrometry (AAS) analysis and to differentiate the types of opal based on the X-ray diffractometry response.

The total organic content (TOC) reaches a maximum of 9.57 wt.% (average 3.61 wt.%). Hydrogen Index (HI) values range from 206 to 515 mg HC/g TOC and indicate the presence of type II and III kerogen. The petroleum potential of the section is very good, but Tmax (up to 424°C) and vitrinite reflectance measurements (0.32 Rr %) indicate the low maturity of the studied section. Despite that, the Production Index is high (0.1-0.3) indicating the presence of migrated oil. Therefore, biomarkers results are inconclusive.

The results from AAS analysis reveal that the average biogenic silica content of the diatomaceous rocks is 60%. Opal-A is present in the majority of the analysed samples, except for two where opal-CT is recognised.

Under the electronic microscope diatom frustules have been observed, and for relative abundance of diatom genera, 300 valves were counted. In all samples the genus Paralia predominate with an average abundance of 68%, followed by Actinocyclus and Coscinodiscus. Rarely, Ellerbeckia, Diplomenora, Opephora, Raphoneis and few specimens of resting spores have been recognised. Majority of determined genera are typical marine (polyhalobous), commonly found in plankton and benthos of coastal areas of subtropical to temperate environments. In some sample, rare abundance of freshwater Ellerbeckia was recognised which may indicate sporadic higher freshwater influence. Paralia is a cosmopolitan genus frequently occurring in shallow water (up to175 m deep) enriched with nutrients, and it is an indicator of high littoral bioproduction. The increased of number Paralia valves coincides with flooding events of the littoral area.

Evaluating seal potential of the chalk-type cap rocks from the Węglówka Oil Field, Outer Carpathians, Poland

Grzegorz Machowski[1], Alicja Pstrucha1, Ewa Pstrucha[1], Katarzyna Górniak[1], Anna Tomczyk[1]

1 AGH University of Science and Technology, Cracow, Poland, corresponding author e-mail: machog@agh.edu.pl

Non-reservoir chalk, which acts as a barrier to the flow of fluids and which prevents hydrocarbons from escaping, and also serves as a pressure seal, is the least known element of the petroleum system. In the Outer Carpathian region, the hydrocarbon deposits located in the eastern part of the Sub-Silesian and Silesian Units (Węglówka, Wola Jasienicka and Grabownica Oil Fields) are thought to be sealed by Upper Cretaceous impure chalk called the Węglówka Marls.

It is hypothesized that the Węglówka Marls are effective sealing rocks. The aims of the paper are: (1) evaluation of the sealing properties of these chalk-type rocks (seal or leak?); (2) explanation how the sealing properties in these rocks developed; and (3) deciphering what geological processes influenced the development and evolution of pore space in the expected sealing rocks. Outcrop samples from the Węglówka Oil Field, which consisted of 19 samples of sealing rocks (Węglówka Marls) and 4 samples of reservoir sandstone (Lgota Sandstones), were studied. Complementary methods such as mercury intrusion, nitrogen gas absorption method, and helium picnometry were applied to measure pore space in the Węglówka Marls. These measurements were taken in order to evaluate the effectiveness of these expected sealing rocks. Field emission scanning electron microscopy imaging was applied to refine the measurements of pore space. Mineralogical composition of the studied rocks was performed using X-ray diffraction.

These studies revealed that the Węglówka Marls: (1) petrographically can be called bioturbated calcareous mudrocks, which have a similar mineral composition (coccolith fragments, swelling clay, quartz), and consequently their lithological features are suitable to act as sealing rocks; (2) their petrophysical properties are as follows: the porosity (mercury porosimetry data) ranges from 15.12 to 26.78%, average pore diameter ranges from 19.8 to 27.4 nm, the permeability ranges from 800 to 3000 nD, and the value of total pore area ranges from 13.16 to 20.32 m2/g; (3) their high total pore area is related to the presence of clay (49 - 62%) and result in low permeability; (4) their porosity values established by mercury and helium porosimetry are higher than the nitrogen gas adsorption results, therefore, it is reasonable to assume that apart from mesopores, the studied rocks contain a considerable amount of micro- and macropores, which contribute to increasing the pore volume; (5) they are low permeability rocks, which are homogeneous on a micro-scale due to micrometer-size material deposited in their sedimentary environment, reworking of sediments (bioturbation), and tectonics which caused clay aggregates to be squeezed between coccolith fragments; (6) in terms of seal capacity, determined by mercury intrusion method, the displacement pressures ranges from 2200 to 3600 psi, what corresponds to a calculated maximum hydrocarbon column they can support of 766 – 1255 m; according to the classification of seal type by sealing capacity these rocks represent type A (hydrocarbon column > 300 m), what allows to conclude that the Węglówka Marls provide very effective regional seal.

Acknowledgments: This research has been financially supported by Statutory funds no. 11.11.140.158, 11.11.140.176, Faculty of Geology, Geophysics and Environmental Protection, AGH UST.

Facies distribution of the Lower and Middle Miocene rock formations in Eastern part of the Drava depression

Author: Rukavina, David - david.rukavina@rgn.hr – University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering
Co Authors: Saftić, Bruno - bruno.saftic@rgn.hr; Cvetković, Marko - mcvetkov@rgn.hr; Kolenković-Močilac, Iva - iva.kolenkovic@rgn.hr – University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering

In the Drava depression, SW part of the Pannonian Basin System (PBS), there is a variety of Lower to Middle Miocene rocks, which were generally formed during sin-rift phase of the basin evolution. These rocks are proven hydrocarbon reservoirs which makes them the valuable object for the detailed study. Input data for the mapping of this Early to Middle Miocene succession is a compilation of the newly acquired observations from outcrops, previous interpretation from deep wells data together seismic data. Integrated approach enabled the construction of a model of facies distribution for rocks that formed during the basin rift and early post rift phase, by associating lithofacies units defined on outcrops and cores to the geophysical measurements in wells and seismic.

Five main lithofacies units were defined based on geological data – rockfall breccia along with alluvial fan to debris breccia and conglomerates (1), volcanic and pyroclastic rocks (2), continental conglomerates to marls (3), shoreface conglomerates, sandstones to basinal turbidites and marls (4) and Badenian Lithothamnion limestones and associated shallow water sediments (5). Rock fall and debris breccia and conglomerates are diachronous, formed from Lower to Middle Miocene, marking sin-rift sedimentation, generally presented in well cores. Volcanic and pyroclastic rocks differ in age, from Lower to Middle Miocene and they can be distinguished in well data and on outcrops. Continental conglomerates to marls are predominantly of Lower Miocene age. They are well presented in several locations on outcrops but intend to be reduced in depression and are the most probably only present in lower portion of the thickest successions of sin-rift sediments. Marine shoreface conglomerates, sandstones to basinal turbidities and marls are of Middle Miocene age, presented primarily within the depression and identified in numerous well cores. Badenian limestones and associated shallow water sediments were observed on outcrops in many locations, but they are generally absent in deeper part of depression, occurring only in one well.

Since sin-rift rocks are formed in tectonically very active setting and environments from continental to marine, their response on well logs doesn't have to be repetitive on wells, but rather dependable on the consolidation and secondary processes. Proximal lobe-hummocky to discontinuous seismic facies is attached to rockfall breccia, alluvial fan and debris breccia and conglomerates along half-grabens margins and those directly overlying the Neogene basement. These rocks are varying in thickness from 10 to 500 m. Volcanic rocks are associated to sub-parallel discontinuous seismic facies, and are predominantly present in the western part of the study area with thickness up to 500 m. Lithofacies interpreted on geological data as continental conglomerates to marls and marine shoreface conglomerates, sandstones to basinal turbidites and marls are associated with oblique low amplitude seismic facies and parallel and sub-parallel continuous seismic facies. Further separation of these two lithofacies using seismic is not possible. They are occurring as the main half-graben infill, but with varying thickness from 10 to 500 m. Well data suggest that Badenian limestones and associated shallow water sediments are, if present in wells, probably resedimented in deeper part of the basin and that they occupied positions on drowned basement heights.

Keywords: syn-rift phase, Badenian, seismic data, Drava depression, Croatia

Triassic rift sedimentation in Eastern Moesia, Romania

Author : Stoica, Alexandra - nicoleta.alexandra.stoica@gmail.com – University of Bucharest
Co Authors : Duduș, Roxana - roxana.dudus@petrom.com – OMV Petrom S.A.
Krezsek, Csaba - csaba.krezsek@petrom.com – OMV Petrom S.A.
Burghelea, Evelina - evelina.burghelea@petrom.com – OMV Petrom S.A.

The existing literature (Paraschiv, 1978) describes Permian to Middle Triassic sedimentation consisting of continental to shallow marine deposits in Moesia, typical for the European passive margin. During the Upper Triassic, the tectonic regime in the Moesian Platform shifted from extensional to a compressional one characterized by continental facies. However, the available maps limit the extent of the Permian - Triassic deposits in the East up to the Intramoesian Fault. The lack of Triassic predicted in the Easternmost part of the Moesia still continues to be a problematic geological issue.

In order to improve the available Triassic facies maps the current study uses well data (logs, thin sections and core samples), 2D, and 3D seismic from the Eastern Moesia to determine the depositional environment as well as the basin's architecture and tectonics.

The 3D seismic interpretation revealed that the tectonics in the studied area is characterized by normal faults in the Lower Triassic that led to the formation of horst and graben structures followed by an inversion of the normal faults in the Upper Triassic. In consequence, the Lower Triassic is marked by syn-rift sedimentation, whereas post-rift deposits are specific for the Middle Triassic. The Upper Triassic sedimentation was influenced by the compressional regime that affected the whole Moesian Platform as the Paleo-Tethys ocean began to close.

According to the analyzed log patterns, core samples, and thin sections from wells located in the Eastern part of the Moesian Platform, Lower Triassic deposits indicate a braided fluvial/alluvial fan environment characterized by a coarse grained facies sourced from the footwall catchments, abundant in iron oxides and argillaceous minerals. Carbonate core samples dated as Middle Triassic consist mainly of bioclastic grainstones specific to a supratidal environment, due to the presence of anhydrite, dolomite and benthic foraminifera, pointing to the existence of a large carbonate platform developed in a period of tectonic quiescence. The observations made on thin sections enabled also a visual estimation of the porosity and reservoir qualities of the intercepted deposits. Although the fault system was inactive in Middle Triassic, the morphology inherited from the horst and graben structures most probably determines areas of different depths with specific facies, from supratidal to subtidal. Despite the fact that some core samples intercepted the continental facies of Upper Triassic, it appears to be mostly under the seismic resolution.

Therefore, this study integrates borehole and seismic data from the Eastern part of the Moesia and brings new information about the extent of the Triassic deposits and their reservoir quality, as well as the basin's palaeo-morphology and palaeo-environment.

Keywords: rift, sedimentation, Triassic, reservoir quality

Hydrocarbon system evaluation on mud log well data in the Southeastern Pannonian Basin, Hungary

Hussain, Shayan - Shayanhssn@gmail.com - Institute of Mineralogy and Geology, University of Miskolc, Hungary
Csizmeg, János - jcsizmeg@vermilionenergy.com - Vermilion Energy, Budapest, Hungary

In hydrocarbon exploration mud log gas chromatographic analysis provide always first direct indication of reservoir fluids. This method implies, the crushed rock from particular formation produces hydrocarbon vapors into the drilling mud which is detectable at surface with use of chromatography. Gas sample is injected into a Flame Ionized Detector (FID) or a gas chromatograph, cutting gas is reported in units the same as the total or components in ppm.

Chromatographic gases are alkanes mostly, which are composed of C1 (methane), C2 (ethane), C3 (propane), C4 (butane), C5 (pentane), also CO2 and H2S are regularly recorded. Calculated ratios act as finger print and can determine the origin of hydrocarbon, like dry gas, condensate, light oil, residual oil, etc. from the extracted C1 - C5 gases. The most applied ratios are the Pixler, the Wetness (Wh), Balance (Bh) and Character (Ch), which are plotted as curves to refine the evaluation of hydrocarbon fluid characteristics in certain reservoir levels.

This study consist of evaluation and interpretation of mud log gas chromatographic data for 23 wells from the Túrkeve area in the Southeastern Pannonian Basin, Hungary, to better understand the hydrocarbon quality according to the areal and depth level differences.

This study also focuses on areas settled in the most prolific HC province of the Pannonian Basin System on the northern flank of the Békés Basin. Early discoveries regarding, the main structural highs related to ground gravity surveys and 2D seismic exploration techniques until 90's. During late 2000s with the application of modern 3D seismic surveys new discoveries happened, which are the source of the data set from the area under study.

Probably two main source rock intervals are producing hydrocarbons for the area, the more oil-prone Middle Miocene (Badenian, Sarmatian) shales and marls form the syn-rift sequence of the Neogene Basin fill sediments and the more gas-prone Upper Miocene (Pannonian) marls. The turbidite sandstone reservoirs were the main targets of the exploratory wells, which represents the most productive stratigraphic sequence in the proposed area. However Pannonian deltaic sandstones, Middle Miocene conglomerates, limestones are also known productive reservoirs, which later share the hydrodynamic system with the fractured Paleozoic, Mesozoic basement reservoirs. In some cases Middle Miocene intervals, mature source rock layers and non-productive reservoirs have been penetrated as well, which gives the opportunity to make further comparative evaluations on the gas chromatographic data.

Keywords: mud logging, gas chromatography, HC gas analysis

The Dukla Unit in the middle part of the Polish Outer Carpathians as a hydrocarbon play

Krzysztof Starzec1, Marta Waliczek1, Grzegorz Machowski1, Aneta Siemińska1, Marek Wendorff1
1AGH – University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Krakow, Poland

The Oligocene Menilite Formation constitutes the primary source rock of the Polish Outer Carpathians. It occurs in three main tectonic units, i.e. the Dukla Unit and its equivalents in the western part of the Polish Carpathians, known as the Fore-Magura Units, Silesian Unit and Skole Unit. The Formation is composed mainly of dark brown shales, chert and siliceaous marls with minor intercalation of sandstones. However, in some areas also thick sandstone bodies occur within shales that may occasionally comprise half of the total thickness of the Formation. One of such areas, called Skrzydlna Tectonic Bay, lies in the middle part of the Polish Carpathians. It has a form of a narrow belt of steeply dipping beds belonging to the Dukla Unit that stretches along a distance of 16 km at the front of the Magura Nappe. To the S and SE the Unit is hidden under the Nappe. Detailed geological mapping, analyses of bituminous shales and sedimentological studies of coarse grained deposits have revealed its hydrocarbon potential.

The Dukla Unit succession in Skrzydlna area comprises mainly the Oligocene Menilite and Krosno Formations. The lower part of the Menilite Formation is composed of typical dark-coloured shales, which in numerous outcrops show natural oil seeps. Upwards, thick-bedded sandy conglomerates occur, which are followed by fining-upwards turbidite sequence (the Cergowa Sandstone Mb). Thick bedded conglomerates form isolated, lens-shaped complexes within the shales. Single complex reaches up to 50 m in thickness and about 1 km in length.

Microscopic observations indicate that the shales are rich in diverse organic matter, predominantly alginite, as lamalginite and occasionally as telalginite, and bituminite as dark yellow to brownish groundmass. The vitrinite macerals often show brown fluorescence in incident blue light. Their composition indicates kerogen type II that is representative for oil prone source rocks. Moreover, thermal maturity of exposed Menilite Formation, characterized by vitrinite reflectance values between 0.60 and 0.80%, is typical for mature organic matter to generate liquid hydrocarbons. Very good hydrocarbon potential is confirmed by geochemical data as well. The TOC content ranges from 1.9 to 7.2 wt. % (av. 4.4 wt. %) and pyrolysable hydrocarbons from 6.2 to 27.1 mg HC/g rock (av. 15.7 mg HC/g rock) classifying the Menilite shales as very good source rocks.

Our analyses of the Dukla Unit deposits in the Skrzydlna Tectonic Bay revealed that within the Menilite Formation two key elements of the petroleum system are present, i.e. good source and reservoir rocks. It is likely that similar deposits occur south of this area, below the Magura Nappe cover. Shaly formations of this Nappe can serve as a good seal. Conglomerate and sandstone complexes in the Menilite Formation may form both structural and/or stratigraphic traps, however, in order to discover them seismic survey combined with detailed sedimentological and stratigraphic analysis, need to be applied.

Acknowledgements. This research has been financially supported by National Centre for Research and Development grants no. BG2/ShaleCarp/14 and Statutory funds no. 11.11.140.176 and no. 11.11.140.005 AGH UST.

Source rock and hydrocarbon potential evaluation based on palynofacies and geochemistry of the sedimentary rocks, Danube Basin

Tomáš Vlček1, Marianna Kováčová1, Katarína Šarinová2, Samuel Rybár1, Natália Hudáčková1, Eva Halásová1 and Petronela Nováková1
1 – Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Mlynská dolina G, 842 15 Bratislava, Slovak republic
2 – Department of Mineralogy and Petrology, Faculty of Natural Sciences, Comenius University, Mlynská dolina G, 842 15 Bratislava, Slovak republic

The Modrany-1 and Modrany-2 wells, drilled in the Želiezovce depression of the Danube Basin penetrated the Miocene (NN5, NN6 and NN9) and Oligocene (NP21-22) sedimentary record with total thickness exceeds 2200m. Biostratigraphy and sedimentology of MOD-1 well have been studied extensively in Kováč et al., 2018 and was delimitated pre-Neogene basement of Transdanubicum and Cenozoic sediments of Kiscell Fm., Bajtava-Špačince Fm., Pozba-Vráble Fm., Ivanka Fm., Beladice Fm. and Volkovce Fm.. Oligocene sediments in northern Hungary, which pass through to Slovakia with high hydrocarbon potential have been studied (Milota et al., 1995). The characteristics of potential source rocks, depositional environment, redox condition in depositional system, kerogen maturation were investigated by standard palynological and geochemical methods. The complex analysis of 46 samples brought results, which were correlated. Palynofacies analysis data (palynomorphs, amorphous organic matter, phytoclasts), were correlated with geochemical data – CIA, TOC, TS, TOC/S, U/Th, SiO2/Al2O3 and the results are applied for semiquantitative kerogen type determination, redox condition in depositional system as well as paleoclimatic characteristics of related terrestrial environment. Rock-Eval pyrolysis is currently standard technique used for rapid assessment of the oil potential, type kerogen and the degree of ripeness of the studied rock sample. The analysis yields several measured parameters including S1, S2, S3, Tmax, HI, OI, PI and GP. The values of geochemical indicators TOC, TS, Ni/Co and the amorphous organic matter values in the Oligocene samples are increased and was determined type of kerogen I-II. According to Milota et al., 1995 this euxinic clay is a good source rock where predominate mostly kerogen I-II with type III in upper part of sequence. The sedimentation took place on the inner shelf or on a regularly flooded coast. During the Early Badenian (Langhian) was dominated kerogen type III and sedimentation proceeded in the oxic part of the inner shelf proximally from the source of organic material. During the Late Badenian (Serravallian), predominated kerogen III and the sedimentation proceeded under oxic conditions proximally to the source of organic material. In the Modrany-2 well was recorded dysoxic event (1255m) and kerogen type III or II. During the Tortonian dominated kerogen type III or IV and recorded oxic condition during sedimentation. During the Early Pannonian sedimentation took a place distally from the source of organic matter and during the Late Pannonian proximally from the source of organic matter. Acknowledgement: This work was supported by the Slovak Research and Development Agency under the contracts APVV-15-0575, APVV-16-0121 and special thanks to Nafta a. s. for an access to the core repositories in Gbely.

References:
Kováč, M., Rybár, S., Halásová, E., Hudáčková, N., Šarinová, K., Šujan, M., Baranyi, V., Kováčová, M., Ruman, A., Klučiar, T. & Zlinská, A., 2018: Changes in Cenozoic depositional environment and sediment provenance in the Danube Basin. Basin Research, 30, 97-131. doi: 10.1111/bre.12244
Milota, K., Kovács, A., Galicz, Z., 1995: Petroleum potential of the North Hungarian Oligocene sediments. Petroleum Geosciences 1, 81-87.

Thermal history modelling of Dolna Kamchia basin (onshore) – implications for source rock maturity

Botoucharov, Nikola – botnd@gea.uni-sofia.bg – Sofia University; Faculty of Geology and Geography; Department of Geology, Paleontology and Fossil Fuels; 15 Tzar Osvoboditel Blvd., 1504 Sofia (Bulgaria)
Stefanov, Yavor - yavor@gea.uni-sofia.bg – Sofia University; Faculty of Geology and Geography; Department of Mineralogy, Petrolology and Economic Geology; 15 Tzar Osvoboditel Blvd., 1504 Sofia (Bulgaria)

The nowadays exploration in the Bulgarian part of the Western Black Sea, including big companies like Total, OMV, Repsol and Shell, is connected with the scientific results and hydrocarbon discoveries from the last decades. They were attracted also by accumulation of significant amount of geological and seismic information from continental shelf, but also from the Dolna Kamchia basin – onshore and offshore. Four industrial (Galata, Kaliakra, Kavarna, Kavarna-East), three semi- or non-industrial (Priseltsi, Novo Oryahovo, Samotino more) gas accumulations were found and tens of hydrocarbon shows were reported. Although, the accumulations are of biogenic gas this is an evidence for petroleum system that is in an immature and early stage of its evolution. Despite the success and improved exploration technologies not many offshore wells were drilled last 25 years and the geology and geophysical data could be reinterpreted and compared with the abundant onshore data.

The aim of the present study is to delineate the thermal history models of the Dolna Kamchia basin (onshore) according geodynamic evolution and palaeogeography features of the region and their implications to source rock maturity. The well and maturity data allowed to define best fitting scenarios for the heat flow and paleotemperature distribution in the basin modelling. Burial and heat flow history of the study area should be viewed in the context of the opening of the Western Black Sea basin and later formation of a post-orogenic basin or a post-Early Eocene foredeep - Dolna Kamchia depression.

According recent investigations and modern concept for source rocks the best generation hydrocarbon potential in the study area shows Ruslar Formation consisting mainly of shale. It contains usually 1 wt% up to 2.0 wt% TOC and geochemical data suggesting the presence of kerogen type III/II. Alternatively, the fine-grained Oligocene-Lower Miocene sediments are considered Maikop Group in Eastern Parathetys.

The illite-smectite geothermometry, vitrinite reflectance (%Ro) and basin modelling on data of several wells as a standard technique for the reconstruction of paleo-heat flow were used to characterize the thermal history of the Dolna Kamchia onshore. The correlation of the geological events, expressed by the basin subsidence curves, thermal history and a calibration by maturity and/or time temperature parameters were essential prerequisites for a successful numerical simulation.

We applied three different heat flow scenarios, using forward and inverse modelling in order to get the best fit between measured and calculated maturity parameters. The scenario 1 shows relatively optimal coverage of measured maturity parameters only after the Illyrian orogeny. The constant heat flow scenario 2 (45 mW/m2) covers just measured %Ro dots on well-core samples and underestimates the calculated %Ro according illite-smectite geothermometry. The constant heat flow scenario 3 (57 mW/m2) demonstrates good fit with converted %Ro dots and overestimates the measured %Ro. The most plausible models (scenario 1 and scenario 2) could be expanded to the offshore area and compared with the well data there. According basin subsidence and thermal history of the Dolna Kamchia depression the sediments of Ruslar Formation is immature onshore and need considerably greater burial depths to realize their hydrocarbon potential.

Keywords: Dolna Kamchia basin, thermal history, source rocks, maturity

Digital mapping of deformation bands and open fractures, Yasamal anticline, Azerbaijan: Developing a predictive model of flow reduction in analogue South Caspian anticlinal structural traps

Vrabec, Marko – marko.vrabec@geo.ntf.uni-lj.si – Department of Geology, FNSE, University of Ljubljana, Slovenia
Weber, John – weberjc@gvsu.edu – Department of Geology, Grand Valley State University, USA
Rzayev, Elshan – elshan.rzayev@bp.com – BP Azerbaijan–Reservoir Characterization, Azerbaijan
Riley, Gregory –gregory.riley@uk.bp.com – BP Azerbaijan–Exploration, Azerbaijan
Alkhasli, Shahriyar – shahriyar.alkhasli@khazar.org - eiLink R&D, Khazar University, Azerbaijan

Major producing onshore and offshore oil fields in the South Caspian Basin are located in anticlinal structural traps. Reduction in reservoir permeability and porosity is commonly encountered in anticlinal crestal and steeply-dipping limbs, which compartmentalizes Pliocene sandstone reservoirs. Very little subseismic structural data is available from these fields. To investigate the relationship between anticlinal geometry, the occurrence of mesoscopic deformation bands and fractures, and related permeability and porosity changes in sandstone reservoir rocks, we conducted a field study of the Yasamal anticline, Absheron peninsula, Azerbaijan. The Yasamal structure is a ~10 km x ~2 km, doubly-plunging, ~N-S trending, thrust-cored, angular and multi-hinged anticline, in which superbly exposed sandstones and mudstones of the Pliocene Productive Series crop out. This structure should provide an excellent outcrop analogue for South Caspian offshore and subsurface structural traps. We mapped the entire anticline digitally in the field using FieldMove software and tablet computers. We also used multiview photogrammetry techniques to acquire 3D models of key mesoscopic structures. We are working to establish a chronology of deformation bands and fractures relative to tilting and folding and to determine how deformation band geometry and intensity and fracture geometry are controlled by structural position on the anticline. We observed and mapped the greatest density of deformation bands, many of which occur in conjugate sets and are multi-generational, in the SE hinge zone and on subvertical to overturned eastern macrofold limb. Deformation bands are less common on the gently dipping western microfold limb. Sandstone clay content acts as an additional controlling factor. Work in the neighbouring Kirmaky anticline shows that curvature gradients in bedding strike may play a major role in deformation band development. Open fractures formed late during folding and tend to be oriented down the dip of bedding on anticlinal limbs. Future work will include microscopic and further outcrop investigations to assess S:C deformation band ratios, and 3D geometric, kinematic, and strain modelling to establish a predictive model of deformation band and fracture occurrence relative to macrofold geometry.

Keywords: South Caspian anticlinal traps, deformation bands, open fractures, structural geology, porosity reduction

Subsidence history of the central Danube Basin (Gabčíkovo depression)

PETRONELA NOVÁKOVÁ1, SAMUEL RYBÁR1, JÚLIA KOTULOVÁ2, MICHAL NEMČOK3,4 and TOMÁŠ VLČEK1
1 – Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
2 – Earth Science Institute of the Slovak Academy of sciences
3 – Energy and Geoscience Inst. at University of Utah, Salt Lake City, USA
4 - EGI Laboratory at SAV, Bratislava, Slovakia

The Danube Basin represents north-western part of the Pannonian Basin System and it is bordered by the Eastern Alps, Western Carpathians and by the Transdanubian mountain range. The central part is represented by the Gabčíkovo depression, where the thickness of the sedimentary fill reaches up to 8000 m (Kilényi & Šefara, 1989). In the northern part the pre-Neogene basement of the Gabčíkovo depression is formed by the Central Western Carpathians units and in the southernmost part by Transdanubian Range units. These units are separated by the Hurbanovo-Diösjöny fault system. This work deals with the subsidence evolution of the Gabčíkovo depression by using PetroMod software. Our geological data come from deep wells Kol-2, Kol-3, Kol-4, ZH-1 and 2D seismics. The rifting phase was set to 14–12 Ma, what is based on available seismic lines and wells. Stretching factor was adopted from Lankreijer et al. (1995) and thickness of the crust and upper mantle was taken from Tasarova et al. (2016). Sarmatian sedimentation (12,8–11,6) is documented only in the northern part (Kol-2, Kol-3, Kol-4) of the depression. Shallow subsidence of this phase is followed by a short hiatus, which lasted till the Pannonian stage. Rapid subsidence in all wells is present during the early Pannonian (8,7–10 Ma) and in the late Pannonian gradual subsidence till the end of Miocene (8,7–6 Ma) follows. After this stage, a short period without subsidence occurs, this is due to the Pliocene inversion recorded in the Danube basin. At ?3,6 Ma the subsidence starts again in the Kol-2, Kol-3, Kol-4. This part of the depression shows an increasing trend in subsidence till ?2,6 Ma. Southwestern margin (above Transdanubian range units) of the area is still exposed to weathering and erosion, which is indicated by possible absence of Pliocene sediments. This uplift is probably caused by reactivation of the Hurbanovo-Diösjöny fault system. What is displayed in ZH-1 well by a decreasing trend in subsidence from ?5 Ma up to ?2,6 Ma. During the Quaternary in all studied wells a barely noticeable increase in subsidence is present.
Acknowledgement: Financial support for this study was provided by Slovak Research and Development Agency under the contracts APVV-16-0121 a APVV-15-0575. Our thanks go to the Nafta petroleum company management for allowing access to the well core repository.

References
Kilényi, E. & Šefara, J. (Eds.) 1989: Pre-Tertiary Basement Contour map of the Carpathian Basin Beneath Austria, Czechoslovakia and Hungary. Eötvös Lóránd Geophysical Institute, Budapest.
Lankreijer, A., Kováč, M., Cloetingh, S., Pitoňák, P., Hlôška, M. & Biermann, C. 1995: Quantitative subsidence analysis and forward modelling of the Vienna and Danube Basins: thin skinned versus thick skinned extension. Tectonophysics, 252, 433–451.

Hybrid event beds in a Late Miocene lacustrine turbidite system, Makó Trough, Pannonian Basin

Zima, Dóra – dora.zima93@gmail.com – Eötvös Loránd University, Pázmány Péter sétány 1/c, H-1117 Budapest, Hungary
Sztanó, Orsolya – sztano@caesar.elte.hu - Eötvös Loránd University, Pázmány Péter sétány 1/c, H-1117 Budapest, Hungary

Hybrid event beds (HEBs) are a distinctive and, in the past decade, well studied class of deposits, which comprises a significant part of turbidite systems. The idealized HEBs consists of five internal divisions: clean, structureless or dewatered sandstone (H1), banded sandstone (H2), mud-rich sandstone with argillaceous clasts (H3), parallel- or cross-laminated sandstone (H4), and mudstone cap (H5). These divisions are cogenetic and their internal structures reflect the rheology changes which can develop within sediment gravity flows. The texture and the character of the H3 division can be very variable, the difference of this and the presence of other divisions are the base of the classification of HEBs. Rheology changes when the turbidity current decelerate, which is closely related to the paleogeography of the basin. The presence of hybrid flow deposits has already been recognized in the Pannonian Basin but has not yet been documented in detail. The aim of my work is to identify and typify hybrid event beds in more than 400 m core material, from the deep-water sediments of the Makó Trough. The narrow, elongated geometry of the Makó Trough strongly confined the route, speed and transport capacity of turbidity currents. The confining effect decreased with ongoing infilling. This had been affected the stratigraphic spread and type of the HEBs. Different type and thickness of HEBs occur in relation with locally-fed mass flow deposits related to the deep-water marls and distally-fed sand-dominated turbidite systems. In the marls HEBs are 0,5-3 meters thick and appear frequently. H3 is a silty sand graded to sandy silt with lumps of sand and shreds of mud and appears without under and overlying divisions. HEBs are not connected to sandy lobes but are isolated. In contrary, in the sandy turbidite system the thickness of HEBs is not larger than 0,2 meter. The five-part divisions are common, banded H2 facies of muddy and mud-free sandstone is dominant, chaotic mud-rich sandstones (H3) are thin. HEBs alternate with medium or thin-bedded turbidites. Their occurrence decreases upwards as the basin-margin topography decreases and became less confining. Hybrid events occur when turbidity currents are transformed or decoupled by the increase of clay content. This suppresses turbulence and a debris flow is induced. Depositing H2 and H3 divisions preserves high clay/silt content mixed with sand. In these poorly sorted sand beds porosity and permeability decreases, thus reservoir quality of the succession deteriorates. Therefore, it is important to isolate the clean sandstone intervals which were created by “pure” turbidity currents and the alternations of clean sandstone and linked mud-rich debrites or “dirty” sandstones and/or chaotic sandy siltstone which deposited from the hybrid events. Well-developed HEBs are common at the off-axis to marginal parts of the lobes. Falcon-TXM Oil and Gas Ltd is acknowledged that the cores have been made available to ELTE for educational and research purposes. This presentation was supported by MOL Academic Aid Program.

Keywords confined basin, hybrid event bed, reservoir, turbidite

Application of surface geochemistry survey in the HC exploration

Morelos, Alejandro - a.morelos@hydrocarbonsystems.com
Csizmeg, János - jcsizmeg@vermilionenergy.com – Vermilion Energy
Márton, Béla - bmarton@vermilionenergy.com – Vermilion Energy
Blažević, David - dblazevic@vermilionenergy.com – Vermilion Energy
Cvetković, Marko - marko.cvetkovic@rgn.hr – University of Zagreb

Analysis of natural hydrocarbon micro seepage is sometimes used by the petroleum industry to assess the occurrence of mature source rocks in poorly explored basins. Various applications of the method have also sought to pinpoint the location of commercially viable subsurface accumulations of oil and gas. The aim of this study was to compare and contrast soil air results anomalies within two geographically distinct, underexplored areas in the Pannonian Basin of Croatia and Slovakia, and perform a controlled test to determine whether the soil gas readings were repeatable, and whether the gas compositions obtained were consistent with subsurface data.

Soil air samples were collected at sampling intervals of approximately 100 and 600 meters from an average boring depth of 1 meter. A subset of the samples were obtained during seismic acquisition operations so that results could be correlated with subsurface structure. Gas components of the samples were measured by gas chromatography to discriminate C1 to C4 in a suspected oil-prone area of Croatia, and from C1 to C5 plus CO2 content in a suspected gas-prone survey area of Slovakia.

Gas composition and concentrations of the analyzed Croatian samples indicate a thermogenic origin for all of the soil gases, and infer the presence of mature source rocks in the subsurface. Gas concentration and composition anomalies suggest that their origin derives from subsurface micro seepage of both heavy and light oils. Occurrences of C1-C2-C3-C4 (-C5) distributions are most likely due to organic facies differences, maturity, thermogenic and biogenic mixtures as well as alteration processes such as biodegradation and water washing. In Slovakia, anomalous CO2 concentrations on surface are consistent with the presence of a known subsurface CO2 accumulation, hence this approach may also help delineate the risk of high CO2 concentrations.

Multiple control samples were collected at various stations and analyzed in the laboratory by high resolution gas chromatography. Results confirm the reproducibility of the subject soil gas sampling method.

Keywords: surface geochemistry, HC micro seepages, gas chromatography, soil gas anomaly

An Overview of Petroleum Source Rocks of Serbian part of Pannonian Basin

Author : Teslic, Sladjana - sladjana.teslic@nis.eu – NTC NIS-Naftagas
Co Authors : Bogicevic, Goran - goran.bogicevic@nis.eu – NTC NIS-Naftagas
Dulic, Ivan – ivan.dulic@nis.eu - NTC NIS-Naftagas
Trifunčević, Sanja – sanja.trifuncevic@nis.eu - NTC NIS-Naftagas
Galambos, Marina – marina.galambos@nis.eu - NTC NIS-Naftagas

This work presents the summary overview of main source rocks for Serbian part of Pannonian Basin. Based on more than 6.600 geochemical analysis from 579 exploration wells source rocks were determined from various stratigraphic members: Mesosoic (Triassic, Jurassic and Cretaceous) and Cenozoic (Oligomiocene, Badenian, Sarmatian, Pannonian and Pontian). During recent studies, source rocks properties were updated with new measurements of core samples, in order to reevaluate organic richness, kerogen type, thickness and maturity of source rocks. In addition, the main genetic properties of original organic matter were determined by using specific biomarker ratios for source rock extracts, with the GC/MS analysis of saturated and aromatic fractions, in order to better evaluate source rocks properties and establish a correlation with crude oils from production wells.
The high quality source rocks were proven in sediments of the Pannonian, Sarmatian, Badenian and Lower Miocene age, with various kerogen types (dominantly Type II and Type I, also Type II/III and Type III). Average TOC for the Miocene source rocks is in the range 2,1-3,1 % with the maximum value of 14,11%. Generative potential is mainly oil prone, which was confirmed with geochemical biomarkers, showing that origin of organic matter (OM) is mixed – marine and terrestrial precursor biomass, with the domination of marine OM part. The OM was deposited under reducing to sub-oxic conditions.
The evaluation of source rocks from the Mesosoic period was updated. Triassic and Jurassic source rocks are, generally, poor to fair quality with maximum potential of 4,13 mgHC/gRock. There should be mentioned that those Mesozoic source rocks are very scarce investigated, with less than 1% of the total number of analyses..Most samples of Cretaceous source rocks have the best quality among Mesosoic source rocks. They are mostly mature or overmature (peak or late oil window to gas window), with fair, mainly gas-prone potential (based on Rock Eval analysis). The claystone Cretaceous source rocks from old well were investigated using specific biomarker ratios to obtain OM origin and original kerogen Type. It was proven that this source rock was originally oil prone, with the kerogen Type II and mixed, marine and terrestrial OM. The OM was deposited under sub-oxic conditions.
In addition, 1-D, 2-D and 3-D basin modeling was used for the reconstruction of burial and thermal history of the formations.

Keywords: source rocks, kerogen, maturation,,origin, biomarkers, Pannonian Basin, Serbia

3D thermal history modelling of the Black Sea basin

Balázs Takács[1], László Lenkey[1], Marius Tilita[2], Ioan Munteanu[2], Corneliu Dinu[3]
1 Eötvös Loránd University, Department of Geophysics and Space Science, Pazmany Peter setany 1/c, 1117, Budapest, Hungary
2 Repsol Exploración S.A., Mendez Álvaro 44, 28045, Madrid, Spain
3University of Bucharest, Faculty of Geology and Geophysics, Traian Vuia 6, Bucharest, Romania

The central part of the Western Black Sea is characterized by a heat flux less than 30 mW/m2, which is below the typical heat flux of the old oceanic basins, with a slight increase in the range of 30-40 mW/m2 in the Eastern sub-basin. The shelf areas show close to normal continental heat flux values of 50-60 mW/m2. The modelling goal is to replicate these values by simulating sedimentation history and tectonic evolution of the basin.

The Western Black Sea is an extensional basin developed as a result of the southward, Early Cretaceous (125-135Ma) drift of the Pontides domain, from the East European craton. The formation of the Eastern Black Sea sub-basin suggests a later opening which might occur in Late Cretaceous-Eocene (70-40Ma), although a single Early Cretaceous synchronous event is not excluded. Hyper-extension led to the formation of oceanic crust in the central parts of these sub-basins. The whole basin inversion occurred in Late Eocene (35Ma), being related to the continental collision of Pontides - Taurides arc and equivalents.

The basement structure and the sedimentation history were reconstructed using the recent basin-wide 2D seismic surveys - Black Sea SPAN. Up to four sediment layers were interpreted along the seismic sections: 1) Upper Miocene and younger, 2) Lower and Middle Miocene, 3) Oligocene and 4) Paleocene-Eocene layer, along with local delineation of the oceanic crust and Moho discontinuity.

The model is built up of mantle lithosphere, thinned continental or oceanic crust, and the above four sedimentary layers. The thermal parameters of the units were taken from the literature. From the viewpoint of the basin thermal history, the heating of the lithosphere due to rifting is crucial. For simplicity, McKenzie type homogeneous stretching (thinning) of the lithosphere was considered. The thinning factors were assessed by dividing the pre-rift crustal thickness (38 km) with the observed crustal thickness. In case of both sub-basins centers with underlying oceanic crust, a thinning factor of 20 was considered that can replicate “infinite” stretching of the continental crust. The rifting process started at 130 Ma and ended between 100 Ma and 70 Ma. The basin center heat flux at the end of rifting period reached values over 90 mW/m2 in the case of an earlier (100 Ma) termination and 80 mW/m2 in case of a later (70 Ma) termination, both followed by exponential decay of the heat flux.

The results show that in case of earlier termination of rifting (100 Ma) the modelled heat fluxes fit the measured ones both in the basin center and the shelf areas. The low values in both sub-basins centers result from the low heat production in the oceanic crust and the sedimentation cooling effect. The higher heat flux values recorded on the shelf areas derive from the higher heat production in the underlying continental crust. A late termination of rifting (70 Ma) results in higher heat flux in the basin centers (40-55 mW/m2), and achieves a good fit in the shelf areas, but misfits in the shelf slope regions, especially in the western sub-basin.

In general, a good fit to the observed heat flux could be achieved by varying the end of rifting period. The thermal modelling admits asynchronous rifting periods, the process ending earlier in the western sub-basin than the eastern sub-basin.

Angle and architecture of merging slopes: implications on deep-water sediment accumulations

Domonkos, Vági - vagi.domonkos@gmail.com – Department of Physical and Applied Geology, Eötvös Loránd University
Pál, Csicsák –csicsak.pal@gmail.com – Vermillion Energy, Budapest
Gábor Varga – gvarga@shpbv.eu – Oil and Gas Development, Budapest
Imre, Magyar - immagyar@mol.hu – MOL Hungarian Oil and Gas Plc
Orsolya, Sztanó - sztano.orsolya@gmail.com - Department of Physical and Applied Geology, Eötvös Loránd University

Lake Pannon was a giant lake in the Central Paratethys region akin to modern day Caspian Lake and was filled by large volume of sediments causing normal regression during the late Miocene-Early Pliocene. A major constituent of basin fill processes was the progradation of shelf-margin slopes. The Paleo-Danube (PD) transport system supplied sediments form the NW, N and W, from the direction of the Alps and the Western Carpathians. The Paleo-Tisza (PT) system arrived from the NE, having a provenance in the Eastern Carpathians. Other, albeit smaller transport systems were documented from SW and SE directions. Temporal and spatial evolution of slopes were reconstructed by mapping coeval sedimentary packages, i.e. clinoforms. During the latest Miocene (ca. 6.8-5 Ma) the PD slope merged with the slope of the PT and Paleo-Körös (PK). As the slopes prograded towards each other, the deep-water areas between them became narrower, and a successively increasing confinement developed. Sediment dispersal varied according to angles between facing slopes. The junction zones of the slopes are of particular interest of this study.

Deposition and erosion shaped not only the feeder slope, but the opposing one as well. These processes were strongly influenced by the initial basin and slope geometries, sediment input rates and base-level changes. At Study area 1, near the central part of the basin, the slopes intersected at an acute angle at about 6,8 Ma ago. Progradation of the PT slope was halted by a major flooding of the shelf, cutting siliciclastic input for a short period, while the PD slope continuously accreted. As a result, deep-water channels coming from NW were deviated to the S by the updip topography, and sand accumulated at the base of PT slope. The lobes produced pronounced onlaps, generating the most debated stratigraphic boundary in the entire Pannonian basin. At Study area 2, near the southeastern edge of the basin, the PD and PK slopes intersected at an obtuse angle ca. 5 Ma ago. Interfingering of clinoforms shows even progradation, where channel directions were not influenced. At Study area 3 on the Battonya High, PD and PK slopes migrated frontally towards each other. Channels continued towards the opposing slope, where sandy lobes deposited in upstream position. Features pointing to axial transport were not mapped, though “escape” of sand might have occurred. Rate of progradation was markedly higher in PD slope, so the narrowing trough rapidly got filled, finally resulting in a major slope collapse event.

The analysis of stratal architecture between two opposing slopes promotes the understanding of deep-water stratigraphic traps and reservoirs related to slope progradation.

This presentation was supported by MOL Academic Aid Program.

Keywords: Lake Pannon, slope, progradation, stratigraphic trap

Palaeoenvironmental analysis and hydrocarbon source rock potential of Permo-Carboniferous shales below the Eastern Molasse Basin, Austria

Author : \, Hartmut - jaeger@georesources.de – GeoResources STC, Leimen, Germany
Co Author : Reutner, Thomas - reutner@georesources.de – GeoResources STC, Leimen, Germany
Co Author : Wiesmayr, Gerhard - Gerhard.Wiesmayr@rag-austria.at – RAG Exploration & Production GmbH, Vienna, Austria

The Molasse Basin is the Northern Alpine Foreland Basin, developed during the final stage of the Alpine Orogeny. Its complex basin fill is made of Cenozoic, Mesozoic and Palaeozoic sediments on a basement of crystalline rocks of the Bohemian Massif. Below the Tertiary and Mesozoic basin fill locally restricted Permo-Carboniferous rift basins along E-W trending Variscan wrench faults are observed, filled with siliciclastic sediments. These sediments are rarely recorded in wells and little is known about the sedimentary systems and palaeoenvironmental conditions, but also about the hydrocarbon source rock potential and its possible contribution to the hydrocarbon plays of the Molasse Basin.

The current study is focused on optical kerogen analysis of the Permo-Carboniferous strata of the Austrian Molasse Basin in Upper Austria, providing new data on palaeoenvironments and the associated hydrocarbon source rock potential. Optical kerogen analysis studies composition and preservation of organic matter. Beside palaeoenvironmental analysis it provides the specific hydrocarbon generating potential for oil and gas, just as kerogen transformation in the actual setting. Three wells were studied: Well A (unfolded autochthonous Molasse), Well B (marginal imbricated, allochthonous Molasse) and Well C (imbricated, allochthonous Molasse).

Optical Kerogen Analysis showed totally terrestrial dominated organic matter, mainly plant debris, for all Palaeozoic samples. It indicates strongly terrestrial influenced environments, as typical in lacustrine to deltaic settings. No clear indicator for marine input is observed. Regarding the hydrocarbon potential most samples are dominated by unproductive kerogen type IV, followed by gas-prone kerogen type III. Oil-prone kerogen type I & II are only of minor importance. Samples from well A and one sample from well B show much less kerogen type IV, but strongly increased oil-prone kerogen type I & II. Most kerogen (types I - III) is poorly preserved, suggesting intense alteration during transport and deposition. Significant kerogen transformation due to hydrocarbon generation is not observed.

TOC values show a wide range from very poor to very good, but poor TOC content is most common. Due to the high amount of unproductive kerogen type IV in most samples the productive kerogen (net-TOC) is much lower than the measured TOC. The net-TOC gas is poor in most samples, rarely fair to good. The net-TOC oil is poor for all samples, mostly very poor, indicating poor to no oil potential in all samples. Due to the basal to lower gas window maturation in all 3 wells, only the oil-prone part of the kerogen could have produced hydrocarbons, indicating a very poor potential for generating hydrocarbons (oil) in the Palaeozoic of the studied wells.

Keywords: Molasse Basin, kerogen analysis, palaeoenvironment, hydrocarbon source rock potential

Organic maturation and thermal history of the Eastern Molasse Basin, Austria

Author : Jäger, Hartmut - jaeger@georesources.de – GeoResources STC, Leimen, Germany
Co Author : Reutner, Thomas - reutner@georesources.de – GeoResources STC, Leimen, Germany
Co Author : Wiesmayr, Gerhard - Gerhard.Wiesmayr@rag-austria.at – RAG Exploration & Production GmbH, Vienna, Austria

The Molasse Basin is the Northern Alpine Foreland Basin, developed during the final stage of the Alpine Orogeny. Its complex basin fill is made of Cenozoic, Mesozoic and Palaeozoic sediments on a basement of crystalline rocks of the Bohemian Massif. Below the Tertiary and Mesozoic basin fill locally restricted Permo-Carboniferous rift basins along E-W trending Variscan wrench faults are observed, filled with siliciclastic sediments. These sediments are rarely recorded in wells and little is known about it. Thus the hydrocarbon potential and possible contribution of these units to the hydrocarbon plays within the overlying Molasse Basin is strongly underexplored. From few wells in the western Molasse Basin some maturation data are available. It shows a more or less continuous increase in maturation to the depth in one place, but a rapid increase of maturation between the Mesozoic and the Palaeozoic in another, reaching always the dry gas window in the Carboniferous.

Main objective of the current study is the analysis of the maturation of the Permo-Carboniferous graben sediments below the Austrian Molasse Basin in Upper Austria. This study also included samples from the Mesozoic and Tertiary, for a better understanding of the palaeothermal history of the entire Molasse basin. Three wells were studied: Well A (unfolded autochthonous Molasse), Well B (margin of imbricated, allochthonous Molasse) and Well C (deeply within imbricated, allochthonous Molasse). Integrated maturation analysis showed a very good fit between the results from vitrinite reflectance and palynomorph colour analysis. The three major stratigraphic intervals - Tertiary, Mesozoic (Upper Jurassic), Palaeozoic - show specific maturation levels, which are very similar in all 3 wells, despite all differences in the structural setting of the wells. The maturation of the Palaeozoic strata is in the basal to lower gas window, with the maximum maturation in well A. This could be related to deeper ancient burial or/and to the thermal overprint of hydrothermal fluid systems, proposed in this well. The Jurassic strata, only recorded in well A, are within the peak oil window. The maturation of the Tertiary is within the lower oil window. No significant local palaeothermal anomalies have been observed within these major units. The significant differences in maturation between these three major intervals indicate huge hiati in the basin fill of the Molasse basin, which are in a similar range in all three wells. Between the Palaeozoic and the Tertiary about 2,5-3 km of section are missing. About 1-1,5 km of section are missing between the Palaeozoic and the Upper Jurassic in well A. Another 1,5-2 km of section are missing between the Upper Jurassic and the Tertiary strata in this well. Therefore the recent basin fill of the Molasse Basin is very fragmentary with huge gaps in terms of time and eroded thickness.

Due to the basal to lower gas window maturation in the Palaeozoic of all 3 wells, only the oil-prone part of the kerogen of the Palaeozoic strata is available for hydrocarbon generation. This clearly limits the hydrocarbon potential in the studied wells, but in higher mature settings a better hydrocarbon potential could be assumed.

Keywords: Molasse Basin, maturation, thermal history, vitrinite reflectance

Geochemistry of oil in the Terek-Caspian Foredeep (Middle Caspian Basin)

Reinhard F. Sachsenhofer – reinhard.sachsenhofer@unileoben.ac.at – Montanuniversitaet Leoben, Chair Petroleum Geology, Austria
Nurdin Sh. Yandarbiev – yandarbiev@mail.ru – Lomonosov Moscow State University, Petroleum Geology Department, Russia
Yuriy O. Gavrilov - gavrilov@ginras.ru - Geological Institute, Russian Academy of Sciences, Russia
Achim Bechtel – achim.bechtel@unileoben.ac.at - Montanuniversitaet Leoben, Chair Petroleum Geology, Austria
Reinhard Gratzer – reinhard.gratzer@unileoben.ac.at - Montanuniversitaet Leoben, Chair Petroleum Geology, Austria

The Terek-Caspian foredeep is located at the northeastern flank of the Greater Caucasus. It reservoirs some big oil fields, including the giant Starogroznenskoye field, and small amounts of gas condensate and gas (Boote et al., 2018). The Mesozoic and Cenozoic succession includes potential source rocks in Middle Jurassic, Eocene (Kuma Fm.) and Oligo-/Miocene horizons (Maikop Grp.). Main reservoirs occur in shallow middle Miocene sandstones (<1200 m) and deep fractured Upper Cretaceous carbonates (1650-5650 m). Traps are mostly related to the Terek and Sunzha anticlines reflecting disharmonic folding and thrusting on overpressured Maikop and Jurassic salt detachment surfaces.

Biomarker and compound specific isotope data from 21 oil samples ranging in depth from 130 to 5650 m have been determined in the present study to distinguish oil families. Because of advanced oil maturity, not all biomarkers could be determined in deep samples. In addition data from six potential source rocks representing different units within the Maikop Group have been investigated to speculate on the active source rocks

Biodegradation is restricted to shallow Miocene reservoirs. Apart from that, many biomarker ratios (e.g. Ts/Tm, MPI-1) show a clear depth trend reflecting increasing maturity. These data suggest that shallow oils (<2000 m) have been generated from source rocks with relative low maturity (0.7-0.8 %Rc), whereas maturity of deeper oils increases from 0.8 to 1.0 %Rr. Interestingly, measured vitrinite reflectance at 5500 m depth is slightly higher (1.4%Rr).

Whereas most depth trends reflect maturity, observed downward increases in pristane/phytane (1.5-2.8) and diasterane/sterane ratios (0.1-0.5) reflect variations in source rocks facies. All oils have low sulphur contents (DBT/Phen ratio <0.15). Oleanane, a biomarker for Upper Cretaceous or Cenozoic source rocks are present in significant amounts in oils from Miocene reservoirs, but also in many oils from Upper Cretaceous (and Paleogene) reservoirs. The absence of oleanane in some deep oils is probably rather due to high maturity than to original absence.

In all oil samples the carbon isotope ratios of individual n-alkanes decrease with increasing chain length. However, three different patterns can be observed: Some oils show a minor decrease with chain-length (e.g. 2 ‰ between n-C15 and n-C29), others show a much stronger decrease (5 ‰) and a third group shows a strong decrease for short chain n-alkanes, whereas the isotope ratios of long chain n-alkanes remain nearly constant. Mixtures of these three end-members occur as well.

Molecular and isotope data from rock extracts from different units within the Maikop Group show similarities, but not a satisfactory fit, with the data from the oil samples. This suggests that the Maikop Group contributed to the accumulated oils, but that it is not the only active source rock.

Boote, D.R.D, Sachsenhofer, R.F., Tari, G., Arbouille, D., 2018. Petroleum Provinces of the Paratethyan Region. Journal Petroleum Geology, 41, 247-297.

New insights into the configuration of Permo-Carboniferous Grabens in St Gallen, Northern Switzerland and its Implication on Geo-Energy Prospectivity

Eruteya Ovie Emmanuel, Omodeo-Salé Silvia, Guglielmetti Luca, Moscariello Andrea
Department of Earth Sciences, University of Geneva, Switzerland

Ovie.Eruteya@unige.ch

The nature and structural characteristics of most Late Paleozoic basins in the Northern Alpine Foreland related to the Post-Variscan orogeny are typically uncertain as very often poorly constrained. This arises from the complexity of their deep-structure buried by thick Mesozoic and Cenozoic sediments, coupled with the masking effect of the younger tectonic events and the scarcity of boreholes penetrating the entire interval down to the crystalline basement. This study seeks to constrain the configuration of Pre-Mesozoic Grabens in the St Gallen Area, Northern Switzerland and highlight its implication on geo-energy exploration.

To achieve this, we analyzed the recent St. Gallen 3-D seismic dataset integrated with gravity data and borehole analogue data from Weiach-1. Seismic interpretation aided by a robust seismic attribute workflow has established the possibility of Permo-Carboniferous sediments in three graben-like structures that developed within the crystalline basement. The Permo-carboniferous fill has been mapped here as seismic facies with high-reflectivity consisting of predominantly dipping reflectors within some subtle more transparent seismic facies typical of the crystalline basement. These graben consists of (1) Unterlören graben in the northern part trending SSW-NNE (c. 3.8 km x 2.3 km x 3 km), (2) St. Gallen graben in the central part trending SW-NE (4.5 km x 1.5 km x 0.7 km) and (3) an unnamed in the southern part trending SSW-NNE (c. 3.8 km x 2.3 km x 1km), albeit their full extent is limited by the size of the 3-D seismic dataset. However, uncertainties exist on the depth and width of the grabens which are bounded by complex fault systems recording a long history of tectonic deformation including Carboniferous extensional strain, Variscan shortening, possible Mesozoic reactivation under the extensional regime and later Alpine compression.

Our findings reveal the possible presence of hydrocarbon-charged Permo-Carboniferous sediments within this segment of the North Alpine foreland basin. This indicates unexplored Post-Variscan plays with significant implications on geo-energy exploration. Fluid plumbing from these grabens may impede the success of a variety of underground geo-energy projects in the younger basin series, including geothermal exploration and development, geological storage of CO2, and nuclear waste repository.

Modelling of the Petroleum System in the St. Gallen Area: Implication for Geothermal Risk Assessment

Omodeo-Salé, Silvia - silvia.omodeosale@unige.ch – Department of Earth Science, University of Geneva (Switzerland)
Eruteya, Ovie Emmanuel, ovie.eruteya@unige.ch - Department of Earth Science, University of Geneva
Cassola, Teodoro - TCassola@slb.com - Schlumberger GmbH, Aachen (Germany)
Zieger, Laura - laura.zieger@emr.rwth-aachen.de - Institute of Petroleum and Coal, RWTH, Aachen University (Germany)
Adatte, Thierry - thierry.adatte@unil.ch – ISTE, University of Lausanne (Switzerland)
Moscariello, Andrea – andrea.moscariello@unige.ch - Department of Earth Science, University of Geneva (Switzerland)

Usually, geothermal exploration activities in green fields such as the one in St. Gallen (North-East Switzerland) are confined to limited areas in the surroundings of the well to be drilled.The chance to move to production operations are strongly dependant on the success of the first exploration well. However, the presence of hydrocarbons in the area is notorious as a potential risk for geothermal exploration. If not properly predicted, the manifestation of overpressured hydrocarbon fluids (oil and gas) can hinder the drilling operations and the whole geothermal project. This was the case of the St Gallen geothermal GT-1 well in 2013. The occurrence of this unexpected event opened several scientific questions, such as: are hydrocarbon hosted in a deep reservoir in the area or do local faults network promote the plumbing of fluids? Are there in the subsurface source rocks mature enough to generate hydrocarbons? What is the realistic estimate of the volume of oil and gas in place in the area?
The potential for hydrocarbon generation and accumulation in a sedimentary basin is strictly related to the temperature attained by the basin infill over time and the presence of organic matter-rich deposits. The temperatures recorded in the basin are a direct consequence of the tectono-sedimentary evolution of the basin. The extension rate of the crust controls the heat flow in the basin area, as a consequence of the asthenosphere upraises, and the sedimentation rate determines the burial depth. Therefore, in order to estimate the volume of hydrocarbons stocked in the subsoil, the subsidence history of the area is taken into account.
The thermal history of the St. Gallen area was quantitatively simulated using computer-based 3D modelling. In the latter, the petrophysical features of the units forming the basin stratigraphic sequence were integrated, together with the geochemical properties of the potential hydrocarbons source rocks. To validate the modelling results, paleothermal proxies, such as vitrinite reflectance, Tmax and illite crystallinity, were used.
The results performed by this work allow us to estimate the thermal maturation state of the potential source rocks of the area and assess the hypothesis on the hydrocarbons generation, migration timing. Thus, an estimate of the volume of hydrocarbons stored in the area can be provided.

The Rift Sequence Stratigraphy of the Itebej Field (Pannonian Basin, Serbia)

Authors: Ivanišević, Saša - sasa.ivanisevic@nis.eu – NIS Gazpromneft, Novi Sad, Serbia, Radišić, Jelena - jelena.radisic@nis.eu – NIS Gazpromneft, Novi Sad, Serbia, Isić, Ivana - ivana.isic@nis.eu – NIS Gazpromneft, Novi Sad, Serbia, Radivojević, Dejan - dejan.radivojevic@rgf.bg.ac.rs – University of Belgrade, Faculty of Mining and Geology, Department of Regional Geology, Belgrade, Serbia

The exploration area of Itebej field is settled in the vicinity of the eastern edge of the Pannonian Basin (Central Paratethys). The rift sequence stratigraphy interpretation of geological, seismic and well-log data enabled separation of pre-rift, syn-rift and post-rift stages which lead to better understanding of the petroleum system elements in the south of the Neogene Srpska Crnja Depression (Makó Depression in Hungary, Tomnatec Depression in Romania). The analysis included interpretation of three 3D seismic sections and well data of 33 deep wells.

Pre-rift stage is represented by deep-water Late Cretaceous turbidites and Late Jurassic ophiolites (ophiolitic mélange) of the Eastern Vardar Zone. The boundary between the syn-rift depositional sequence and pre-rift stage is marked by unconformity at the bottom of Miocene sediments. The rift initiation system tract was confirmed by several wells which drilled coarse siliciclastic sediments of the Early Badenian age. During the Middle Miocene after the early syn-rift stage, a “wide-rift” stage (Tari et al., 1999) marked by marine transgression began. All wells at the Itebej structure drilled through the rift climax system tract sediments which include reef limestones, sandy limestones (rarely) and coarse carbonate sandstones deposited during the Early Badenian Age. Above these shallow marine sediments, the Early Badenian pelagic deeper-water sediments with marls, sandy marls and marly limestones were deposited. The immediate post-rift system tract sediments represented by the Lake Pannon deep-water hemipelagic marls were deposit during the Pannonian sensu lato.

The hemipelagic marls deposited in the Srpska Crnja Depression are the main source rock for Itebej field, while the source rock potential of the Badenian sediments is significantly lower. The reservoir rocks of the Itebej structure are syn-rift reef complex sediments and pre-rift deep-water turbidites. The syn-rift carbonate reservoir rocks have high-quality petrophysical properties with commercial quantities of heavy to heavy medium paraffin-base crude oil. The seal rock are deep-water syn-rift pelagic sediments and hemipelagic post-rift marls of the Lake Pannon.
Keywords: Central Paratethys, Itebej field, rift sequence stratigraphy, reef sediments, petroleum system

References

Tari, G., P. Dovenyi, I. Dunkl, F. Horvath, L. Lenkey, M. Ștefănescu, P. Szafian, and T. Toth, 1999. Lithospheric structure of the Pannonian basin derived from seismic, gravity and geothermal data, in The Mediterranean Basins: extension within the Alpine Orogen, edited by B. Durand, L. Jolivet, F. Horvath and M. Serrane, pp. 215-250, Geol. Soc. London Spec. Publ. 156.

The study of the oligocene electrofacieses in the Paratethys region

Author: Cristea Dragos - dragos.cristea89@icloud.com – Oil and Gas University of Ploiesti, Romania

The identification of lithofacies relies on core data analysis which can be expensive and time consuming as against the electrofacies which are straight forward and inexpensive. To date, challenges of interpreting as well as correlating well log data has been on the increase especially when it involves numerous wellbore that manual analysis is almost impossible.

An accurate and proper understanding of the hydrocarbon reservoir requires a comprehensive study of the sedimentary and diagenetic characteristics of reservoir rocks. Integration of different geological and petrophysical studies has an important role in identification of production zones and main factors controlling the reservoir quality. Well logs have the advantage, over cores, of providing a continous record over the entire well and can be obtained in conditions where coring is impossible. Therefore well logs data can give a good lithologic descriptions of formations.

This paper investigates the possibilities for an automatic stratigraphic interpretation of a Kliwa Sandstone reservoir in the Paratethys region in Romania through statistical pattern recognition and rule-based method. The idea involves seeking high density clusters in the multivariate space log data, in order to define classes of similar log responses. A hierarchical clustering algorithm was implemented in each of the wellbores and these clusters classifie the wells into four classes that represent the lithologic information of the wells. These classes known as electrofacies are calibrated using a developed decision rules which identify four lithologies, Sandstone, Argillaceous Sandstone, Sandy Shale and Shale in the well logs data. These can form the basis of correlation to generate a subsurface model.

Thus, separation of reservoir facies based on available logs known as log facies or electrofacies, can be used as a useful, practical and economical procedure in this regarde. In addition, study of the recognized electrofacies from petrophysical point of view and in relation to hydraulic flow units, provides a suitable understanding of the reservoir properties and production zones.
Pattern recognition methods are used to identify the patterns of the wireline log reading from wellbore. This paper explores the opportunity of automating the interpretation and analysis of well log data of gamma ray, neutron and density logs using a statistical pattern recognition approach.

The objective of this paper was to use the computer software algorithm which similarly stores log curve shape information for various lithologies, and interprets new data by comparing the known shapes to unknown data. The interpretation algorithms were tested on logs from 3 wells drilled in the Runcu-Bustenari region of the Moesian Platform. The classifier produced the best results for this homogeneous clastic lithology.

In conclusion, advances in computer hardware technology now make it possible for many of these interpretation techniques to be performed on an inexpensive, desktop computer. The results showed that cluster analysis is a precise, rapid, and cost-effective method for zoning reservoirs and determining electrofacies in hydrocarbon reservoirs.

Organic-rich turbidites in the Upper Cretaceous of the Magura Basin (Outer Carpathians) – palaeontological and lithological record from the Świątkowa Member of the Ropianka Formation

Waśkowska Anna1, Uchman Alfred2, Starzec Krzysztof1, Golonka Jan1, Machowski Grzegorz1, Pstrucha Ewa1.

1AGH University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, A. Mickiewicza Av. 30, 30-059 Kraków, Poland, corresponding author e-mail: waskowsk@agh.edu.pl.
2 Jagiellonian University, Institute of Geological Sciences, Gronostajowa 3a, 30-387 Kraków, Poland.

In the Outer Carpathian basins, sedimentation of organic-rich deposits took place mainly in the Silesian domain, much less in the more southern Magura domain, mostly during Early Cretaceous, Late Cretaceous–Early Paleocene and the Oligocene times. In the northern part of the Magura domain (Siary Zone), this type of sedimentation is represented by the Świątkowa Member (Late Cretaceous–Early Paleocene) of the Ropianka Formation. The Świątkowa Member is 300 m thick and composed of thin- and medium-bedded turbiditic sandstones and subordinate marls interbedded with mudstone shales. In some segments of the Ropica Górna bridge section, medium-bedded turbiditic, organic rich shales prevail. They are Late Cretaceous in age. Their individual beds show recurrent lithology, TOC content and occurrences of benthic foraminifers, which have been observed in there intervals, from the base to the top. Interval A refers to the basal, 3 cm-thick portion of the turbidites, which is built of greenish-gray, hard calcareous mudstone with mica flakes and small amount of the sand grains. Its TOC content ranges from 0.5% to 1%. Benthic foraminifera are moderately diverse and generally moderately abundant. Only tubular forms are abundant. Some of them are pyritized. Interval B embraces the middle lower up to lowermost middle part of a single turbidite, which is built of: heavy gray, hard calcareous mudstone. Its TOC is above 1%. Benthic foraminifera are not numerous, very poorly diverse agglutinated taxa, but with abundant tubular forms, mostly pyritized. Interval C refers to the uppermost of the bed (the upper half of the turbidite). It is composed of soft and plastic green calcareous mudstone with darker spots. TOC content is below 0.5%. Benthic foraminifera are numerous and taxonomically diverse agglutinated taxa, with relatively high number of Saccamminidae and a distinctly lower number of tubular forms, which are not pyritized.

Sediments of the intervals A and B have been redeposited from shallower parts of the Magura Basin. That significant amount of the organic matter suggests that the currents transported material from the oxygen minimum zone into basinal parts. Organic matter accumulated mostly in the interval B, probably because of hydraulic sorting.

The interval C represents mostly the background, foremost pelagic sediments of the basinal part, which have been deposited under oxic conditions. This caused much lower accumulation of organic matter and conditioned the higher diversity of the benthic foraminifera. The oxic conditions enable colonization of the sediments by the burrowing macrobenthos, which is represented by the trace fossils Phycosiphon incertum, Planolites, Thalassinoides, Scolicia, Zoophycos, Nereites irregularis, Mammilichnis, Chondrites, and ?Helminthopsis. Bioturbation caused that sediments of the interval C is partly mixed with sediments of the intervals A and B. The oxic conditions enabled also an occurrence of inceramid bivalves.

Acknowledgements. This research has been financially supported by National Centre for Research and Development grants no. BG2/ShaleCarp/14 and Statutory funds no. 11.11.140.005, 11.11.140.176, Faculty of Geology, Geophysics and Environmental Protection, AGH UST. A.U. was additionally supported by the Jagiellonian University (DS funds).

Pleistocene Caspian sea-level changes: onshore reconstruction of the Kura Basin coastline evolution

Author : Jorissen, Elisabeth L. - e.l.jorissen@uu.nl - Palaeomagnetic Laboratory 'Fort Hoofddijk', Faculty of Geosciences, Utrecht University, Budapestlaan 17, 3584 CD, Utrecht, The Netherlands
Co Author : Abels, Hemmo A. - H.A.Abels@tudelft.nl - Department of Geosciences and Engineering, Delft University of Technology, Stevinweg 1, 2628 CN, Delft, The Netherlands; Wesselingh, Frank P. - Frank.Wesselingh@naturalis.nl - Naturalis Biodiversity Center, P.O. Box 9517, 2300 RA Leiden, The Netherlands; Aghayeva, Vusala - vagayeva1@gmail.com - Institute of Geography, Azerbaijan National Academy of Science, Huseyn Javid Avenue 151, AZ1143, Baku, Azerbaijan; Aliyeva, Elmira - e_aliyeva@yahoo.com - Department of Sedimentology and Paleogeography, Geological Institute of Azerbaijan (GIA), Huseyn Javid Avenue 29A, AZ1143, Baku, Azerbaijan; Krijgsman, Wout - W.Krijgsman@uu.nl - Palaeomagnetic Laboratory 'Fort Hoofddijk', Faculty of Geosciences, Utrecht University, Budapestlaan 17, 3584 CD, Utrecht, The Netherlands

The Caspian Sea witnessed drastic sea-level changes over the last million years, with severe impacts on environmental evolution, driving anthropogenic and biotic migration. This largest isolated basin in the world seems to be overly sensitive to sea-level variations, due to restricted connection with the marine realm. Studying historical records around the Caspian Basin might be the key to better apprehend the complexity of sea-level oscillations recorded in this isolated basin. Our aim is to discuss the amplitude, frequency and drivers of Caspian sea-level oscillations.

The Hajigabul section records sediments deposited on the northern margin of the Kura Basin, a former embayment of the South Caspian Basin. The 2500m-thick well-exposed and stratigraphically continuous succession documents the entire Plio-Pleistocene interval (Productive Serie, Akchagylian, Apsheronian, Bakunian and Khazarian regional stages). If the Akchagylian, Bakunian and Khazarian highlight long term high stands, the Productive Serie and Apsheronian are marked by lower stands. The Apsheronian stage represents the most spectacular time interval, as it is marked by numerous fully recorded regressive sequences. Sequences are regressing from offshore up to backshore, lagoon and paleosol deposits, established by detailed sedimentological and paleontological observations. A sea-level curve is constructed based on estimated water-depths for each facies associations. Cyclostratigraphical analyses are performed to assess the frequency of sea-level oscillations. The climatic impact on sea-level variations is tested by measuring stable oxygen isotopes on brackish water ostracods.

This study proposes well-documented stratigraphic and isotopic models for the Pleistocene Caspian Sea. This research constitutes a first step towards a better comprehension of the amplitude, recurrence and forcing mechanisms of Caspian sea-level changes. This complex isolated sea appears to be ruled by drivers specific to the basin, which differ from forcing mechanisms registered in the open ocean. Models developed in this study may form good analogues for other (semi-)isolated basins located world-wise.

Keywords: Paratethys, isolated basin, beach deposits, coastal evolution, regressive sequences, sea-level changes, Milankovitch cycles

In search of Oligocene Oil Reservoirs in the autochthonous Molasse in Upper Austria: Image Log Analysis of deep water clastics

Exner, U (1)., Scheucher, L. (1), Miersemann, U. (1), Kästenbauer, M. (1), Piani, E. (1,2) and Troiss, W. (1)
(1) RAG Exploration & Production, Schwarzenbergplatz 16, 1015 Wien
(2) now at: RDG E&P GmbH, Schwarzenbergplatz 16, 1015 Wien

The majority of the oil fields in Upper Austria are located in Eocene and Cenomanian sandstones, where shallow and transitional marine sediments deposited during marine transgressions host numerous layers with good reservoir properties. However, some oil accumulations were encountered in deep marine reservoirs of the Zupfing Formation of Oligocene age. In contrast to the well-studied Eocene sediments (see Scheucher et al., this conference), the depositional mechanisms, transport directions and distribution of potential reservoir rocks within the Zupfing Fm. is poorly constrained. On the other hand, the depositional mechanisms of reservoir rocks in the Egerian Upper Puchkirchen Formation have been studied intensively in the past decades. In the Upper Puchkirchen Formation, the presence of a large deep-marine channel belt, parallel to the axis of the basin, can clearly be seen on 3D seismic data and the existence of reservoir rocks has been proven by numerous successful wells. This channel belt was sourced by deltaic and shallow marine deposits to the W, in the Bavarian part of the Molasse Basin. However, it remains unclear if the conglomerate/sandstone layers of the underlying Zupfing Fm. were deposited in a similar environment as the Upper Puchkirchen Fm.

Previous attempts to define reservoir quality and distribution by extraction of seismic attributes were not successful, as seismic data cannot resolve thin reservoir packages at the given depth > 3000 m below the Earth's surface. Additionally, reservoir quality in the Zupfing Fm. is not entirely controlled by depositional processes, but also by the presence of various types of carbonate cement. Thus, a direct prediction of reservoir quality cannot be inferred solely from the distribution of sandstones and conglomerates.

This study aims to combine all available log and core data from selected wells, which encountered coarse clastics in the Zupfing Formation. Focusing on the re-interpretation of vintage borehole image logs, a catalogue of image lithofacies was established and, in addition to high-resolution dip data, previously unrecognized sedimentary structures and units were identified, e.g. slump folds, erosional surfaces or graded beds. Moreover, detailed information on the spatial distribution and degree of carbonate cementation was obtained from recently acquired, high-quality FMI logs.

With this new database, a new depositional model was established, in order to derive transport directions and improve the understanding of the distribution of potential reservoir rocks.

Keywords: Northern Alpine Foreland Basin, deep-water depostis, Zupfing Fm., slump folding, FMI

Biostratigraphy and paeloegeography of the Slovenj Gradec Basin (Slovenia, Central Paratethys)

Ćorić, Stjepan - stjepan.coric@geologie.ac.at - Geologische Bundesanstalt, Wien, Austria
Mirka Trajanova - Mirka.Trajanova@GEO-ZS.SI - Gelological Survey of Slovenia, Ljubljana, Slovenia
Kristina Ivančič Kristina.Ivancic@GEO-ZS.SI - Gelological Survey of Slovenia, Ljubljana, Slovenia

The Slovenj Gradec Basin is situated in the northern Slovenia at the margin of the Pannonian Basin System. The evolution of this basin is connected with the global 3rd order cycles. The reconstruction of the Slovenj Gardec basins paleogeographic evolution is based on mapping (1:5.000), section recording, calcareous nannofossil biostratigraphy, petrography, and tectonic evolution of the wider neighbouring areas, particularly the Pohorje tectonic block. Additionally, lithological column of the borehole MD-1/05 was interpreted on the base of the drilling cuttings petrography, and biostratigraphy determined on the base of calcareous nannofossil analyses.

Sedimentation started in terrestrial environment at the transition of the Ottnangian to the Karpatian with deposition of talus and alluvial fan sediments and terminated in the late Early Badenian. During this period, three transgression-regression cycles can be traced, corresponding to the TB 2.2, TB 2.3 and TB 2.4 cycles.

At the highstand system tract in the Early Badenian, the sea flooded the entire Slovenj Gradec Basin, and obtained connection with the Mediterranean. The first transgression of the cycle TB 2.2. can be correlated to NN4 Zone (co-occurrence of Sphenolithus heteromorphus and Helicosphaera ampliaperta). Regression stage at the Karpatian/Badenian boundary is correlated to the Bur5/Lan1, during which the sedimentation took place in terrestrial environment. The second transgression can be correlated to TB 2.3 cycle (upper NN4). This Early Badenian transgression initiated in transitional environment with simultaneous deposition of lagoonal and deltaic sediments. The second Badenian transgression can be correlated to the global sea-level rise and corresponds to TB 2.4 transgression cycle. Sediments contain rich nannofossil assemblages with Helicosphaera waltrans and can be attributed to the lower NN5 Zone. At the end of the Early Badenian, the Slovenj Gradec Basin connection with the Central Paratethys was closed. Deposition terminated with fresh-water coal, marking basins' dying-out.

After the late Early Badenian to Plio-Quaternary, the area of the Slovenj Gradec Basin was exposed to broadly SSW-NNE compression and erosion. Based on investigations of calcareous nannofossils, Mediterranean zones MNN4a, MNN4b and MNN5a were identified. The connection with the Mediterranean region was established during NN4 (MNN4a) and probably interrupted during regression stages between Karpatian/Early Badenian and NN4 Early Badenian/NN5 Early Badenian. The connection was finally interrupted in upper NN5.

The sediments reflect proximity of the hinterland and evolution from fluvial/limnic, via transitional to marine environment in advanced stages of transgressions. No younger sediments were recorded in the basin, which indicates cessation of sedimentation in the late Early Badenian and subsequent erosion prior to the onset of the Pliocene-Quaternary fluvial sedimentation.

Keywords: Keywords: Slovenj Gradec Basin, Central Paratethys, Pannonian Basin System, Miocene, biostratigraphy, paleogeography, sequence stratigraphy

Additionaly calcareous nannoplankton bioevents of the Central Paratethys during Miocene

Ćorić, Stjepan - stjepan.coric@geologie.ac.at - Geologische Bundesanstalt, Wien, Austria
Eva Halásová - evahalasova21@gmail.com - Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
Michal Jamrich - mjamrich@gmail.com - Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia

Except for the standard calcareous nannofossil zonation of Martini (1971), also the regional zonations by Andrejeva-Grigorovič & Halásová (2001) and Mărunteanu (1999) can be applied for the subdivision of Neogene sediments in the Central Paratethys. However, the ongoing investigation of upper Oligocene and Miocene sediments from the Alpine-Carpathian Foredeep, Vienna Basin, Styrian Basin, Lavanttal Basin, and Danube Basin revealed additional events, that can be used for a more precise biostratigraphic subdivision and correlations within the Central Paratethys: (1) Based on the FO of Helicosphaera carteri in the uppermost NP25 Zone, position of the Oligocene/Miocene boundary can be identified within the Egerian interval. Additionally, uppermost Oligocene sediments contain important biostratigraphic species Pontosphaera rothii and P. dessueta (NP24/NP25 zones). (2) Pontosphaera ebelsbergii with a short stratigraphic range was described from the lowermost Miocene (NN1 Zone). (3) FO Helicosphaera ampliaperta is defined at 20.4 Ma, Burdigalian. This easily recognizable event within the NN2 Zone can be used for the subdivision of Eggenburgian into the upper and lower part, and the correlation with the Mediterranean (4) Lehotayová (1975) described Reticulofenestra excavata from Eggenburgian sediments from central Slovakia (borehole ČČ-3; Čausa near Handlová). This placolith is present in Eggenburgian and Ottnangian sediments from the Alpine-Carpathian Foredeep and in the Waschberg Unit. R. excavata has a short stratigraphic range (Eggenburgian to Karpatian) and can be successfully used for a precise subdivision of the lower Miocene sediments. (4.1) Short acme event of Helicosphaera ampliaperta accompanied by absence/decrease of Sphenolithus heteromorphus allow us to determine NN4b Zone (sensu Grigorovič et al. 2001) from Bukovec, Cerová Lieskové and Radošovce samples, Slovak part of VB and in Malý Krtíš, DB. (5) LO of Helicosphaera waltrans was successfully used for the subdivision of Badenian deposits. Hitherto, it has been observed only within the NN5 Zone. Co-occurrence of H. waltrans and H. ampliaperta (NN4 Zone) was found in the Molasse Basin (borehole Langenlois). NN5a and NN5b zones (sensu Grigorovič et al. 2001) were found in the Slovak part of VB (Gajary 23, Zohor-1 well). NN5a was also identified in DB (Čebovce outcrop) and NN5b, NN5c in Trakovice-1, DB. (6) Late Badenian regional correlated horizon with common Calcidiscus premacintyrei, Sphenolithus abies, abundant discoasters is detected in DB boreholes (Báhoň-1, Bučany-2, Trakovice, Nová Vieska-21, Pozba-3, Ratkovce) and VB (Stupava and Malacky boreholes). (6.1) A short bloom of Calcidiscus pataecus characterizes Badenian/Sarmatian boundary. This event can be applied for detecting this boundary and for the correlation of the Central Paratethys basins. Such bloom was not described from Slovak basins yet, only occasional presence. Within Danube Basin the Badenian/Sarmatian transition NN6 Zone was assigned based on high numbers of Calcidiscus tropicus, Calcidiscus macintyrei, Braarudosphaera bigelowii parvula, Sphenolithus abies (borehole ŠVM-1 Tajná). (7) Praenoelaerhabdus banatensis, an endemic species important for the subdivision of the upper Miocene (Pannonian) of the Pannonian Basin (ŠVM-1), was identified from VB as well. Pannonian endemic species Reticulofenestra tegulata is described in (Danube Basin, borehole Zlaté Moravce-1). Isolithus semenenko (borehole Modrany-2, Vráble-1), Zelený Háj-1, is also described from the Eisenstadt-Sopron Basin; Lackendorf, Piusz-puszta). We need to point out, a further investigation of the studied area is essential and ongoing so that we can correlate relation of the Central Paratethys areas more precisely considering a diachronous and lateral shift.

Keywords: calcareous nannofossils, Central Paratethys, Miocene, biostratigraphy

Tracing the late Miocene evolution of the NW Pannonian Basin using the authigenic 10Be/9Be dating and biostratigraphy: Broader Eisenstadt-Sopron Basin case study

Šujan, Michal, Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
Tari, Gabor, Exploration and Production GmbH, Vienna, Austria
Braucher, Régis Aix-Marseille Université, CEREGE, Aix-en-Provence, France
Kováč, Michal, Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
Beidinger, Andreas, Exploration and Production GmbH, Vienna, Austria
Jamrich, Michal - Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
Ruman, Andrej - Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
Kováčová, Marianna - Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia
Hudáčková, Natália - Department of Geology and Paleontology, Comenius University in Bratislava, Slovakia

Upper Cenozoic epicontinental sequences of the Central Paratethys often have a poorly constrained geochronological framework due to highly endemic fauna, lack of datable volcanic ashes and discontinuous depositional record unsuitable for magnetostratigraphy. As a novel geochronological tool, we used the authigenic 10Be/9Be dating method, which is able to date sedimentation of clay particles in sediments. The method is based on the ratio of 10Be produced by cosmic rays in the atmosphere (analogous to 14C) and of 9Be derived by chemical weathering from eroded rock sequences. Both isotopes adsorb to the surface of clay minerals in the water column and their ratio decreases only due to decay of the 10Be, providing a chemically closed system. The major uncertainity in the applicability of this method is the assumption of the initial 10Be/9Be ratio, which varies mainly with sedimentary environment and drainage basin lithology.

The authigenic 10Be/9Be dating method was applied in the NW Pannonian, as a pilot study, to three outcrops of the Upper Miocene succession of the broader Eisenstadt-Sopron Basin of Austria and Hungary, intergrated with biostratigraphy using nannoplankton, foraminifera and palynology. Age calculations followed the same initial authigenic 10Be/9Be ratios as were defined in Slovakian part of the NW Pannonian Basin recently. The outcrop at Piuszpuszta revealed the presence of Paratethyan Sarmatian foraminifera in its lower part, and only a few metres above appeared nannoplankton correlative to the NN9 zone, yielding mean weighted 10Be/9Be age of 10.2 ± 0.6 Ma. Based on the obtained data it is expected, that the outcrop recorded two distinct floodings of the Sarmatian and early Pannonian separated by a period of non-deposition. The second outcrop of Lackendorf represents a Pannonian prodelta to delta foreset succession, also within the NN9 nannoplankton zone, but with a mean weighted 10Be/9Be age of 8.75 ± 0.25 Ma. This sequence represents the regressive part of the Lake Pannon succession. The third sampled locality at Nikitsch has a Pannonian alluvial facies and the 10Be/9Be ages range between ca. 7.75 and 6.0 Ma. Based on our results, the age-dated units in the three outcrops correspond to the Kálla/Nemčiňany, Beladice/ Újfalu and Volkovce/Zagyva Formations, respectively, as defined recently in the adjacent Danube Basin of the NW Pannonian Basin. The Slovak Research and Development Agency supported the research under the contracts Nos. APVV-14-0118, APVV-15-0575, APVV-16-0121 and SK-AT-2017-0010.

Keywords: geochronology, Pannonian Basin System, cosmogenic nuclides, Lake Pannon, terrestrial facies, lacustrine facies

Late Miocene variation of accommodation in the Drava Trough: stratigraphic forward modeling and field observations

Kovács, Ádám – kovacs.adam13@gmail.com – Department of Physical and Applied Geology, Eötvös Loránd University, Budapest, Hungary
Špelić, Marko – mspelic@hgi-cgs.hr – Croatian Geological Survey, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb
Balázs, Attila – balatt@gmail.com – Department of Sciences, Università degli Studi Roma Tre, Rome, Italy
Magyar, Imre – immagyar@mol.hu - MTA-MTM-ELTE Research Group for Paleontology Budapest, Hungary
Sztanó, Orsolya – sztano@caesar.elte.hu - Department of Physical and Applied Geology, Eötvös Loránd University, Budapest, Hungary

This study focuses on the so-called Pa(n)-4 sequence boundary or intra-Messinian unconformity and its appearance in the Drava Trough. A surface with similar geometric relations, i.e. folded/tilted lacustrine beds overlain by onlaps, can be observed in many places over the Pannonian Basin (PB). The regional nature of this surface led to the conclusion that it can be correlated basin-wide and it is a result of a major lake-level drop related to the Messinian Salinity Crisis (MSC) even though the Lake Pannon had no direct connection to the Mediterranian Sea. In contrast others argue, studying this feature in the eastern part of the PB, that a local interplay of structural events and the superposition of two different sediment feeder systems may have caused the observed geometry. There is still no consensus about the nature or the age of this surface. Prior to the events leading to the formation of this unconformity a significant flooding event took place. Stratal stacking is remarkably different in the Drava Trough compared to the one of the Eastern PB, though large thickness of shallow-water deposits is a common feature.

The main goal of this study is to analyze factors controlling stratal geometries and to understand what change of the depositional environments occurred in relation with the above described events. The DionisosFlow stratigraphic modeling software was used constrained by seismic stratigraphy to reveal interactions of controlling factors. The extent of the Pa(n)-4 was traced in 2D seismic sections from the Mecsek Mts. (SW Hungary) to the Papuk Mts. (N Croatia). The model takes into account numerous factors such as sediment supply, tectonic uplift or subsidence rate. With the backstripping method three different scenarios were modeled: a) structural, b) climatic and c) sediment-supply controlled versions. By modifying input parameters, different effects became dominant and the variations in stratal geometries were analyzed. In addition, field observations from the margin of the Papuk Mts. helped to identify similar events in outcrops. A Late Miocene angular unconformity could be studied within the lacustrine succession, between profundal calcareous marls and shallow-water deltaic sands and clays.

The hypothesis was tested favoring basin inversion and other factors rather than a major lake-level fall causing the prominent unconformity, with the onlap geometry. Results of the modeling are relevant to the expression of the MSC in the Pannonian Basin.

This presentation was supported by MOL Academic Aid Program and NKFIH 116618.

Keywords: DionisosFlow, intra-Messinian unconformity, Lake Pannon, basin inversion

A key section for the Early Pannonian (Late Miocene) of the Transylvanian Basin (Romania): integrated stratigraphic results from the Guşteriţa clay pit

Botka, Dániel - botkadani@gmail.com – Department of Palaeontology, ELTE
Csoma, Vivien - csoma.vivien7@gmail.com – Department of Palaeontology, ELTE
Šujan, Michal - miso@equis.sk – Department of Geology and Paleontology, Comenius University
Braucher, Régis - braucher@cerege.fr – CNRS-IRD-Collège de France, CEREGE, Aix-Marseille Université
Sant, Karin - karin.sant@gmail.com – Paleomagnetic Laboratory Fort Hoofddijk, Utrecht University
Ćorić, Stjepan - stjepan.coric@geologie.ac.at – Department of Sedimentary Geology, Geological Survey of Austria
Bakrač, Koraljka - kbakrac@hgi-cgs.hr – Department of Geology, Croatian Geological Survey
Krizmanić, Krešimir - kresimir.krizmanic@ina.hr – INA Plc.
Bartha, István Róbert - istir@caesar.elte.hu – Department of Physical and Applied Geology, ELTE
Silye, Lóránd - lorand.silye@ubbcluj.ro – Department of Geology, Babeș-Bolyai University
Magyar, Imre - immagyar@mol.hu – MTA-MTM-ELTE Research Group for Paleontology; MOL Plc.

The Transylvanian Basin (TB), enclosed between the Eastern and Southern Carpathians and the Apuseni Mts. in Romania, accommodates a several-hundred-meter thick Upper Miocene (Pannonian) sedimentary sequence. Data on its fossils are few and scattered in the literature, consequently its biochronostratigraphic assessment implies much uncertainty. The magnetostratigraphic correlation of some recent polarity measurements partly remained disputable. Radiometric age measurements have never been published from these formations. In order to improve the stratigraphic resolution and the reliability of correlations in the Pannonian of the TB, we investigated 17 outcrops of deep-water formations across the TB. The largest and one of the most fossiliferous outcrops is Guşteriţa (today part of Sibiu), therefore we regard it a reference section for the entire TB. The deep-water Pannonian marl, outcropping in ~55 m thickness in the clay pit of Guşteriţa, has been mined there for more than hundred years, and consists of grey, laminated and massive silty marl layers and thin, very fine, cross-laminated sand intercalations. We studied four sections within the clay pit. In October 2015, macrofossils and marl samples for authigenic 10Be/9Be isotopic measurements were collected from the lower, middle, and upper parts of the mine (Guşteriţa 1, 2, and 3). Later, in June 2017, the uppermost 25 metres of the quarry (Guşteriţa 4) was sampled for macro- and microfossils, and a detailed magnetostratigraphic investigation was carried out as well. All the four studied sections can be assigned into the Undulotheca rotundata mollusc lineage subzone of the C. banatica mollusc assemblage zone (~11–10.2 Ma) and into the Hemicytheria tenuistriata? and Propontoniella candeo ostracod biozones. According to the palynological and calcareous nannoplankton studies, the Guşteriţa 4 section belongs to the Spiniferites bentorii oblongus (~11.3–10.8 Ma) and the Pontiadinium pecsvaradense (~10.8–10.6 Ma) organic-walled microplankton biozones. All samples from the Guşteriţa 3 and 4 profiles contain endemic Pannonian calcareous nannofossils represented by the species Isolithus semenenko, I. pavelici, Noelaerhabdus jerkovici, and Praenoelaerhabdus banatensis. Blooms of ascidian spicules (Perforocalcinella fusiformis) in some of the samples were observed. Samples also contain calcareous nanno- and organic-walled microfossils redeposited mostly from the Middle Miocene. 3 samples were analysed for authigenic 10Be/9Be isotopic measurements. The calculated age data provided a weighted mean value of 10.84 ± 0.4 Ma. Magnetostratigraphic samples showed normal polarity for the entire Guşteriţa 4 section, therefore, taking into consideration the biostratigraphic data, we correlate it with the C5n.2n magnetic chron (11.056–9.984 Ma, ATNTS2012).

(Funded by the Hungarian National Research, Development and Innovation Office NKFIH – 116618).

Keywords: chronostratigraphy, biostratigraphy, magnetostratigraphy, authigenic 10Be/9Be isotopic dating

Structural development of south Caspian deep structures

Dr. Arzu Javadova
Caspian consulting service company, Burnaby, Canada, www.caspiancsc.com, arzu.javadova@caspiancsc.com

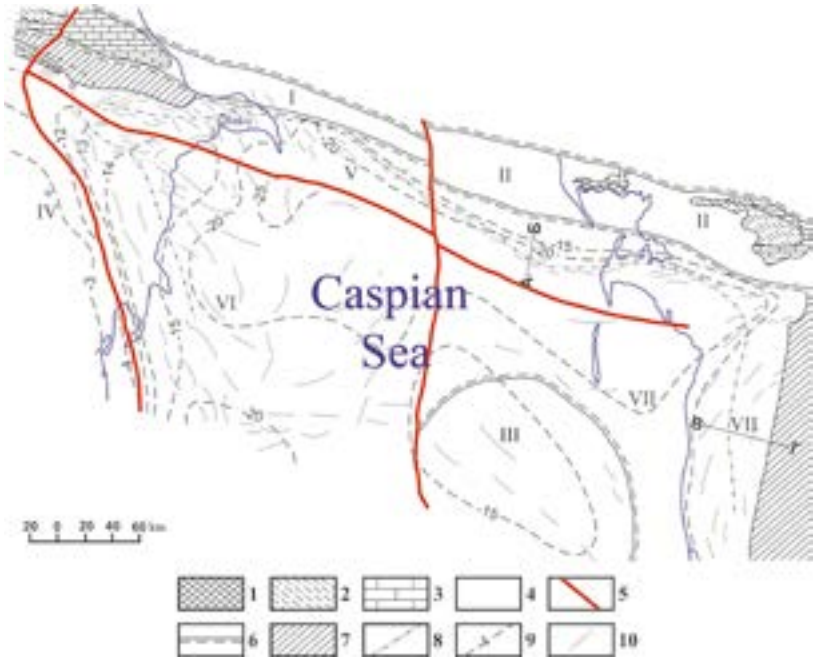
In recent years, the search for oil and gas fields in the south Caspian basin has been one of the key activities of upstream companies. The high oil and gas exploration prospect of the basin is due to the large presence of subsidence with a significant thickness of sediments, in which there are reservoir rocks, rocks seals and source rocks. Prime focus was to investigate the structural development of the some deep-water perspective structures of the south Caspian basin over the time. Prime focus was to investigate the structural development of the five structures based on isopach and paleo-structure maps for Top Pereryva formation of Middle Pliocene Productive series. All structures started forming during Akchagyl period. Giant gas field Shah Deniz and Nakhchivan structure being most prominent. Recently discovered Absheron and Umid -Babek structures were slightly less pronounced at this stage. Structural growth continued throughout late Pliocene and Pleistocene. Zafar-Mashal structure was formed slightly later, primarily during Pleistocene. Structures at Top Pereryva formation level were present accordingly. Absheron discovery bears a relatively high risk of not being closed towards north in up-dip direction. Nakhchivan structure bears a similar risk towards north-west, however not as clear due to data limitations. Shah Deniz and Umid-Babek fields are regarded similar with respect to their structural history, whereas Shah Deniz overall is more pronounced. Zafar-Mashal prospect overall forms a structure only during Pleistocene. Previous drilling results showed that none of the wells revealed direct HC presence in the Pereriva formation reservoirs. Recent successful exploration result showed that all these fields and structures are large with potentially multli-layer productive reservoirs and therefore contain significant volumes of HC.

Geodynamic mechanisms of formation of the Black and Caspian sea structure

V.Yu. Kerimov, R.N. Mustaev, U.S. Serikova, K.I. Dantsova
Russian State Geological Prospecting University

A distinctive feature of the Caspian-Black Sea region is the significant activity of various geodynamic mechanisms. They play a decisive role in the manifestation of complex geo-fluid dynamic processes. The determining factor in the formation of regularities of transformations, transport and the formation of some self-organizing structure with characteristic features of the spatial variability of natural fields (temperature, pressure, density, etc.) is the differentiation of fluid spheres according to the intensity of renewal. In an optimal way, in the sedimentary column, those reactions are supported (from among the possible ones), the characteristic velocities of which are consistent with the flow rate of the substance in drains systems. The transformation process itself occurs when particles collide (molecules, radicals, ionic complexes, etc.). This means that in the zone of substance transformation both the convective and diffusion components of the flow must be commensurate, that is, the main zones of the most intense chemical transformations in the underground environment are diffusion boundary layers of convective zone-waveguides and adjacent high-gradient areas of diffusion zones.

Structural scheme of the South Caspian depression



1 - Paleozoic; 2 - lower and middle Jurassic; 3 - Upper Jurassic and Cretaceous; 4 - Cenozoic sediment complex; 5 - faults determining the block structure of the consolidated crust; 6 - structural boundaries of the axial zones of the folded structure of the Greater Caucasus and the uplift of Kuba-Dag-Big Balkhan; 7 - regional tectonic covers; 8 - axes of regional minima of gravity; 9 - iso-gypsum relief of the surface of the consolidated crust; 10 - anticlinal structures in the sedimentary cover.

As a result of the active manifestation of geo-fluid dynamic processes directly in the strata of plastic rocks — waveguides, there is a constant imbalance, which leads to the inevitability of redistribution of fluids in the volume of these strata of rocks. This, in turn, is accompanied by the movement of the rocks containing the fluids themselves. The latter affects the processes of folding and the occurrence of complex inversion, structural relationships between uneven formational complexes of sediment due to injection or injection of hydrocarbon fluids.

In the Cenozoic-age basins of the Caspian-Black Sea region, geodynamic mechanisms associated with geo-fluid dynamic processes — the realization of the elastoplastic properties of thick clay strata — play a prevailing role in these conditions. In a more general case, it is legitimate to conclude that one of the significant factors in the formation of the described types of folding in geosynclinal regions is the effect of the manifestation of abnormally high pore pressures in regional geo-fluid dynamic processes.

The geo-fluid dynamic activity of the Caspian-Black Sea region can be estimated by the frequency of eruption of mud volcanoes. Absolutely all small-focus earthquakes are located exclusively within the geofluid of dynamically active zones.

Palinspastic reconstruction of a regional cross-section through the Carpathian Bend Zone: Implications of salt tectonics on the structural inventory and HC traps.

Author : Arnberger, Klaus - klaus.arnberger@omv.com - OMV Petrom, Upstream Division
Co Author : Tămaș, Dan - danmircea.tamas@ubbcluj.ro - Babeș-Bolyai University, Dep. of Geology and Center for Integrated Geological Studies
Co Author : Schleder, Zsolt - zsolt.Schleder@omv.com - OMV Upstream
Co Author : Krezsek, Csaba - csaba.Krezsek@petrom.com - OMV Petrom, Upstream Division

The foreland of the Carpathian Bend Zone is part of a thin-skinned fold and thrust belt, located between the South and East Carpathians. It represents one of the most prolific hydrocarbon producing areas onshore Romania with more than one hundred years of production history. The tectonic evolution involves the closure of the Magura Basin, imbrication of its sedimentary succession and thrusting onto the Moesian Platform. The structural style is dominated by sets of thrust related anticlines and synclines that have undergone substantial tightening and are locally pierced by evaporates. Mechanically this deformation is facilitated by four main detachment levels, Oligocene and Aquitanian shales and the evaporate levels of Lower Burdigalian and Badenian.

Two main deformation phases can be identified: The Badenian to Mid Sarmatian closure of the Magura Basin, attributed to imbricate stacking and translation of the sediment stack onto the undeformed foreland and the Latest Miocene to recent (Wallachian) phase which is characterized by out of sequence thrusting, partially by reactivation of pre-existing thrusts, and significant uplift of the Subcarpathian nappes in the Quaternary, while the fore deep basin was still subsiding. This late uplift caused exhumation and erosion in the Hinterland and deposition of 2-3km sedimentary cover of the foreland structures.

A regional cross section was constructed extending from the frontal Carpathian nappes in the north to the buried Carpathian thrust front in the south. The orientation was chosen perpendicular to the assumed tectonic transport direction crossing some of the main HC producing structures of the Carpathian Bend Zone, (e.g. Runcu-Bustenai, Baicoi and Aricesti). The interpretation is based on seismic data and, at the anticlines, on well information from production and deep exploration wells. However complex salt bounded structures are usually difficult to image on seismic, therefore comparison with scaled analogue models, involving multiple detachment levels with ductile and more brittle behavior, helped to validate the interpretation. Palinspastic restoration of the section reveals 39km (44%) internal shortening plus 41km translation onto the Moesian platform. The restored position of the sedimentary succession provides insights the paleogeography of the Magura Basin.

Keywords: Carpathian Bend Zone, salt tectonics, palinspastic reconstruction, fold and thrust belt

Interplay between Tectonics and Sedimentation in the Upper Cretaceous Molasse Base: New Play Types in a Mature Basin

Exner, U., Scheucher, L., Retzl, M., Hulka, C., Wiesmayr, G. & Reutemann, M.
RAG Exploration & Production, Schwarzenbergplatz 16, 1015 Wien

Upper Cretaceous sediments are known to underlie the Eocene-Oligocene deposits of the Molasse Basin in Upper Austria, not only from surface outcrops in the area around Regensburg in Bavaria, Germany, but also from abundant wells reaching the autochthonous deposits above the crystalline basement rocks of the Bohemian Massif.
In Upper Austria, most of the known Upper Cretaceous hydrocarbon reservoirs are found in sandstones of Cenomanian age. These deposits represent transgressive sequences of varying reservoir quality. Traditionally, these reservoirs were exploited as secondary targets in areas where the transgressive Eocene Sandstones serve as main target for oil production. The Cenomanian Sandstones are lower in porosity, and in many areas permeability is reduced by the presence of Glauconite, other clay minerals and/or carbonate cementation.

In general, Upper Cretaceous strata overlying Cenomanian sandstones are represented by a thick, shale-dominated succession, with only minor intercalations of sandstones. If sandstones are present, they usually show poor reservoir qualities. These units are interpreted as shallow marine shelf sediments deposited some 10 km from the shoreline in the Northeast.

In contrast, proximal areas are characterized by a sand-prone, partially terrestrial succession, ranging from Cenomanian to lowermost Paleocene. Despite their excellent reservoir properties, no significant hydrocarbon accumulations have been encountered so far.

The planning of exploration wells from the 1960's to 1990's was based on 2D seismic lines of mostly poor to very poor quality. Only the most obvious faults were recognized on these data, and all of them were interpreted as post-Eocene normal faults. Recently, the acquisition of a modern 3D seismic survey in eastern Upper Austria, delivered a significant improvement, allowing a far more detailed evaluation of the areas' hydrocarbon potential.

New observations include:
- SW-directed basement thrusts onto the Upper Cretaceous sediments, which were also confirmed by recent drilling results.
- Syn-sedimentary monoclinal folds above blind basement thrusts, which strongly influence and spatially limit the deposition of uppermost Cretaceous (and lowermost Paleocene) sandstones and conglomerates/ breccias.
- Post-Eocene E-W trending normal faults, which may trap hydrocarbons in downthrown fault blocks due to juxtaposition of Eocene and Upper Cretaceous sandstones against thick Upper Cretaceous shales.
- Possibly Miocene SW-NE striking strike-slip fault offsetting the Molasse down to the crystalline basement.
- Estuaries and incised valleys of presumably Eocene age deposited on the hanging wall of SW-directed thrusts, directly overlying the crystalline basement.

In the light of these new interpretations, various promising new play types can be defined, which have not been recognized so far.

Keywords: Upper Cretaceous, Basin Inversion, Basement Thrust, Thick Skinned Tectonics

The Carpathian-Pannonian basins of eastern Paratethys from S Poland to Hungary - a review of recent exploration activities

Gawenda, Piotr - piotr.gawenda@ihsmarkit.com – IHS Markit Global Sarl

Petroleum provinces of the Carpathian-Pannonian area (eastern Paratethys) have a long history of prolific exploration. Some 700 fields were discovered in the region so far, with the reserve base exceeding 1 Bbo and 20 Tcfg. Although mature, the region remains Europe's prime area of hydrocarbon activity to this day, with close to 200 exploratory wells drilled recently and elevated activity planned in the near-term. The renewed exploration interest in the area results primarily from successful deployment of 3D reflection seismic (combined with sophisticated signal modelling), new structural models for the reservoirs/traps formation and use of new production techniques. The presentation reveals E&P operations from S Poland to Hungary during past 5 years, listing the major factors driving exploration and key successful operations.

In Poland, almost the entire acreage within the Miocene foredeep-Outer Carpathian fold-and-thrust belt is licensed to domestic PGNiG and ORLEN Upstream. While the former company is active in the area since long, ORLEN Upstream has entered the region recently through asset acquisitions and tenders. Acting separately or as partners, the companies acquired over 1,500 sq km of 3D seismic and drilled nearly 80 exploratory wells since 2013, discovering several new hydrocarbon pools (albeit small) and re-evaluating some vintage fields, e.g. Przemysl. In addition, PGNiG is unlocking (believed to be substantial) hydrocarbon potential within the tight Miocene mudstone-sandstone series in the sub-thrust position. The exploration success within the Outer Carpathian fold-and-thrust belt still remains elusive, owing to poor seismic imaging of the flysch series. New model for the tectonic evolution of the system seems necessary to further unlock the potential of this complex terrain.

The prolific acreage in the Czech Republic and Slovakia is found in the fold-and-thrust/foreland successions, as well as in the Pannonian Basin (Danube Basin, East Slovak Sub-basin) and its lateral equivalent, the Vienna Basin. MND in the Czech Republic and Nafta in Slovakia are the principal explorers/producers. Although operations in the recent past related mainly to preserving production, few new pools were discovered. A new exploration project is underway to unlock the (dormant since long) Neogene series in the Danube Basin in Slovakia.

In Hungary, the series of interest primarily span the Palaeogene and Neogene basins. The latter unit, comprising several depocentres with thick and variable sedimentary fill, is a traditional area of interest for MOL that discovered the bulk of the country's hydrocarbons. To stimulate exploration in this well-explored basin, the authorities are organising tender calls since 2013, offering new areas for licensing. Some 30 contracts were granted this way to Hungarian Horizon Energy, MOL, O&D Development, Panbridge, Vermilion Energy, and further rounds are planned. Ensuing, the companies reprocessed vintage seismic data, acquired some 1,500 sq km of new 3D seismic and drilled close to 100 wells. A number of new pools was discovered, with the production brought on-line swiftly due to well-developed pipeline network. Several new projects are pursued, with the drilling scheduled for 2019 and beyond.

Concluding, despite long history of exploration/production, the areas along the Carpathian-Pannonian transect are experiencing a revival of exploration interest, attracting substantial level of interest from the domestic and international players. In the past few years, sizeable new acreage was procured (Hungary, Poland), the operators acquired 2D/3D seismic projects and drilled close to 200 new exploratory wells. As unlicensed acreage remains available, the view on the prospectivity of the Carpathian-Pannonian province, particularly within the deeper (Miocene) plays, syn-rift series and tight or HPHT reservoirs, remains upbeat.

Keywords: Carpathian-Pannonian, hydrocarbons, exploration, seismic, drilling

Evidences of strike-slip deformation associated with the Mid-Miocene rotation and collision of the Southern Carpathians

Druga[1], A.G., Arnberger[1], K.; Tyler[1], E., Krezsek, C.
1 OMV-Petrom, Bucharest, Romania
Corresponding Author:Ancagabriela.Druga@petrom.com

The purpose of this contribution is to delineate the subtle structural features such as faults and associated fractures in the western part of the Getic Basin, Southern Carpathians, Romania. The proper illumination of the fault network can have a significant impact on production. Small scale faults can substantiate the compartmentalization of the reservoir; therefore can influence the fluid parameters (e.g. recovery factor).
The structure of the Southern Carpathians has been completed during the Mid Miocene collision of the Carpathians with the Moesian plate. This deformation has been accommodated by thin-skinned in sequence thrusting and folding in addition with 30 degrees clockwise rotation of the Carpathians (Schmid et. al., 2008). Although, the rotation has been demonstrated by magnetostratigraphic studies (Vasiliev et. al.,2009), the effect in the structural style was rarely identified.

We applied multi-trace attributes techniques on a Mid Miocene hanging wall anticline in order to visualize possible features associated with the rotation. Multi-trace attributes rely on the characteristics of the seismic data set and are commonly used to bring out a particular property such as lateral discontinuity, without introducing artefacts. The work-flow used in this study includes discontinuity attributes such as variance (Van Bemmel and Pepper, 2000) and chaos (Randen et al., 1999) and edge enhancement filters. Giving the small scale of the faults the edge detection attributes were computed directly from the PSDM 3D seismic data without any seismic conditioning. Edge enhancement filter was then applied to the Variance, Chaos volumes and the results were compared and used for manual and automatic fault picking.

Taking into consideration the 30 degrees clockwise rotation of the Carpathians around the Moesian Platform in the Mid Miocene, the targeted structural features correspond to a right later strike-slip transfer zone that accommodated the shortening and rotation of the Getic foredeep. The multi-trace attributes along with the ant-track filter revealed a small scale fault network with an N-NE to S-SW direction similar to the expected orientation of the structural features. The antithetic strike-slip fracture set that occurs at the surface of the anticline presents a high angle of 75-90 degrees clockwise direction to the dextral main fault and can be identified as Riedel shears. The shear fractures propagate a short distance out of the main fault, but are coeval with it. The geometrical arrangement of Riedel shears is indicative of the sense of movement within the wrench zone.

The applied techniques proved to be very efficient in delineating the fault network and associated fractures. The structural features appear to be consistent throughout most of the volume attributes extracted. The resulting volumes were successfully used for both manual and automatic fault picking. The presence of the fracture network in the area is sustained not only by the drilling history, but also by the fluid parameters.

Keywords: ant-track, variance, chaos, fault, interpretation, attributes, Getic Basin,

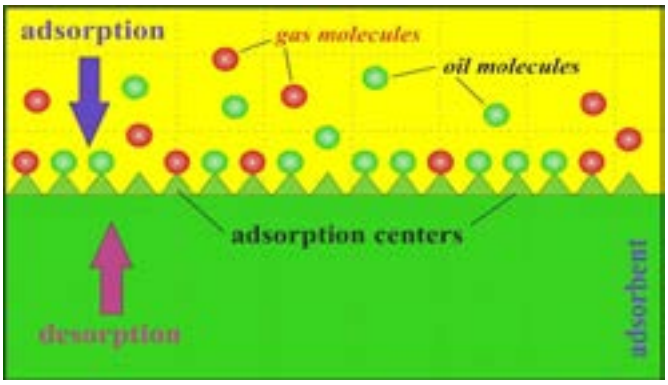
References:
Schmid et al., 2008, The Alpine-Carpathian-Dinaridic orogenic system: correlation and evolution of tectonic units, Swiss Journal of Geosciences, Volume 101, Issue 1, pp 139-183
Randen, Trygve. (1999). Automatic extraction of fault surfaces from three-dimensional seismic data. Seg Technical Program Expanded Abstracts. 20. 10.1190/1.1816675.

Van Bemmel, P. P., and R. E. Pepper, 2000, Seismic signal processing method and apparatus for generating a cube of variance values: U.S. Patent 6,151,555
Vasiliev, Iuliana & Matenco, Liviu & Krijgsman, Wout. (2009). The syn- and post-collisional evolution of the Romanian Carpathian fore deep: New constraints from anisotropy of magnetic susceptibility and paleo stress analyses. Tectonophysics. 473. 457-465. 10.1016/j.tecto.2009.04.002.

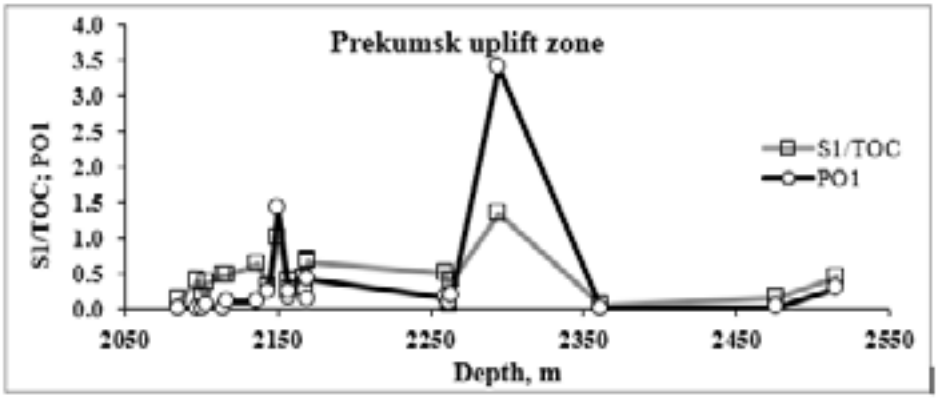
Organic porosity is an important factor in the formation of hydrocarbon accumulations in low-permeable shale strata of the Maikop series of the Black and Caspian Sea basins

M.V. Zakharchenko, V.Yu. Kerimov, R.N. Mustaev, I.M. Salihova
Russian State Geological Prospecting University

An important role in the formation of hydrocarbon accumulations in oil and gas sequences belongs with the organic porosity, which is void spaces of organic origin formed at transformation of the organic matter into hydrocarbons. Organic porosity or porosity in the kerogen texture forms in the process of the rock organic matter (OM) thermal maturation and is capable of affecting the adsorption of the generated oil. The adsorption process of the generated oil results in an increase of the matter concentration on the phases' separation boundary. At oil generation, in a compact and immature kerogen begin forming organic pores («kerogen porosity»). By the end of the oil window, they form a connected system thereby providing space for the generated oil hydrocarbons. Results of the conducted studies in organic porosity allow considering the organic pores in kerogen texture as substantially contributing in the space of newly-formed reservoirs in the oil source sequence. A study of OM geochemical parameters' specifics in the samples from wells drilled at the subject prospects allowed reviewing the causes of hydrocarbon retaining capability both by the mineral matrix and by the source rock kerogen. Based on the results of the programmed pyrolysis by the Rock-Eval-6 method an estimate has been performed of organic (kerogen) porosity. This estimate allows determining the forecast retention volume of HC generated in the process of katagenesis. At shallow source rock depths, hydrocarbon emission forms a porous surface retaining, first of all, components of elevated molecular mass and polarity. Detached from the kerogen surface are in the first place light and saturated HC's and only after that the heavy HC's. Thus, certain selectivity is taking place. Overall, the effect of oil-saturation increases with a growth of organic porosity.



Hydrocarbon molecule's adsorption model in organic pores.



Oil-saturation index ISO vs. kerogen porosity PO1

Oil and gas in the Mura-Zala Basin (NE Slovenia)

Miloš Markič, Geological Survey of Slovenia, Dimičeva ulica 14, SI-1000 Ljubljana, milos.markic@geo-zs.si (corresponding author)
Jernej Kerčmar, Petrol Geo, Mlinska ulica 5D, SI-9220 Lendava, jernej.kercmar@petrol.si
Dejan Šram, Geological Survey of Slovenia, Dimičeva ulica 14, SI-1000 Ljubljana, dejan.sram@geo-zs.si

The most prospective geological area for oil and gas in Slovenia is the Neogene Mura-Zala Basin (Fig.1) situated in the SW part of the Pannonian Basin System. Within the Mura-Zala Basin, Middle-to-Upper Miocene strata of the Petišovci area have the most known potential for oil and gas reserves and resources. Oil and gas were discovered in this area in 1942 – as an extension of the already known Lovászi field in the neighbouring Hungary. Also in Croatia, there were known oil and gas fields at Selnica and Peklenica, having been exploited already since the mid of 19th century.

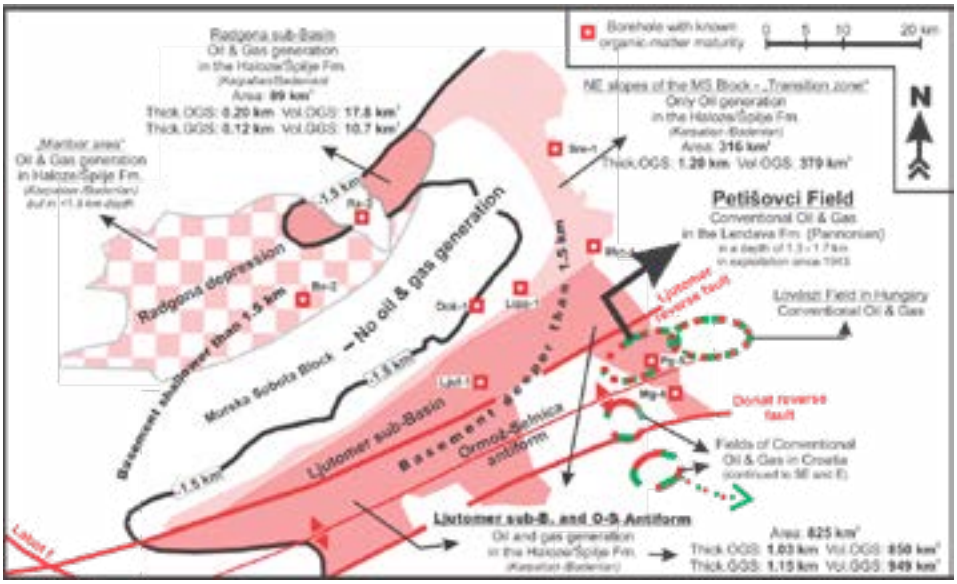


Fig.1: The areas of oil and gas generating strata (OGS and GGS) in the Mura-Zala Basin (NE Slovenia). Petišovci oil and gas field connected to the Lovászi field (H), and two fields of the Medjimurje area (CRO) are shown in the SE part of the map.

Oil- and gas-bearing reservoirs of the Petišovci area (7 × 2 km wide) are divided into two bed-sets, the shallow and the deep one. Both bed-sets consist of alternating 10–40 m thick impermeable marls and porous oil- and gas-bearing sandstones of low porosity – below 15 %, decreasing with a depth to ca. 7 % only. The Petišovci hydrocarbons are therefore characterized as the tight ones. Shallow oil and gas reservoirs occur in 4 main horizons in a depth interval from 1000 to 1800 m. They were exploited in the 1950s (mostly oil) and 1960s (mostly gas). Nowadays, they are depleted – offering a possibility for e.g. storage of imported natural gas or of CO2. The deep reservoirs start at a depth of 2200 m and are developed as ca. 17 tight gas-bearing ("A-Q") layers down to a depth of 3550 m (deepest wells), maybe even more. The deepest well was Mg-6 (3858 m) drilled in 1985 being also the only one reaching the pre-Tertiary carbonate basement.

The whole set of the Petišovci reservoirs is a typical antiform setting formed by lifting between the Donat and Ljutomer reverse faults (Fig.1). It is interpreted that hydrocarbons were generated in an originally synform setting (to reach the oil and gas maturity windows), which was later lifted – lifting had lasted still in the Pontian times as known from the coal measures antiform structure in the uppermost Mura Formation. This lifting with accompanying fissure system enabled the migration of hydrocarbons upwards into porous sandstone reservoirs in which the hydrocarbons were trapped by impermeable marl lay

Pore system characterization of the high-maturity Lower Llandovery shale reservoir of the Narol-Biłgoraj zone (SE Poland)

Alicja Pstrucha[1], Ewa Pstrucha[1], Grzegorz Machowski[1], Paweł Poprawa[1]
1 AGH University of Science and Technology, Cracow, Poland, corresponding author e-mail: pstrucha@agh.edu.pl

Porosity characterization is essential in shale reservoir study because it affects the gas reserves and the design of fracturing treatment. In this study, thirteen core samples of the Lower Llandovery shales were analyzed in terms of their pore structure. The samples were collected from the N-2 borehole, from the depth interval of 2711,1 – 2731,8 m. The borehole is located in the Narol-Bilgoraj zone (south-eastern Poland). The samples were studied using the Mercury Porosimetry (MP) method. Additionally, the TOC test results were used.

The petrophysical parameters obtained from the MP method for the studied shales are differentiated, indicating heterogeneity of the pore space structure. The effective porosity is low and amounts around 1,0%. The highest mercury intrusion is observed for the pore diameters smaller than about 0,01 μm, corresponding to the nanopores (< 0,1 μm) realm. The capillary pressure curves show a minor but diversified hysteresis – from 1,7% to 34,2% (11,0% on average) of intruded mercury remains in the pores after reaching atmospheric pressure. Small mercury entrapment may suggest inconsiderable amount of ink-bottled-shape pores. Further, the shape of these curves is often referred to a pore structure composed of a mixture of slit-shaped and ink-bottled-shaped pores, which are usually related to organic and clay mineral pores. In this study, due to relatively high mercury withdrawal efficiency the predominance of slit-shaped pores seem to be mostly presumable.

The positive correlation between TOC and percentage pore volume of nanopores and negative relationship between TOC and contribution of larger pores to the effective porosity imply that the nanopores are more easily developed in organic matter than in mineral matrix. The study presents strong, positive relationship between the effective porosity and TOC, with coefficient of determination R2 equals to 0,82 and coefficient of correlation r equals to 0,91. Extrapolation of the regression line to TOC=0% enable to obtained a porosity value of 0,62%, corresponding to porosity contributed by inorganic pores. Thus, basing on a regressed slope of 0,135, the pores contributed by organic matter was estimated and the results vary in the wide range of 2,12% up to 64,22%, with a mean value of 31,69%, which is comparable with results for similar rocks, presented in the literature.

A diffusion of the methane and an adsorption of this gas on the pore walls become significant at pore sizes below 0,05 μm, and below 0,01 μm become even stronger, whereas at pore sizes larger than 0,05 μm permeation of free gas may occur. For the studied samples the dominant pore system within the nanopore realm suggest that the possible transport mechanism is diffusion. Further, predominance of pores smaller than 0,01 μm may indicate that the adsorption process is efficient, especially in the organic pores. Thus, the pore structure significantly reduces capability of studied mudstones to transfer fluids, but at the same time enhances their storage capacity.

Acknowledgements. This research has been financially supported by Statutory funds no. 11.11.140.176, Faculty of Geology, Geophysics and Environmental Protection, AGH UST.

Application of the XRF measurements for unconventional potential assessment based on a field section of the Sękówka Creek (Outer Carpathians)

Wojtowicz Michał[1], Hejnar Jan[2], Starzec Krzysztof[3], Wronka Aneta[4], Schnabel Wojciech[4]
[1]Petrophysics consultant, Warsaw, Poland
[2]Polish Academy of Sciences - Institute of Geological Sciences, Krakow, Poland
[3]AGH – University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Krakow, Poland
[4]Geokrak Ltd., Krakow, Poland

Extensive number of rock samples has been collected from the surface section of the Sękówka Creek (Outer Carpathians) representing Eocene and Oligocene clastic sedimentary sequence. The XRF analyses have been conducted on 1478 prepared (crushed and homogenized) samples. Analyses were performed in Geokrak laboratory in Cracow using Bruker S1 Titan 600 handheld device. Then, this data have been used to assess mineral composition and identify hot shale horizons.

Hot shale horizons have been determined with the use of selected elements and oxides as indicators for anoxic conditions, enriched organic carbon content and clay content. Mineralogy has been assessed using enhanced version of the MINLITH algorithm. The MINLITH algorithm provides the way of calculating normative mineral composition of sedimentary rocks from XRF datasets. Oxides content and experience derived rules are the base for these calculations. Methodology for the MINLITH algorithm is based on the CIPW algorithm for igneous rocks. Results of mineralogy assessment based on original and enhanced version of the MINLITH algorithm have been compared to show that some shortcomings present in original version of the algorithm could be overcome.

Implications for unconventional potential assessment based on obtained results have been thoroughly discussed. First of all, these results could be used as a pre-survey for the identification of the best productive intervals and intervals optimal for hydraulic stimulation.

Combining XRF analyses performed using handheld analyzer with our proprietary algorithm proved to be very cheap and efficient method for assessing mineralogy.

Described methodology has been applied to field data, however it could be also very efficient and especially very useful in case of data from wellbores. Possible further applications of this methodology for data acquired from wellbores or as a pre-survey phase of exploration have been also discussed. Most important one is use of mineral composition derived from XRF analyses for formation evaluation, which in turn gives better estimates of porosity and saturation.

Diagnostic textural and structural features of eolianites and their reservoir potential: an example from the Atlantic Coast of Morocco

Niklas, E.
UAM, Institute of Geology,
Poznań, Poland

The concept of „eolianites" evolved dramatically in the last century [1]. Lately, eolianites are usually defined as rocks of aeolian origin composed of carbonate grains, partly or totally cemented by carbonates [2]. These rocks are formed in coastal areas by the accumulation of wind-driven carbonate debris of shallow marine origin. Contrary to their siliciclastic counterparts, they have undergone early meteoric diagenesis making their preservational potential relatively high. Nowadays eolianites are important for both the academia and for the petroleum industry as well, because of their seemingly wide global distribution and good reservoir properties. Eolianites could be mistaken for deposits of high energy subtidal flats and, indeed, a few reservoir units (e.g. in the Persian Gulf) have been reinterpreted as eolianites.

This study focused on eolianites exposed in a cliff at Aglou Beach at the Atlantic coast of southern Morocco, about 100 km south of Agadir. The studied section of eolianites at this outcrop is up to 6 m thick. The field work included textural and structural description of the rock, measurements of angle and azimuth of the dip of cross strata and collection of up-down oriented samples. The composition of eolianites and their textures were further examined in thin sections under petrographic microscope.

The studied eolianites have cross-laminae sets whose thickness is in the range between 1.5 and 2 m. The dip angle of the cross laminae varied between 10° and 22°, whereas dip azimuths indicated that along-shore, north-easterly winds were responsible for deposition of the major part of the carbonate sand preserved in studied sedimentary section.

Microscopic observations showed that the grain framework of eolianites was dominated by bioclasts, such as foraminifera and fragments of bryozoans, crinoid stems, brachiopods and bivalve shells. Other components included quartz and feldspar grains, peloids, lithoclasts and heavy minerals. Grains were found to be angular to subangular and poorly sorted. The verticalization of grains, which is a post-depositional feature of eolianites formed by grain reorientation due to percolating meteoritic water, was poorly identifiable. The pin-stripe lamination, the other feature considered as diagnostic for eolianites [1], was not observed. This is probably due to poor sorting caused by the abundant bioclasts, which have lower density than the quartz grains, and therefore wind with a given speed could simultaneously transport grains of various size [1]. The studied eolianites had high porosity and quite good permeability, making them potentially good reservoir rocks. The various cement types recognized include circumgranular cement, drusy mozaic and grains mozaic cements, all indicating diagenesis in a meteoric-vadose zone.

References
[1] McLaren S.J, 2007. Aeolianite. In: Nash D.J. & McLaren S.J. (eds.) Geochemical Sediments and Landscapes, Blackwell Publishing Ltd., 145-165.
[2] Frebourg G., 2010. Carbonate Coastal Dunes: Potential Reservoir Rocks? Thèse de doctorat: Univ. Genève, 2010, no. Sc. 4221.

Evidence for Badenian marine transgression in Belgrade (Serbia)

Filip Anđelković[1] and Dejan Radivojević[1]
1University of Belgrade, Faculty of Mining and Geology, Department of Regional Geology, Belgrade, Serbia. E-mail: filip.andjelkovic@rgf.rs and dejan.radivojevic@rgf.bg.ac.rs

The only true marine depositional environment in the Serbian part of the Central Paratethys belongs to the Badenian stage. Belgrade is located on the southern rim of the Pannonian Basin (Marović et al, 2007). Badenian sediments in the Belgrade area are represented by four facies: Rakovica clastics, Tašmajdan limestones, Višnjica clays and Konjarnik schlier (Anđelković M., 1987; Anđelković, M.&Anđelković, J., 1997; Anđelković F. & Radivojević, 2018). Of these, clastics (conglomerates, sands and sandstones) and limestones (mostly subreefal) have the greatest extent and palaeogeographic significance.

The onset of transgression is well-marked by the occurrence of typical basal conglomerates at several locations in the city area, especially at Kalemegdan fortress and Rakovica stream. These conglomerates contain rich marine mollusc fauna, belonging to the Ostrea order, which are not found in the underlying bedrock. The transgression is further represented by a thick layer of sands and sandstones, showing a near-shore environment. This sandy level is overlain by subreefal limestones of "Leitha type", which indicate a slightly deeper depositional environment.

All of these palaeogeographical changes were enabled by the general connection between the Central Paratethys and the Mediterranean, which definitely existed during the early and middle Badenian (Rögl, 1999).

The overlying Sarmatian sediments, on the other hand, are represented by mostly brackish depositional environment (Anđelković M., 1987), except in its lowest part. The severing of connections with the Mediterranean is the cause for the partial isolation and fall of salinity (Rögl, 1999).

REFERENCES

Anđelković, M. 1987. Geology of the wider Belgrade area – Geology and geodynamics. Institute for regional geology and palaeontology, Faculty of Mining and Geology, p. 428 (in Serbian)
Anđelković, M., Anđelković, J. 1997.Badenian cycles in Serbia. Geološki anali Balkanskog poluostrva, 61-2, 1-13
Anđelković, F., Radivojević, D. 2018. A contribution to the knowledge of facial diversity of Badenian sediments in the Belgrade area, 17th Serbian Geological Congress, Vrnjačka Banja, 232-236
Marović, M., Toljić, M., Rundić, Lj., Milivojević, J. 2007. Neoalpine Tectonics of Serbia. Serbian Geological Society Monography, p. 87
Rögl, F. 1999. Mediterranean and Paratethys. Facts and hypotheses of an Oligocene to Miocene paleogeography (short overview). Geologica Carpathica, 50-4, 339-349

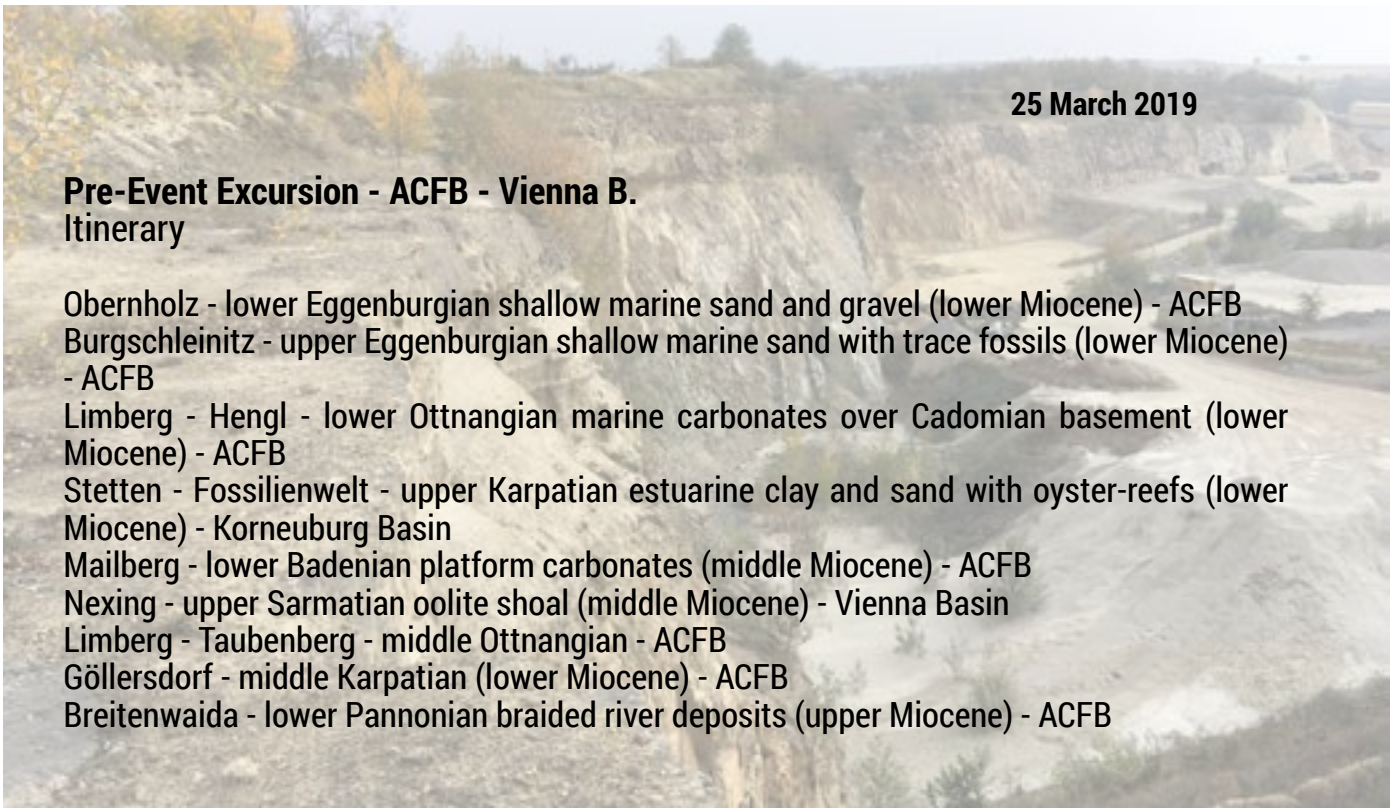
Clay mineralogy of Miocene mudstones of the Lower Austrian Molasse Basin

Meszar, Maria (Department für Geodynamik und Sedimentologie, Wien, AUT); Gier, Susanne (Department für Geodynamik und Sedimentologie, Wien, AUT); Palzer-Khomenko, Markus (Department für Geodynamik und Sedimentologie, Wien, AUT); Knierzinger, Wolfgang (Department für Geodynamik und Sedimentologie, Wien, AUT); Wagreich, Michael (Department für Geodynamik und Sedimentologie, Wien, AUT)

Miocene mudstones of seven wells in Lower Austria were investigated in a joint project of OMV and the University of Vienna which aimed at a revision of the stratigraphy of this part of the Central Paratethys. The Lower Austrian Molasse Basin (LAMB) is part of the North Alpine foreland basin and was formed in relation to the advancing alpine orogenic front. Up to 2000 m of sands, silts and clays were deposited in deeper parts of the basin. Herein, we analysed the clay mineralogy of 7 wells (74 samples) across the LAMB.

In the LAMB Karpatian sediments overlying a carbonate minimum interval are attributed to the Laa Formation. Beneath the Laa Formation the Traisen Formation comprises the uppermost Ottnangian sand-dominated and calcite poor sediments south of the Danube. In the north, the upper Ottnangian Wildendürnbach Formation represents basinal pelitic deposits, also poor in calcite. The fine grained and carbonate bearing sediments below the Traisen and Wildendürnbach Formations are termed Robulus Schlier s.l. The lower boundary of the pelitic Schlier-succession is marked by bioturbated sandstones. The informal term Basal Sands is used to denote quartz, K-feldspar and kaolinite-rich, but mica-poor sands covering the basement.

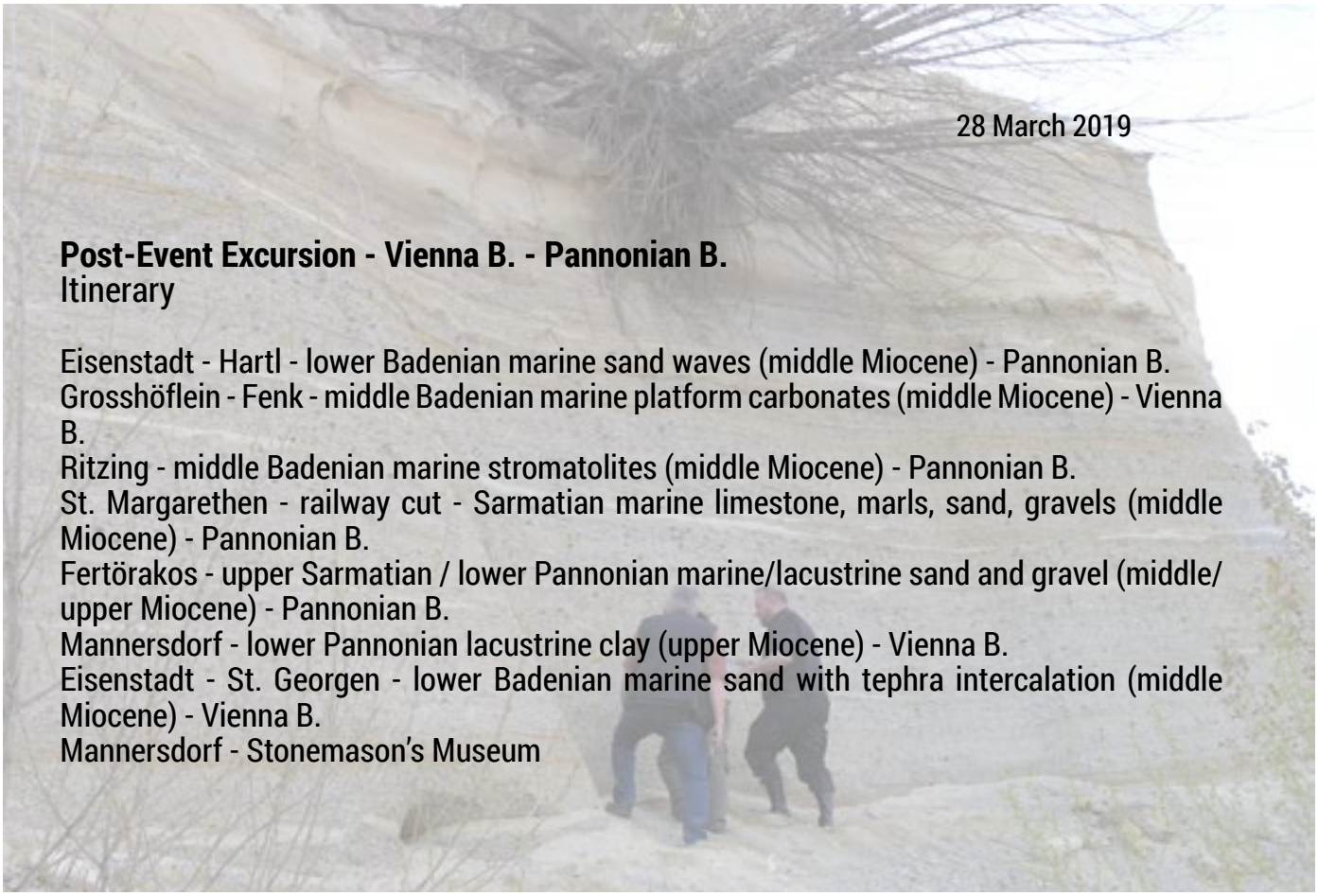
The results of the qualitative and quantitative evaluation of clay minerals in the seven wells allow some correlation with the recently proposed lithostratigraphic boundaries. The main clay minerals are illite and smectite with smaller amounts of chlorite, kaolinite and rarely some vermiculite. In wells Streithofen 1 and Schaubing the formations show distinguishable differences. The Robulus-Schlier s. l. is characterized by lower kaolinite amounts compared to the overlying Traisen Formation. The kaolinite values in the Basal Sands reach up to 93% and can be explained by chemical alterations under prolonged warm and wet climates at the surface of the Bohemian Massif basement. High smectite values up to 70% in the Wildendürnbach Formation of well Wildendürnbach K4 could be related to distal fall-out tephra of the western Inner Carpathian volcanic arc.



25 March 2019

Pre-Event Excursion - ACFB - Vienna B.
Itinerary

Obernholz - lower Eggenburgian shallow marine sand and gravel (lower Miocene) - ACFB
Burgschleinitz - upper Eggenburgian shallow marine sand with trace fossils (lower Miocene) - ACFB
Limberg - Hengl - lower Ottnangian marine carbonates over Cadomian basement (lower Miocene) - ACFB
Stetten - Fossilienwelt - upper Karpatian estuarine clay and sand with oyster-reefs (lower Miocene) - Korneuburg Basin
Mailberg - lower Badenian platform carbonates (middle Miocene) - ACFB
Nexing - upper Sarmatian oolite shoal (middle Miocene) - Vienna Basin
Limberg - Taubenberg - middle Ottnangian - ACFB
Göllersdorf - middle Karpatian (lower Miocene) - ACFB
Breitenwaida - lower Pannonian braided river deposits (upper Miocene) - ACFB



28 March 2019

Post-Event Excursion - Vienna B. - Pannonian B.
Itinerary

Eisenstadt - Hartl - lower Badenian marine sand waves (middle Miocene) - Pannonian B.
Grosshöflein - Fenk - middle Badenian marine platform carbonates (middle Miocene) - Vienna B.
Ritzing - middle Badenian marine stromatolites (middle Miocene) - Pannonian B.
St. Margarethen - railway cut - Sarmatian marine limestone, marls, sand, gravels (middle Miocene) - Pannonian B.
Fertörakos - upper Sarmatian / lower Pannonian marine/lacustrine sand and gravel (middle/upper Miocene) - Pannonian B.
Mannersdorf - lower Pannonian lacustrine clay (upper Miocene) - Vienna B.
Eisenstadt - St. Georgen - lower Badenian marine sand with tephra intercalation (middle Miocene) - Vienna B.
Mannersdorf - Stonemason's Museum

AAPG

AAPG EUROPE GTW

Exploration and production in the Black Sea, Caucasus and Caspian Region

Batumi, September 18-19, 2019

AAPG Europe Conference Co-chairs: Gabor Tari and Giorgi Tatishvili

AAPG Europe is proud to announce a Regional Technical Workshop scheduled to take place on 18-19 September 2019. This ground-breaking event will occur in the wonderful city of Batumi in Georgia, located right at the coast where the mountain range of the Lesser Caucasus plunges beneath the Black Sea.

Recent years have seen a rise in E&P activities in this region. In particular, Georgia just announced a tender for many onshore blocks and the much anticipated international offshore Georgia bid-round will also be announced this year. Our AAPG GTW will offer a unique opportunity to find out more about these ongoing projects, meet the government entities and regulating agencies. Moreover, this event will also serve for networking with participants from not only other interested E&P companies, but also from various academic institutions engaged in research in the broader region. The meeting programme will also include two one-day field trips, before and after the event, from Batumi to the nearby Rioni Basin and the Achara-Trialet thrust-fold belt.

REGIONAL AND TOPICAL THEMES

This conference will concentrate on hydrocarbon exploration and production in the Central and Eastern Paratethys regions, not only from a petroleum systems point of view, but also from a broader geology and geophysics perspective. The geographic focus will be on the very large Black Sea and Caspian Sea basins and the various Alpine folded belts and their foredeep/foreland basins in the same region including the Carpathians, Balkans, Pontides, Crimea, Greater/Lesser Caucasus and the Elburz mountain ranges.

WHO SHOULD ATTEND?

This event will be of interest to upstream oil and gas industry professionals exploring the broader area of Central/Eastern Europe and Asia. Participation by academic researchers and students with an interest in hydrocarbon exploration and regional geology is also most welcome.

PLANNED TECHNICAL SESSIONS

1) Exploration case studies from play definition to drilling
2) Appraisal, development, production and EOR case studies
3) Petroleum systems analysis: what is proven and what is speculative?
4) Stratigraphic overviews and intra/inter-basin correlation challenges
5) Basin modelling from regional to prospect scale
6) Folded belts in Central/Eastern Europe: case studies from the Alps to the Caucasus
7) Marine connections and paleogeographic changes
8) Plate tectonic models and large-scale paleogeographic reconstructions
9) Unconventional exploration
10) Neotectonics and seismic hazards in the region

For further information contact Marta Diaz at mdiaz@aapg.org
+44 (0) 207 836 3201

Thank you to the Europe Regional Conference 2019 sponsors and endorsers

Media Partner