

Once upon a time ...

Laboratory testing of thermal water reinjection



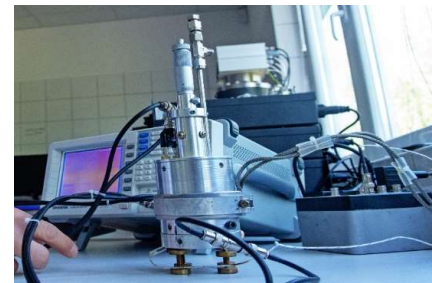
Ferenc Fedor, PhD, MBA

Owner, CEO
GEOCHEM Ltd.

Reinjection workshop, Szeged, 16.04.2024

Short introduction of our activity related to the water reinjection

- 15 years experience in geothermal R&D&I
- Methodological, equipment and software development related to this field
- R&D management of various EU founded or partially founded geothermal projects (GOP, GINOP)
- Fully equipped petrophysical and well completion investigation laboratory
- International relations via CAPES (Geoenergy Europe Metacluster – COSME financed)



OUR SERVICES

- **Reservoir qualification**

- Acoustic velocity measurement – SRL-A1000
- Reservoir state permeability measurement – RS-PPD-1
- Gas permeability measurement – Coreval-700
- Measurement of electrical properties – EPS 700
- Relative permittivity measurement



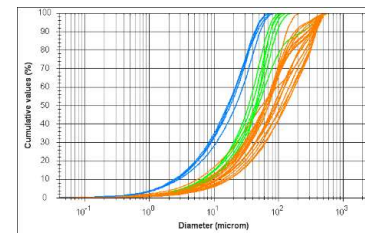
- **Pore structure investigation**

- Porosity and density measurements – gas pycnometer - Pentapyc 5200e
- Pore size distribution measurement – mercury-porosimeter - Poremaster-60 GT
- Physisorption-, microporosity measurement – Autosorb-1-MPV



- **Grain size/shape analysis-sedimentology**

- Particle size distribution measurement – CILAS 1180 LD
- OCCHIO Zephyr ESR
- ISO/ASTM Sieve analysis



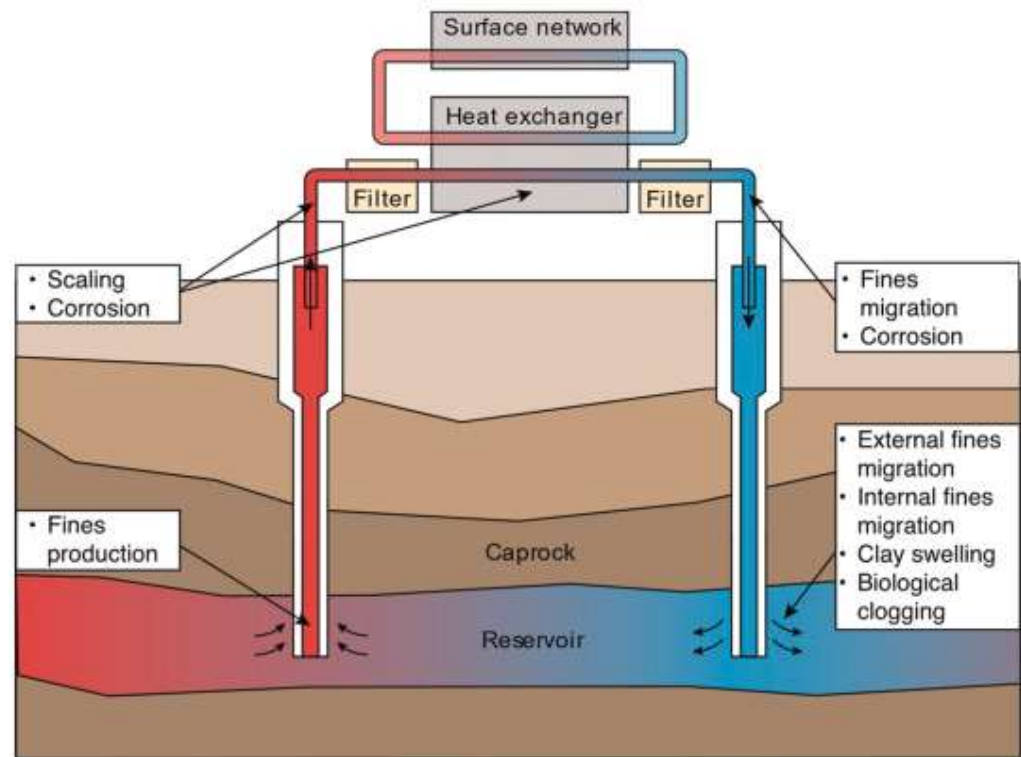
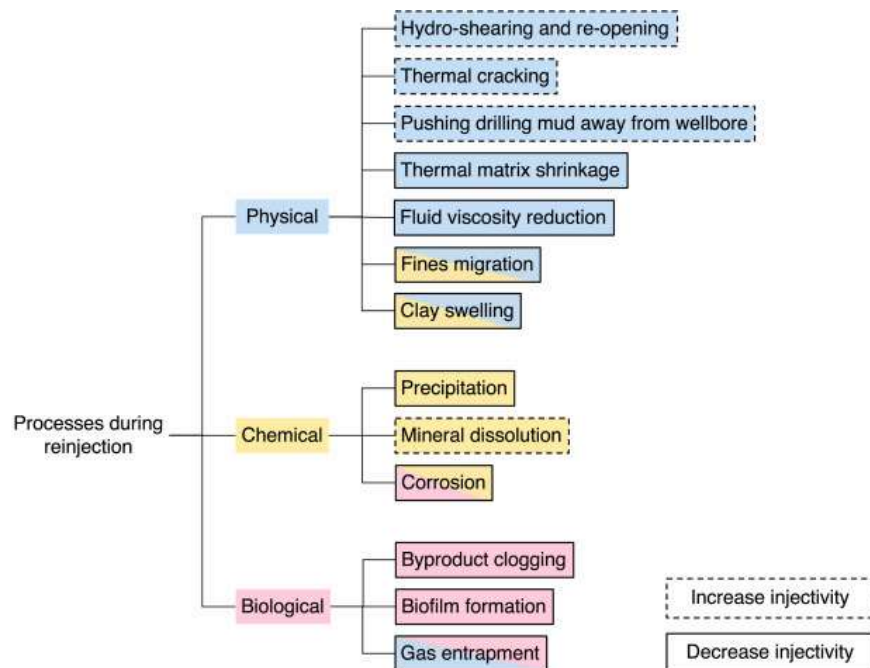
OUR SERVICES

- **Drilling & Stimulation Properties (joint operation with Mecsekérc)**
 - Formation damage evaluation system – self designed
 - Fracture conductivity measurement system – self designed
 - Leak-off measurement system – self designed
 - Proppant qualification (ISO 13503-5)
 - HPHT mud/gel viscosity - CHANDLER 5550
- **Aging**
 - Benchtop Temperature Humidity Test Chamber (Xi'an LIB)
- **Sample preparation**
 - Drilling, end-facing, embedding, drying, 3D scanning, etc.
- **Product, method and software development (R&D)**
 - Cryodesiccation
 - Smartlab
 - Artificial cores
 - MEIT3D



Formation damage – Prevention instead of repairing a damaged zone

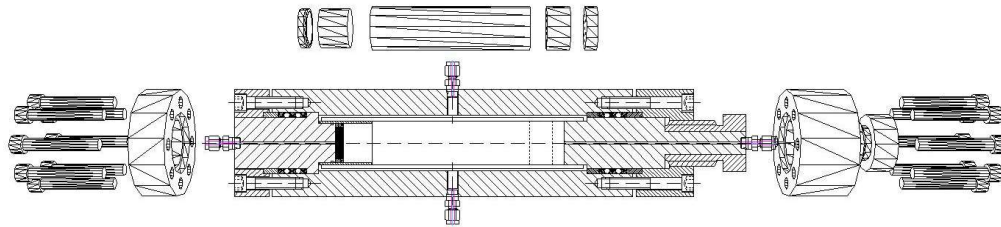
„Formation damage is an undesirable operational and economic problem that can occur during the various phases of oil and gas recovery from subsurface reservoirs including drilling, production, hydraulic fracturing, and workover operations.”
(Civan, 2005)



Drilling & Stimulation Properties – Formation Damage Evaluation and Simulation

- Formation damage testing (with gravel packed core holder)

Pore pressure:	max. 400 bar
Confining pressure:	max. 1000 bar
Differential pressure on rock:	max. 30 bar
Temperature:	max. 150 °C
Liquid inflow speed:	1-60 cm ³ /min
Core sample-1:	Ø1-1,5"x50-200 mm with 3 core holders
Saturation:	water and oil saturation is provided with a pump
Sample arrangements:	sandstone, sandstone+proppant+filter sand+proppant+filter.
Filter:	wire filter, $d_{50} \approx 5 * D_{50}$
Flow:	two way
Turning and rotating of core holder	30°, 60°, 90°

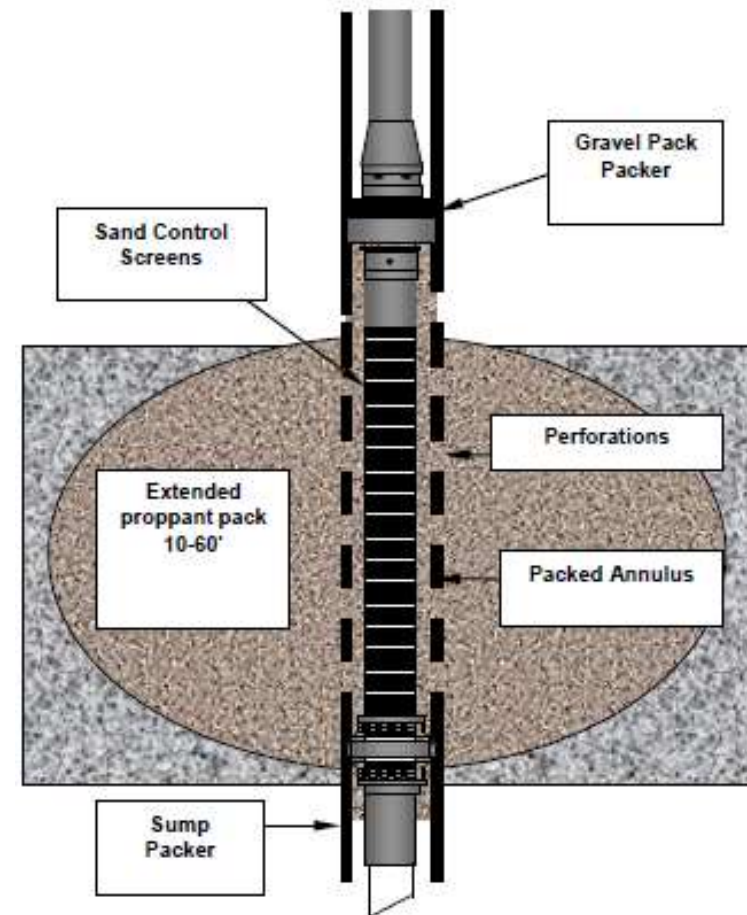


- Gravel packing experiments
- Inverse-reverse permability of the system
- Critical flow velocity measurements
- Clogging experiments
- Formation stimulation
- Water-water, water-rock interaction

Well completion: Frac&pack, proppant conductivity

Questions:

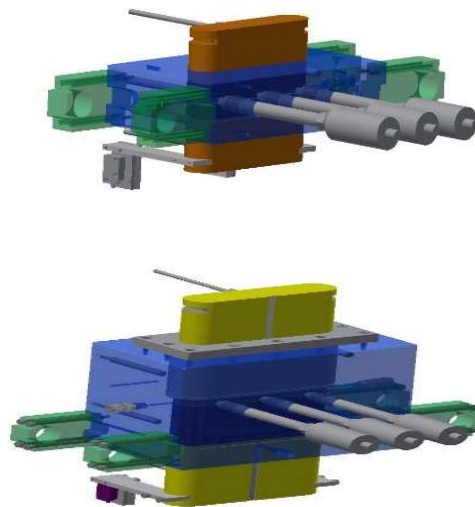
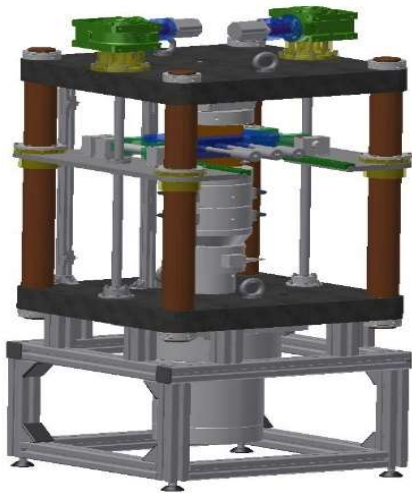
- How can we design hydraulic fracturing?
- What proppant can be used?
- How can we design the injection fluid to deliver the proppant to the fracture zone?
- How does the behaviour and permeability of the proppant change during stress?
- How can the formation be stimulated?
- Etc.



Drilling & Stimulation Properties – Proppant conductivity evaluation system

- Fracture Conductivity Measurement**

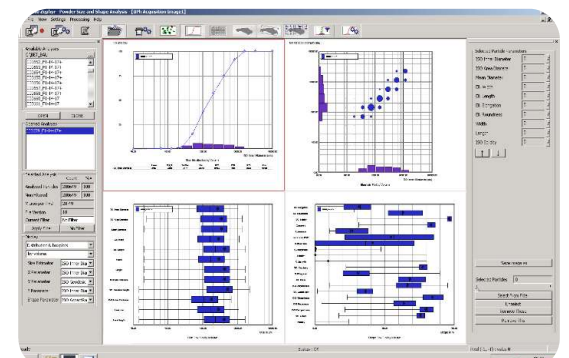
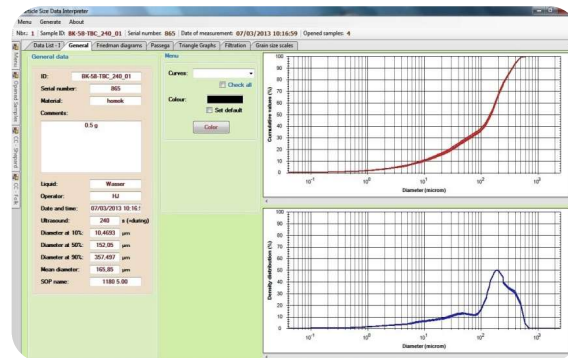
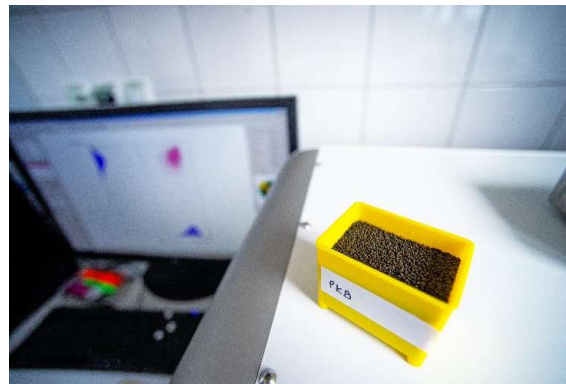
Max. Loading	650 kN (~ 1000 bar fracture closure stress)
Max. Temperature	300 °F / 150 °C
Max. Pore Pressure	70 bar
Tech standards	ISO 13503-5:2006, API1 RP-612
Sample	Special form



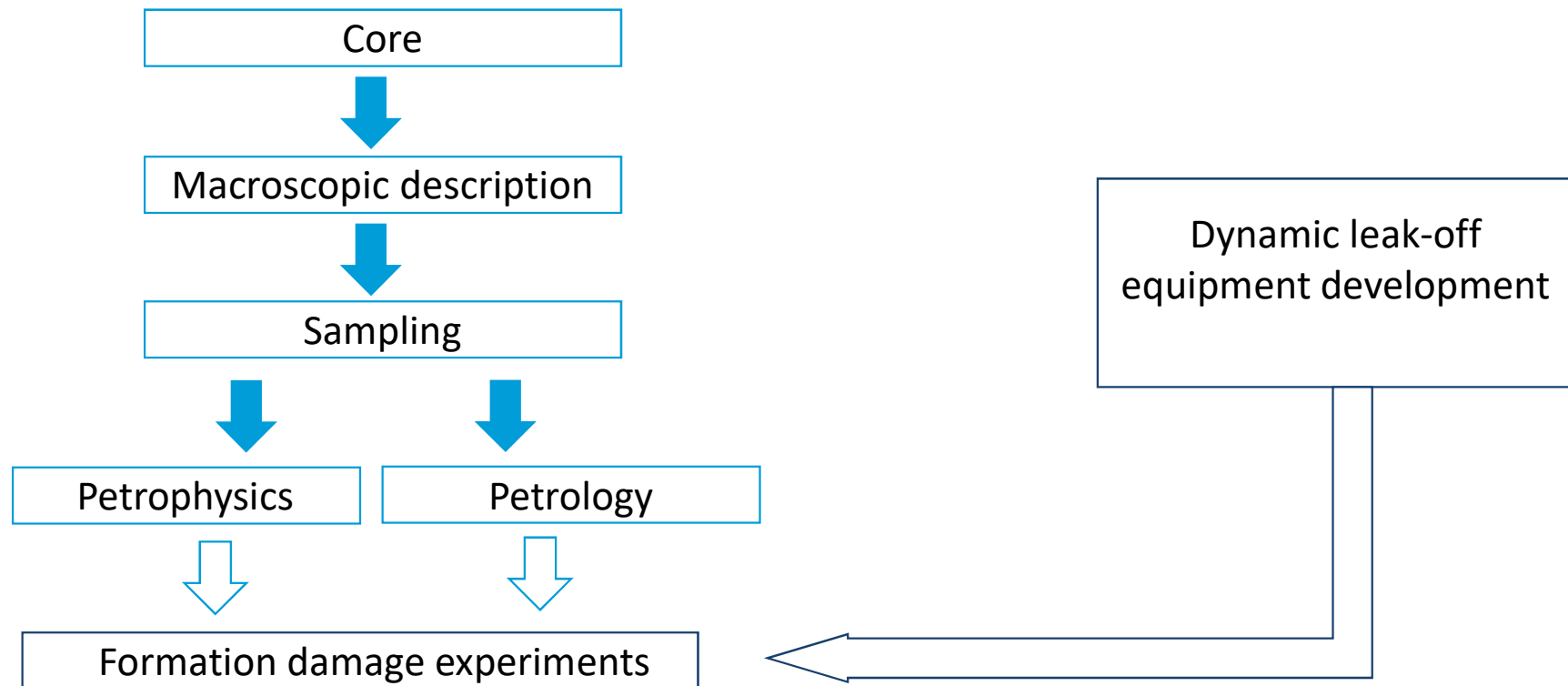
Drilling & Stimulation Properties – Proppant qualification

ISO 13503-2: Measurement of properties of proppants used in hydraulic fracturing and gravel-packing

- Sieve analysis
- Proppant sphericity and roundness
- Acid solubility
- Turbidity test
- Bulk density, apparent density and absolute density
- Crush-resistance test



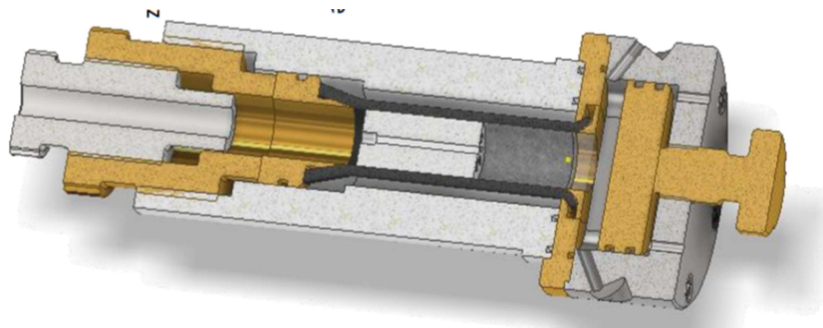
Dynamic leak-off experiences - workflow



Drilling & Stimulation Properties – Dynamic leak-off measurement system

- Dynamic leakoff test apparatus

Max. Pore Pressure	2,000 psi / 14 MPa
Max. Confining Pressure	7,250 psi / 50 MPa
Max. Temperature	300 °F / 150 °C
Shear rate in the cell	40 / sec
Max. shear rate in the shear history simulator	~ 3000 / sec



Leak-off parameters

Dynamic mud filtration

Inverse-reverse permeability of mud
filtrated rock

NAME	DATE
MM079-3M-T-01LEAKOFF	2022-09-07
MM079-3M-T-02LEAKOFF	2022-09-07
MM079-3M-T-03LEAKOFF	2022-09-07
MM081-2M-T-01LEAKOFF	2022-09-06
MM081-2M-T-02LEAKOFF	2022-09-06
MM079-4M-T-01LEAKOFF	2022-09-07
MM079-3M-T-LEAKOFF	2022-09-07
MM079-2M-T-FULLLEAKOFF	2022-09-07
STATUS_2022_09_05_1LEAKOFF	2022-09-06
STATUS_2022_09_05_2LEAKOFF	2022-09-06
TEST3LEAKOFF	2022-09-06
STATUS_2022_09_05_1LEAKOFF	2022-09-06
STATUS_2022_09_05_2LEAKOFF	2022-09-06
STATUS_2022_09_02_FOLLYLEAKOFF	2022-09-06
STATUS_LEAKOFF	2022-09-06
STATUS_2022-09-02LEAKOFF	2022-09-06

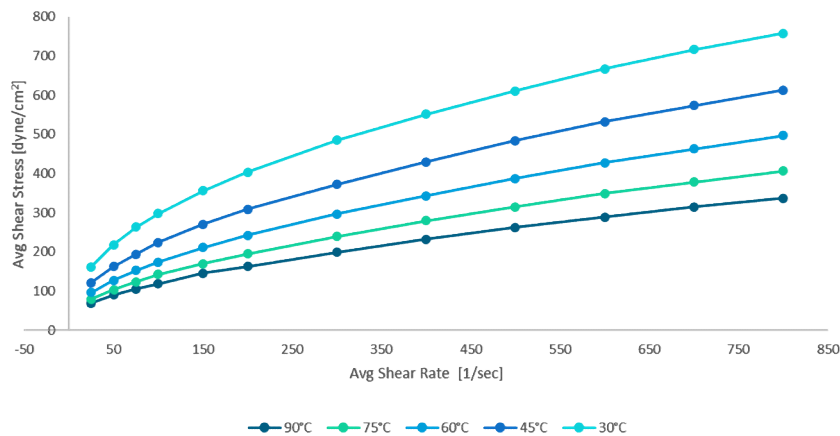
GENERAL PROPERTIES	DATA LOG
MEASUREMENT NAME	MM079-3M-T-01
MEASUREMENT DATE	2022-09-07
SAMPLE IDENTIFIER	MM079-3M-T-01
SAMPLE MATERIAL	Granite
OPERATOR	Granite
SAMPLE DIAMETER (MM)	10.5
SAMPLE LENGTH (MM)	10.5
SAMPLING INTERVAL (SEC)	2
LIQUID TYPE	Water
LIQUID DENSITY	1
START DATA LOG	RESET EXPORT

Petroleum and natural gas industries. Completion fluids and materials.
Part 6: Procedure for measuring leakoff of completion fluids under dynamic conditions
(ISO 13503-6:2014)

Drilling & Stimulation Properties – Rheological characterisation

- Chandler Instruments – Model 5550 HPHT Viscometer**

Max. Pressure	2,000 psi / 14 MPa
Max. Temperature	500 °F / 260 °C
RPM / Shear Rate	0,1-1000 rpm with standard R1 rotor and B5 bob
Shear rate accuracy	+/- 0,01 rpm
Tech standards	ISO 13503-1, API RP 39



T [°C]	K'	n'	τ	μ^* @170 s ⁻¹ [cP]
30	3,823	0,446	37,77	222
45	2,59	0,47	28,95	170
60	1,939	0,481	22,93	135
75	1,576	0,481	18,64	110
90	1,458	0,464	15,80	93

MAIN RELATED REFERENCES:

Petroleum Industry – Upstream

- **2020 –** : Water-rock interaction, relative permeability, critical flow velocity: TDE IST, PetrolGeorge
- **2019 –** : Petrophysical investigations on reservoir rocks for MOL, TDE IST, O&GD, PetrolGeorge
- **2014 – 2015:** Petrophysical investigations on reservoir rocks for RAG Kiha Ltd.

Geothermal research:

- **2012-2014:** R&D work related to Mecsekérc Plc's GOP-1.1.1-11-2012-0033 project (petrophysical qualification of Upper Pannonian core samples, investigation of migrating clay content, the determination of best practices of well completion in unconsolidated sandstones, etc.)
- **2017- :** R&D work related to Mecsekérc Plc's GINOP-2.2.1 project (petrophysical qualification of Upper Pannonian core samples, investigation of migrating clay content, the determination of best practices of well completion in unconsolidated sandstones, etc.)

SOME PUBLICATIONS:

HORVÁTH, J., KORONCZ, P., FEDOR, F., HLATKI, M.: ***Petrophysical and geomechanical analysis of Upper Pannonian unconsolidated sandstones***, in Török, Á., Görög, P., Vásárhelyi, B. (eds) Civil Engineering and Rock Mechanics 2013, Hantken, Budapest, pp. 229-240 (Hungarian) (ISBN 978-615-5086-06-09)

HORVÁTH, J., KORONCZ, P., FEDOR, F.: ***Petrophysical and hydrodinamical investigation of unconsolidated rocks – measurement vs. empirical estimation***, in: Cvetkovic, M., Novak-Zelenika, K., Geiger, J. (eds) Geomathematics – from theory to practice, Croatian Geological Society, 2014, pp. 167-174 (ISBN 978-953-95130-8-3)

PUSZTAI, P., KORONCZ, J.P., KUNCZ, M., JOBBIK, A., FEDOR, F.: ***A New Method for Determining Propped Fracture Permeability***, In: Hatvani, I.G., Erdélyi, D., Fedor, F.: Abstract book of the GeoMATES'22, p.88, 19-21.05.2022, Pécs, ISBN: 978-963-7068-14-0

KORONCZ, P., VIZHÁNYÓ, Zs., FARKAS, M. P., KUNCZ, M., ÁCS, P., KOCSIS, G., MUCSI, P., FEDOR-SZÁSZ, A., FEDOR, F., KOVÁCS, J.: ***Experimental Rock Characterisation of Upper Pannonian Sandstones from Szentes Geothermal Field***, Hungary, Energies 2022, 15(23), 9136; <https://doi.org/10.3390/en15239136>

PUSZTAI, P., KORONCZ, P.J., KUNCZ, M., JOBBIK, A., FEDOR, F.: ***Semi-analytical approach to the determination of fracture permeability***, Int. J. Geomath 14, 16 (2023). <https://doi.org/10.1007/s13137-023-00227-8>



That's all the tale!
Thank you for your kind attention!

Epilogue

Due to the economic situation, one of the best equipped petrophysical laboratories in the EU closes and its equipment is sold. It's up to you to re-open it elsewhere, under someone else's ownership, or lose 15 years of innovation and knowledge. If the latter happens, building a new laboratory will require an investment of billions of forints and at least 2-3 years to acquire the adequate knowledge.