Energy & Geoscience Institute
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In Development

Circum-Adriatic

Evaluation of the Petroleum Systems of Dinarides, Albanides, Hellenides & Apennines

Principal Investigators:

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Investment per Sponsor
$50K (USD)

Duration
12 months

Project I 01291

Value

- Determination of crustal types, architecture and plate configuration for robust thrustbelt/basin model
- Development of stratigraphic relationships for key areas for basin modeling
- Characterization of all major source rocks, reservoir rocks, seals and trap retention
- Inventory of oils, gases and potential source rocks from the region from all available sources

Key Deliverables

1. Arc GIS project including all data, profiles and maps addressing problems to be solved, which are listed in the Task list.
2. Short explanatory text with accompanying graphic documentation on the results of the tasks focused on individual open problems listed in the Task list.

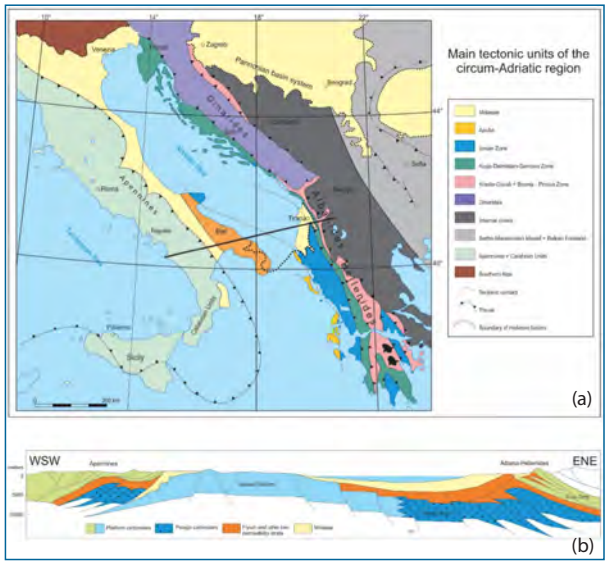

Figure 1: Study area with (a) map of main tectonic units of the Circum-Adriatic region and (b) transect through the southern Apennines, Adriatic Plate, and central Albanides (modified from Nemčok et al., 2013).

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Significance & Rationale

Depending on their occurrence in respective orogens, the sediments accreted in thrustbelts of the Dinarides, Albanides, Hellenides, and Apennines reflect a complex history of evolution from the late Triassic-Early Cretaceous rifting (Figure 2a), Middle Jurassic-Eocene failed rift or passive margin development (Figure 2b), and Early Cretaceous-present-day passive margin and subsequent thrustbelt development (Figure 2c), resp. syn-orogenic deposition in associated foredeep/foreland basin system (Figure 2d) (e.g., Dercourt et al., 2000; Roure et al., 2004; Kapnistos et al., 2007; Fantoni and Francoisi, 2010; Massini et al., 2013; Doglioni, 2015; Wrigley et al., 2015). In detail, these processes occurred during different time intervals in each thrustbelt, although the western and eastern groups of thrustbelts have somewhat similar tectonic event timing. Their development histories are reasonably known, which allows us to compare their similarities and differences, understanding their development engines and controlling factors (Figure 3). The next step further from this comparison is to develop predictive tools allowing one to understand the distribution of source rocks, reservoir rocks, seals, trap timing, expulsion timing, and pooled hydrocarbon preservation trends.

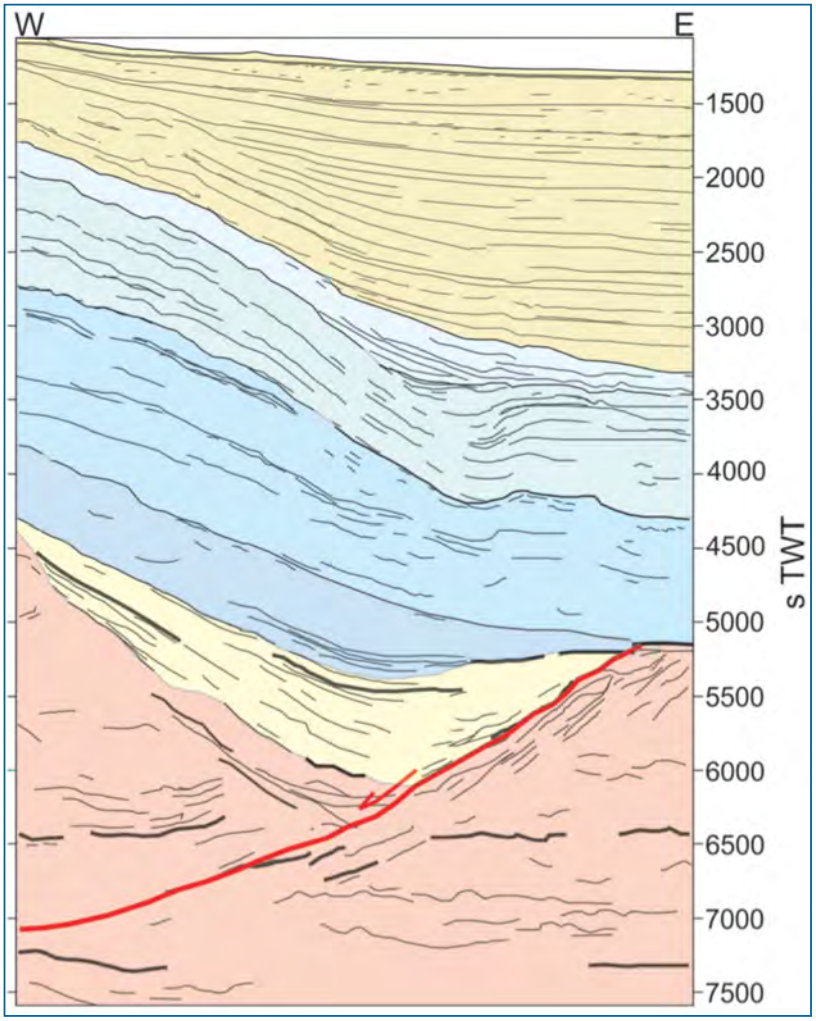

Figure 2A: Section through the northern portion of the Ionian Unit imaging a small Upper Triassic half-graben underneath the Hellenides décollement and lateral facies changes in the overlying Jurassic strata. Note that the syn-rift evaporite occurrence must be restricted to small rift units.

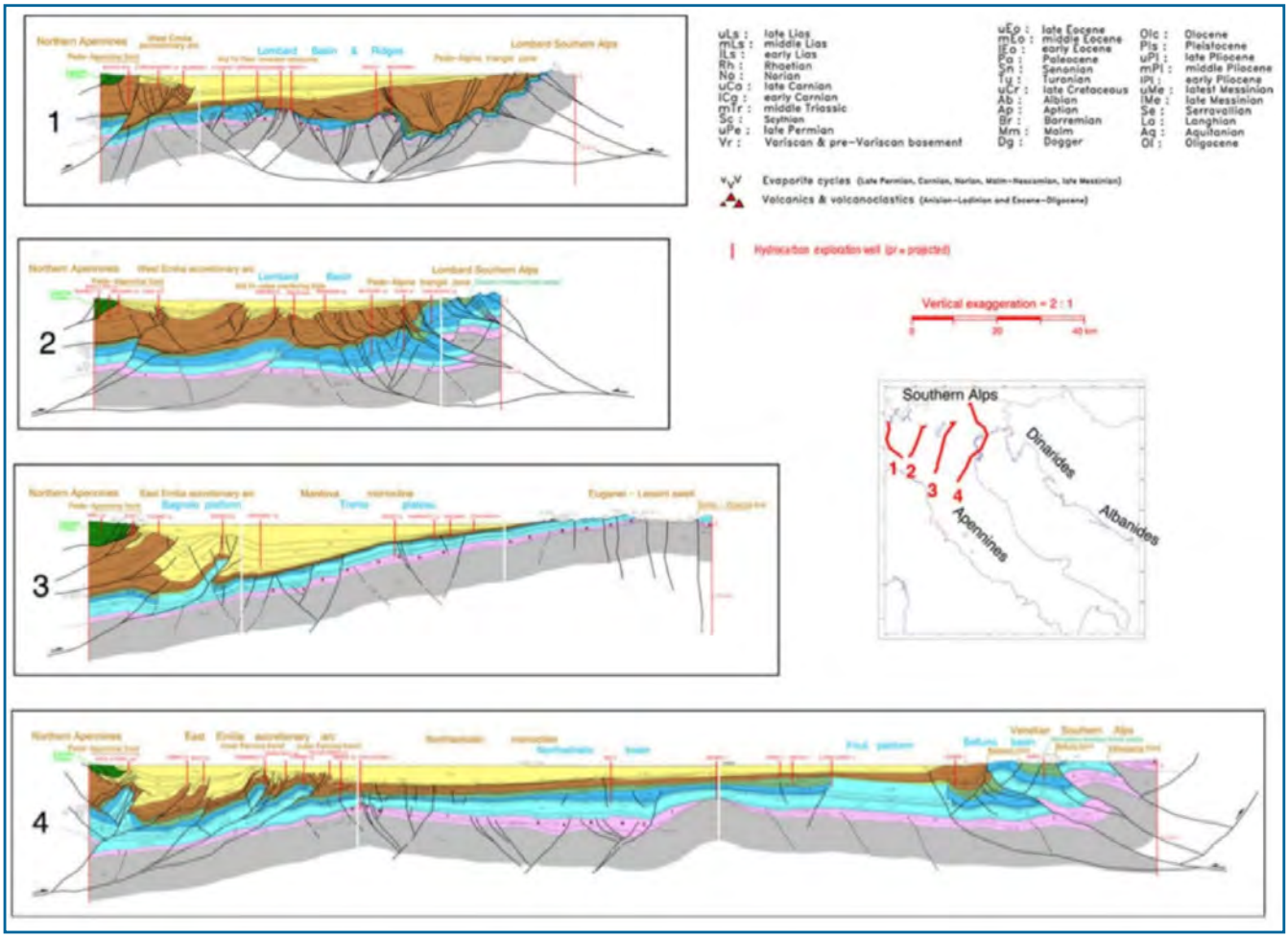

Figure 2B: Deformed balanced cross sections through the Northern Apennines, Southern Alps and their shared foreland plate (Fantoni and Francoisi, 2010). Note the geometries of the syn-rift and passive margin strata in the least deformed portions of sections 1 and 2, and in the relatively undeformed portions of the foreland plate in sections 3 and 4. Triassic, Jurassic and Cretaceous strata are shown in pink, blue and green, respectively.

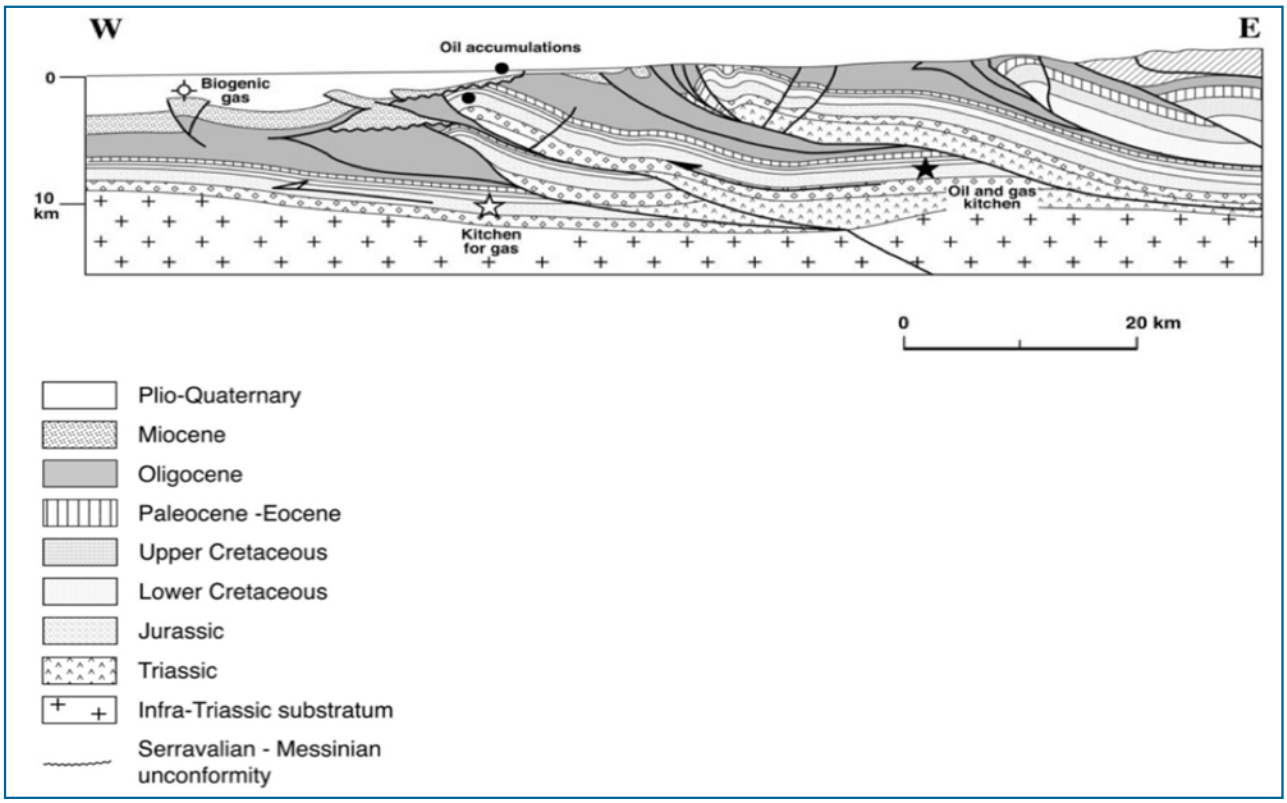

Figure 2C: Deformed balanced cross section through the Ionian Basin and southern Albanides, from the Sazani Zone to Kruja Zone, with indication of petroleum systems and migration pathways (Roure et al., 2004).

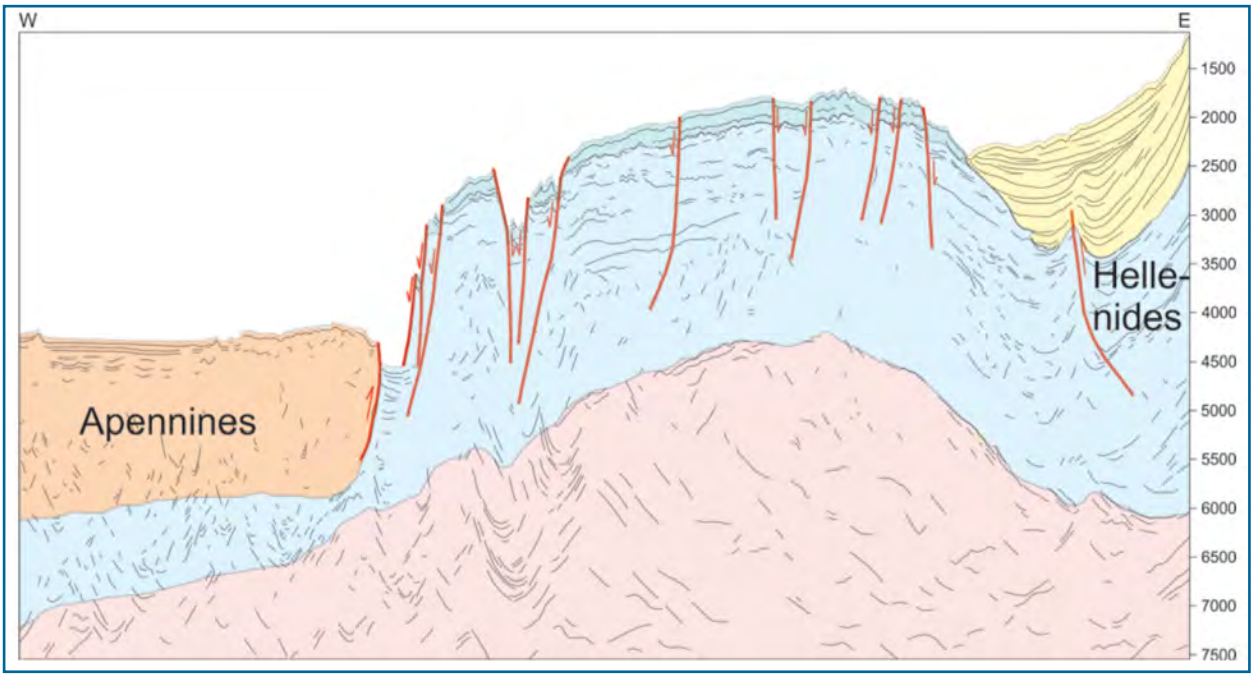

Figure 2D: Section through the Hellenides and Apennines, also imaging the narrow foreland plate flexed between them. The forebulge (in fact the entire remnant foreland plate on the surface) is just about 60 km wide.

The study area is a prolific hydrocarbon province with a number of producing and discovered fields.

In the Apennines, the oil fields are hosted by reservoirs of the syn-rift and passive margin strata. Gas has been proven to be trapped in the thrustbelt and foredeep/foreland sediments. The Gaggiano oil discovery has been made in the pre-rift strata, proving them as a possibility.

In the Hellenides, oil has been proven to occur in the syn-rift, passive margin, thrustbelt and foredeep reservoir rocks, while the gas has been understood to be hosted by the Tertiary thrustbelt and foredeep strata only.

In the Albanides, the pre- and syn-rift reservoirs with oil are lacking. The oil has been proven to reside in the Cretaceous and Miocene thrustbelt and foredeep strata, while gas in known to reside inly in the Neogene sediments of thrustbelt and its foredeep.

In the Dinarides, the petroleum systems have to be proven while their foreland is rather prolific, with a number of gas fields in both Croatian and Italian waters, hosted by the passive margin and foreland strata. There is a number of Croatian oil fields, resp. discoveries in the Cretaceous and Paleocene sediments. The post-Miocene sediments host gas accumulations. Vlasta-1 well indicates that pre-rift reservoirs are possible as well.

Exploring in Croatia has been made difficult by the poor quality of seismic imaging in the past. The good-quality imagery has been acquired only relatively recently.

There is a renewed exploration activity and its strong governmental support in Croatia, culminating with announced results of the first ever onshore license round, with six awards of acreages located in the Drava Basin and Slavonia regions of the Pannonian basin system in summer of 2015. Furthermore, there is an anticipated upcoming license round focused on the Sava Basin of the Pannonian basin system and the Dinarides.

Together with renewed exploration activity in Greece, this encourages us to propose this project focused on petroleum systems of all four thrustbelts with an understanding that each of them allows to recognize a system which is either to be found or disproved in the remaining thrustbelts. Such integrated regional approach may have a chance to find the gaps in the knowledge of petroleum systems of each thrustbelt, especially when the work with existing data will be combined with original research targeting missing constraining geochemical, structural and sedimentological data.

The project will bring together experts from four institutions, including: EGI at the University of Utah, Bratislava Branch, Department of Geology at University of Zagreb, Croatia, Mining Support Kft., Budapest, Hungary and Carlo Magno, Madonna di Campiglio, Italy. The same group of researchers was invited to present an invited talk at the IHS Scouting Conference held in Athens during 13-14 May, 2016.

Data Sources

Type of Data	Quantity
2-D reflection seismic profiles for geoseismic trace sections or geological cross sections	The number of profiles will be determined at the project kick-off meeting when sponsors will have the opportunity to determine the amount of input data they will contribute.
Gravity data	Coverage of the whole study area will be attempted.
Magnetic data	Coverage of the whole study area will be attempted.
Biostratigraphic data	The number of wells with data (resp. outcrop data) will be determined at the project kick-off meeting when sponsors will have the opportunity to determine the amount of input data they will contribute.
Geochemical data	The number of samples and analyses completed will be determined during the project work flow to address all key issues as necessary.

Major Goals

1. Determination of crustal types, architecture and plate configuration based on synthetic interpretation of reflection and refraction seismic images, and magnetic, heat flow and various types of gravity data (various degree of availability for different areas).
2. Development of thrustbelt/basin model from all available geophysical and geological data, including structural architecture and lithostratigraphy of accreted strata.
3. Development of stratigraphic models for key areas for basin modeling purpose with defined stratigraphic tops, major unconformities, depositional environment and lithology.
4. Definition of thermal histories for key areas based either on calibration data or choosing thermal regimes of present-day tectonic analogs.
5. Characterization of all involved source rocks, reservoir rocks, seals, determination of expulsion timing of working source rock kitchens, and migration pathways. This task will include determination of trap retention.
6. Inventory of oils, gases and potential source rocks from the region from all available sources.
7. Comparison of determined trap timing with calculated expulsion timing for all recognized petroleum systems in selected representative areas.

Study Area

The study area (see Figure 1 for location) incorporates thrustbelt portions of the Dinaridic, Albanidic, Hellenic and Apennine orogens, together with their individual foredeeps and shared foreland.

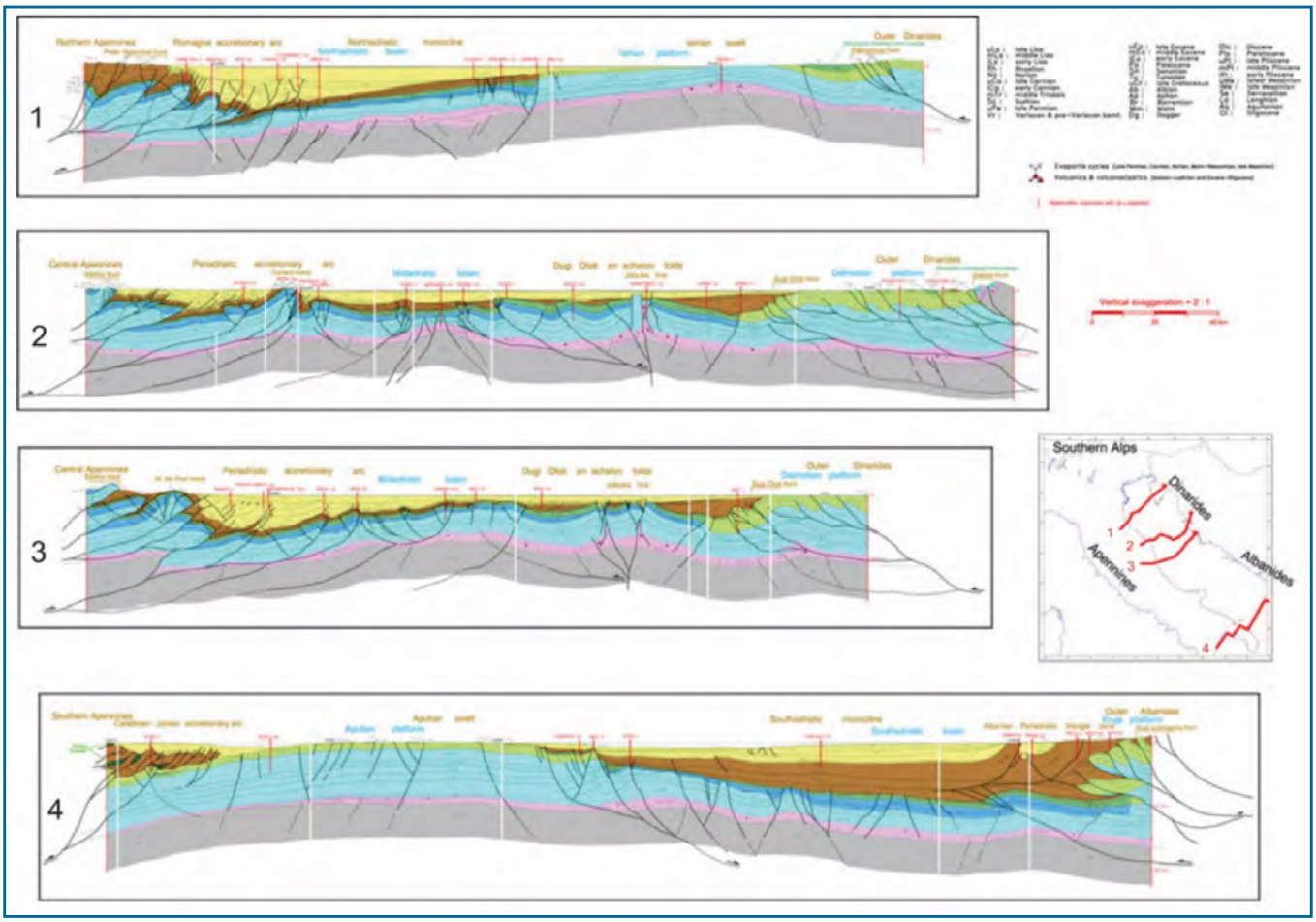

Figure 3: Deformed balanced profiles through the neighboring western and eastern thrustbelts slicing through the different parts of the orogenic system (Fantoni and Francoisi, 2010).

Significant Tasks

Available data gathering and processing leading to:

- Identifying and delineating thrust sheet geometries
- Determining lithostratigraphy of individual thrust sheets
- Developing thrustbelt geometry maps
- Determining thermal history of thrust sheets
- Determining burial history of sediments accreted in thrust sheets
- Determining migration pathways
- Developing thrust sheet development timing maps
- Determining trap retention
- Evaluating and ranking petroleum systems
- Developing GIS-based petroleum system models

Processing leading to individual petroleum system ranking:

- Source rock richness and maturity distribution maps
- Structures (structure mapping and timing)
- Reservoir categorization (permeability – qualitative or quantitative distribution maps, mapped permeability separation into categories; i.e., excellent, good, fair and poor)
- Seal categorization (permeability – qualitative or quantitative distribution maps, mapper permeability separation into categories; i.e., excellent, good, fair, poor)
- Expulsion timing determination
- Trap versus migration timing matching

Deliverables

1. Arc GIS project including all data, profiles and maps addressing problems to be solved, which are listed in the Task list.
2. Short explanatory text with accompanying graphic documentation on the results of the tasks focused on individual open problems listed in the Task list.

Research Team

Staff	Expertise/Affiliation
Michal Nemčok, Ph.D. Principal Investigator	Structural Geology, Research Professor – EGI, University of Utah
Júlia Kotulová, Ph.D. Co-Principal Investigator	Petroleum Geochemistry, Research Scientist – EGI, University of Utah
Samuel Rybár	Sedimentology Scientist – EGI, University of Utah
Professor Bruno Tomljenović	Department of Geology, University of Zagreb, Croatia
Dr. Marco Zanella	Carlo Magno, Madonna di Campiglio, Italy
Dr. Béla Márton	Mining Support Kft., Budapest, Hungary

Project Timeline, Report & Investment

Project duration is 12 months and investment per sponsor: $49,989 (USD). Project sponsors will be updated regularly regarding analyses and interpretations and a final report will be delivered after the final project meeting.

Tectonics												
Sedimentology												
Geochemistry												
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**

EGI Technical Contact

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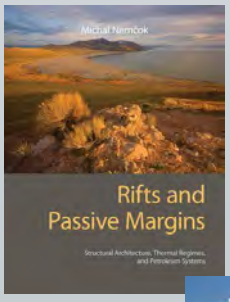
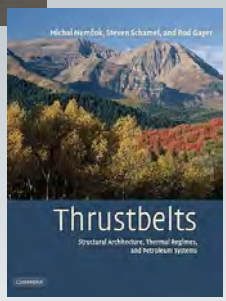
Research Interests

- Continental break-up processes and controlling factors
- Thrustbelt development and controlling factors
- Fracture development prediction





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Michal holds a Ph.D. in Structural Geology from the Comenius University, Bratislava. He has 35 years of applied and basic research experience at the Slovak Geological Survey, University of South Carolina, University of Wales, Cardiff, Imperial College London, University of Salzburg, University of Wurzburg, and University of Utah. He joined EGI in 1998 and is a Research Professor and Structural Group leader. Michal has published 80+ articles, coauthored 5 monographs, and coedited five books.

Continental Break-up Processes & Controlling Factors

Continental break-up research focuses on both extensional and transform settings, with a focus on driving mechanisms and controlling factors to achieve predictive models with respect to structural architecture, thermal regimes, and petroleum systems. The main research contribution includes understanding anomalous thermal and uplift histories of transform margins, break-up mechanisms in extensional settings, and micro-continent-releasing mechanisms. A summary of his last eight years of break-up research is recorded in a monograph titled *"Rifts and Passive Margins; Structural Architecture, Thermal Regimes and Petroleum Systems"* published by Cambridge University Press, and authored by Nemčok, M. Together with co-authors, a new monograph called *Strike-slip Terrains and Transform Margins—Structural Architecture, Thermal Regimes & Petroleum Systems* is being written in contract with Cambridge University Press.

Thrustbelt Development & Controlling Factors

Michal's current research focuses on the thrustbelt-foreland interactions, with a concentration on driving mechanisms and controlling factors behind thick-skin tectonics, foreland plate flexure mechanisms, and flexural faulting in control of structural architecture and play concept elements. The main research contribution includes the factors and mechanisms leading to the lack of foreland flexing and transitions from initial inversion to full accretion. Accompanying research focuses on modeling of the fluid flow mechanisms occurring in the thrustbelt front and its foreland. A summary of thrustbelt research is written in a monograph called *"Thrustbelts; Structural Architecture, Thermal Regimes and Petroleum Systems",* published by Cambridge University Press, and authored by Nemčok, M., Schamel, S. and Gayer, R.. Current research findings are summarized in several articles included in the Geological Society of London Special Publication 377, which is edited by Nemčok, M., Mora, A., and Cosgrove, J.

Fracture Development Prediction

Fracture prediction research includes both detailed well core, rock outcrop and numerical simulation studies focused on predicting timing, location and kinematics of developing fractures. Most of the fracture studies come from thrustbelts, although some core-based studies come from various geothermal reservoirs. The main research contribution includes tools capable of predicting fracture locations, kinematics and propagation timing in two and three-dimensions for hydrocarbon reservoirs in thrustbelts, which were tested by well-based fracture data. Accompanying research includes understanding the role of mechanical stratigraphy on developing structural architecture. This research is published in a number of journals run by structural and geothermal communities.

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Research Interests

- Unconventional Gas Systems
- Organic geochemistry
- Petroleum geology
- Organic petrology
- Basin modeling (PetroMod)
- Petroleum systems
- Anoxic events
- Calibration of organic and inorganic thermometers

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Júlia Kotulová, PhD

Research Scientist

Júlia earned a Ph.D. in Geology, an B.Sc., RNDr. (M.Sc. equivalent) in Geology, Geochemistry and Economic geology from Comenius University, Bratislava, Slovakia. Julia joined EGI in 2011 with extensive experience as a geochemist and petroleum geologist, having spent the previous nine years working at the Department of Geophysics and Non-Renewable Energy Sources, State Geological Institute of Dionýz Štúr (Geological Survey), Bratislava, Slovak Republic. Prior to this, Julia worked with the Geological Institute at Slovak Academy of Sciences. Julia collaborates with the geochemistry lab and other researchers in the Salt Lake City office from her primary location in EGI's Bratislava office.

Research Related to Hydrocarbon Systems

- Integration of geology, geochemistry, and basin modeling for a holistic understanding of hydrocarbon generation, migration, entrapment, and preservation in order to identify regional characteristics and to de-risk new exploratory plays and prospects. Design, acquisition, implementation and interpretation of geochemical data applied to petroleum exploration and exploitation.
- Design, implementation and management rock, oil, and gas sampling and analytical programs.
- Organic geochemistry research into the molecular and isotopic composition of source rocks, oils, and gases for reservoir geochemistry, source rock quality, and thermal maturity evaluation.
- Organic petrology research with an emphasis on source rock evaluation, coal and paleoenvironmental/organic facies characterization; multi-dimensional geochemical basin modeling for the reduction of petroleum exploration risk.

Global Basin Studies

Júlia has experience with various types of basins around the globe – from the Carpathian accretionary wedge, fore-arc basins, back-arc Black Sea and Danube Basins, and the intra-arc Transcarpathian Neogene Basin to the Intermountain Basins of Slovakia – with a focus on petroleum systems, geohistorical models, thermal evolution, and fluid flow dating and duration. Her experience with passive margin basins includes the Central and Equatorial Atlantic and NW Australian margins. She also has experience with shale gas research (Central Europe, Russia, Ukraine and South America) for biogenic and thermogenic shale gas systems, geological storage of CO_2 as related to the Northern part of the Pannonian basin system, Ocean Anoxic Events research (Aptian OAE 1a and Oligocene Antarctic glaciation Oceanic Anoxic Oi-1 events), PetroMod geochemical models and Petrel 3-D geological models (East Slovakian Neogene and Intermountain Horna Nitra Neogene basins), and visual kerogen analysis (Tethys: Aptian; Paratethys: Cretaceous to Neogene in the Carpathian accretionary wedge and the Circum Black Sea region, Neogene in the North part of the Pannonian Basin).