Horizon of ^{1}H-NMR for Energy issues

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AGH UST of Science and Technology

Horizon Europe Matchmaking Event
Energy Research

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Short introduction of the institution

Organizationally, **LaTiS - NMR Tomography & Spectroscopy Lab** is part of the Pore Systems research group. And it operates within the Fossil Fuels Department of the Faculty of Geology, Geophysics and Environmental Protection – one of the 17 faculties of AGH-UST.

Such a short story concerns LaTiS and the group of Pore Systems. To learn about the enormous potential of the entire AGH-UST, please visit the website:
WWW.AGH.EDU.PL

LaTiS - **NMR Tomography & Spectroscopy Lab and** Pore Systems research group:

WWW.NMRLAB.AGH.EDU.PL

Infrastructure: 4 NMR scanners, uCT scanner, MICP, etc

Research Team: Physicists, Chemists, Geologists, Geophysicists, Material Engineers, Programmers,..

Expertise (of your institution/company/university)

Your potential contribution to a consortium:

The LaTiS laboratory enables to conduct unique noninvasive investigations of porous systems by NMR methods and other complementary techniques according to the highest world standards, adding to them their own innovative solutions for diffusion measurements, protected by US, JP and European patents and international patent applications.

Keywords:

Rock cores (carbonates, sandstones, shales, zeolities, hydrogels), Porosity and its types, Types of fluids (water, hydrocarbons) and their binding degree in pores. Also under pressure overburden.

Running - EnerGizerS (2020 -2023): CO_2-Enhanced Geothermal Systems for Climate Neutral Energy Supply - The main aim of the Polish-Norwegian consortium is to take action supporting climate protection through the use of clean and eco-friendly geothermal energy with a simultaneous reduction in CO2 emissions from burning fossil fuels.

Completed international projects if any: NMR-ROCKS (2013-2017), ShaleCarp (2014-2018), BlueGas(2015-2019), ...

The National Centre for Research and Development

Norway grants

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Possible topic or topics of Horizon Europe you wish to address (please try to link it to the energy related topics we indicated in the invitation letter). If there are concrete calls, you are interested in, please specify!

This allows for a wide spectrum of research relevant to:

- renewable energy (bioenergy, geothermal, biofuels ..),
- carbon storage, hydrogen storage, hydrocarbon purification and separation...
- more you can imagine in relation to the title …….

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LaTiS
NMR Tomography & Spectroscopy Lab
AGH-UST, Department of Fossil Fuels

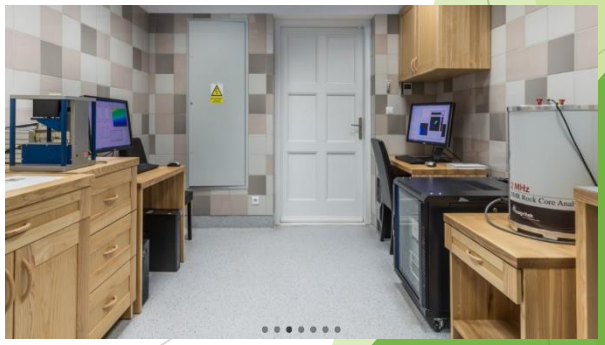
A - PSD and its types	B - Additional Geophysical parameters by NMR
Porosity and its distribution (PSD - Pore Size Distribution) measured with the minimum echo time TE = 40 us, • **Free and bound water content indices**: **FFI, BVI, CBW**, cut-off times (T2 Cutoffs) • **Types of liquids** filling the pore space - generation of 2D maps (after 1D and 2D Laplace transform), relaxation time distributions T1, T2 and diffusion coefficient D: D-T2, T2-T1, T2-T2, also in the spatial version (Spatially resolved T2).	• **Saturation profiles** and spatial pore distribution profiles, • **Permeability** - determined from the pore distribution, • **Conductivity** – 2D, 3D determined form DTI, • **Capillary pressure** with pore constraints. • Measurement of **profiles**, relaxation times **T1, T2 and diffusion** coefficients in the presence of **high gradients (22T/m)** with a resolution of 10μm (NMR-MOUSE).
C - Measurement in overburden conditions	**D - 2D and 3D measurements at Low or High Field NMR**
• Measurement of profiles, relaxation times T1, T2 and diffusion coefficients under **overload conditions** (up to 6000 Psi) (RCA-2MHz).	• **LF** 1D-3D **MR imaging** with one of following sequences: SE, SE-DWI, RARE, EPI, **SPI**, SPRITE (24MHz) sequences. • **HF** 2D-3D high field **MR imaging** with following sequences: **ZTE**, EPI, (400 MHz) sequences.

• **2 MHz NMR Rock Core Analyzer** with a diffusion system, designated for testing porous systems, in particular shale rocks and tight types.

• **24 MHz Tomography** system that allows to perform complete tomographic experiments 1-3D.

• **Rock core pressure system** - an adapter for measurements under simulated pressure conditions, allowing testing of samples at pressures up to 6000 psi.

• **20 MHz NMR-MOUSE** that allows to study objects in the presence of high gradient fields (22T/m) and a resolution of up to 10μm.



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Own innovative solutions

- A method of **precise determination of porosity in the full range** (including nanoporosity) and its types (for shale and rock type tight) taking into account and eliminating signals from the matrix, OH groups, organic matter, clay minerals.
- **ILT software** - own algorithms for Inverse Laplace Transform.
- **GLLP** program - Platform between **laboratory** data and **well-logging** data, especially dedicated for applications to well logging/ seismics softwares.
- **BSD-DTI** program - For analysis and visualization of **coefficients and diffusion tensors**.
- **Method** for testing the coefficients and diffusion tensor in DWI and DTI experiments also using **BSD-DTI** (protected by US, JP and European patents)

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Selected publications in papers included in the JCR database (2016-2021) containing the results of research on porous systems in geology, geophysics, material engineering

- Aliya Mukhametdinova, et all. **NMR relaxometry interpretation of source rock liquid saturation — A holistic approach. Marine and Petroleum Geology 2021**, 132, 105165. https://doi.org/10.1016/j.marpetgeo.2021.105165.
- Wagemann, et all. **Screening Metal–Organic Frameworks for Separation of Binary Solvent Mixtures by Compact NMR Relaxometry**. **Molecules 2021**, 26, 3481. Stoch, G et all. **Enhanced Resolution Analysis for Water Molecules in MCM-41 and SBA-15 in Low-Field T2 Relaxometric Spectra**. **Molecules 2021**, 26, 2133. Mazur, W. et all. **Attempts at the Characterization of In-Cell Biophysical Processes Non-Invasively—Quantitative NMR Diffusometry of a Model Cellular System. Cells 2020**, 9, 2124.
- Mastalska-Popławska, J et all. **Water Interactions in Hybrid Polyacrylate-Silicate Hydrogel Systems. Materials 2020**, 13, 4092.
- A. Fheed, et all. **Fracture orientation and fluid flow direction recognition in carbonates using diffusion-weighted, nuclear magnetic resonance imaging: An example from Permian. Journal of Applied Geophysics 2020**; 174: 103964
- A. Krzyżak, et all. **Identification of Proton Populations in Cherts as Natural Analogues of Pure Silica Materials by Means of Low Field NMR**. **The Journal of Physical Chemistry C 2020**; 124(9):5225-5240.
- Artur T. Krzyżak, et all. **Overcoming the barriers to the exploration of nanoporous shales porosity**. **Microporous and Mesoporous Materials 2020**; 298: 110003.
- J. MASTALSKA-POPŁAWSKA, et all. **Synthesis and characterization of cross-linked poly(sodium acrylate)/sodium silicate hydrogels**. **Polymer Engineering and Science 2019**; 59(6): 1279–1287.
- A. Fheed, et all. **Exploring a carbonate reef reservoir – Nuclear Magnetic Resonance and Computed Microtomography confronted with narrow channel and fracture porosity. Journal of Applied Geophysics 2018**; 151:343-358.
- W. Węglarz, et all. **ZTE MRI in high magnetic field as a time effective 3D imaging technique for monitoring water ingress in porous rocks at sub-millimetre resolution. Magnetic Resonance Imaging 2018;** 47:54–59.
- Z. T. Lalowicz et all.. **Translational and Rotational Dynamics of molecules confined in zeolite nanocages by means of deuteron NMR**, **J. Phys. Chem. C 2017**; 121(47):26472–26482.
- A. Fheed, A. Krzyżak. **A textural and diagenetic assessment of the Zechstein Limestone carbonates, Poland using the transverse Nuclear Magnetic Resonance relaxometry**. **Journal of Petroleum Science and Engineering 2017**; 152:538-548.
- Ł. Kaczmarek, et all. **High-resolution computed microtomography for characterization of a diffusion tensor imaging phantom. Acta Geophysica 2017**; 65:259-268..
- I. Habina, et all. **Insight into oil and gas-shales compounds signatures in low field 1H NMR and its application in porosity evaluation**. **Microporous and Mesoporous Materials 2017**; 252:37-49.
- A. Krzyżak, et all. **Low field 1H NMR characterization of mesoporous silica MCM-41 and SBA-15 filled with different amount of water**. **Microporous and Mesoporous Materials 2016**; 231:230-239.
- W. Węglarz et all.. **ZTE imaging of tight sandstone rocks at 9.4T - comparison with standard NMR analysis at 0.05 T. Magnetic Resonance Imaging 2016**; 34(4):492-495.

Thank you for your attention and welcome for cooperation

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