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The importance of measuring thermal and acoustic properties on rock analogues in geothermal potential assessment studies: the example of Northern Apennines Triassic carbonate platform and underlying basement rocks

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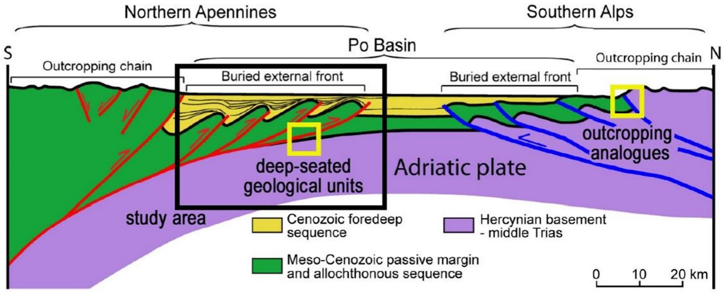
INTRODUCTION

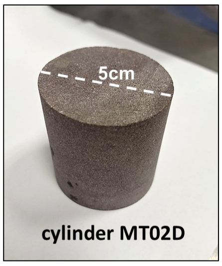
Regional-scale geothermal potential assessment relies on geological, petrophysical and thermal modelling strategies. The InGEO project aims to develop an innovative exploration workflow that integrates geological and geophysical data as well as other direct and indirect information to characterize the geological and thermal structures of the deep-seated Mesozoic carbonate reservoir in the Romagna and Ferrara buried folds sector. The Romagna and Ferrara folds (black rectangle) represent the outer deformation front of the Northern Apennines thrust and fold belt, which is buried under a thick foredeep clastic sequence deposited during the Alpine (Eocene-Miocene) and the Apennine (Pliocene-Quaternary) sedimentation cycles. During the Neogene-Quaternary compressive tectonics the Mesozoic carbonate sequence has been significantly deformed resulting in multiple thrust structures and shallow ramp anticlines.

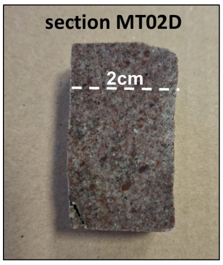


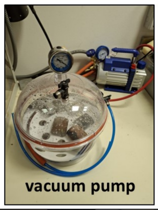
MATERIALS AND METHODS

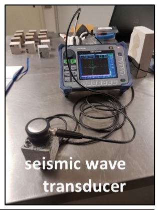
We conducted a field campaign aimed at collecting and investigating the physical properties (mechanical and thermal) of rock samples representative of the Northern Apennines Triassic carbonate platform and underlying basement rocks. As in the study area these geological units are deeply buried (> 5 km), we collected lithological analogues outcropping in the Southern Alps (Iseo Lake area), which rely to the Adriatic Plate Meso-Cenozoic passive margin and Hercynian basement (yellow rectangles).

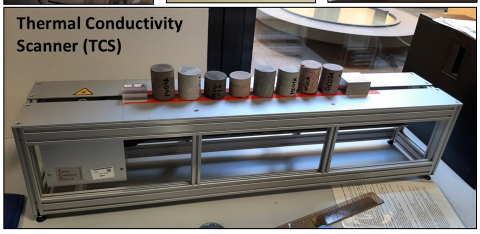
Sampling Fieldwork











Sample preparation and characterization

The rock samples are cut to obtain a cylindrical shape with dimensions appropriate for the laboratory measurements. Thin sections for petrographic studies are prepared.

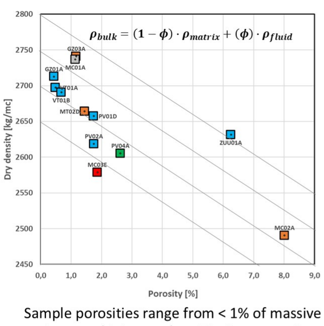
Sample	Unit	Lithology	ρ_b (g/cm³)	V_b (cm³)	ρ_o (%)	λ (W/m·K)	α (m²/s)	C_p (J/kg·K)	V_p (m/s)	V_s (m/s)	ν (-)	E_D (GPa)	UCS* (MPa)
GZ01A	ANG	limestone	2,71	98,6	0,44	3,24	1,43E-06	835	5143	3327	0,14	68	93
PV01D	BRU	limestone	2,66	65,4	1,74	2,84	1,38E-06	776	5714	2948	0,32	61	86
PV02A	BRU	limestone/chert	2,62	100,6	1,75	2,75	1,51E-06	697	5556	3067	0,28	63	88
ZUU01A	ZUU	limestone	2,63	74,4	6,25	2,36	1,14E-06	789	4054	2404	0,23	37	63
VT01A	GVT	dolomite	2,70	94,5	0,49	2,97	1,32E-06	833	6629	3315	0,33	79	101
VT01B	GVT	dolomite	2,69	99,9	0,68	3,07	1,42E-06	802	6238	3166	0,33	72	95
PV04A	RSL	marl	2,61	104,7	2,62	2,71	1,25E-06	832	5161	2840	0,28	54	80
MT02D	SRV	sandstone	2,66	90,0	1,44	3,50	1,50E-06	875	5122	3096	0,21	62	71
GZ03A	CDG	sandstone	2,74	94,2	1,17	3,24	1,54E-06	768	3816	2652	0,03	-	-
MC02A	CDG	sandstone	2,49	108,2	8,01	2,88	1,30E-06	891	2481	1650	0,10	15	26
MC01A	MVX	micashist	2,74	95,0	1,14	3,19	1,75E-06	667	2984	1917	0,15	23	-
MC03E	MVX	rhyolite	2,58	78,7	1,87	2,87	1,65E-06	677	5155	3106	0,22	60	253

*UCS calculated according to Rahman et al. 2023 from E_D

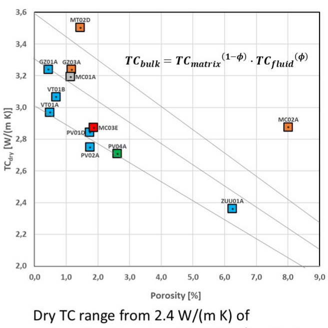
RESULTS

In total **44 samples** has been collected from different geological units. Laboratory analyses (petrographic and geophysical) are in progress. The following petrophysical properties are investigated:

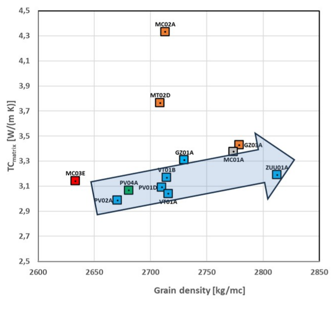
- Density and porosity (according to EN 1936:2006)
- Thermal properties (thermal conductivity, thermal diffusivity)
- Mechanical properties (dynamically measured compressional and shear waves velocities)
- Mineral composition



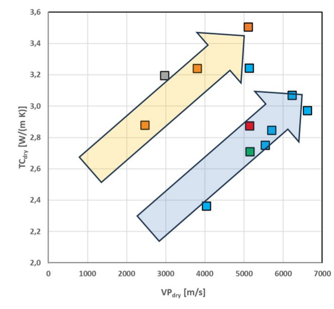
Sample porosities range from < 1% of massive carbonates (dolostone) to 8% of metasandstones. Overall, dry bulk density decreases with increasing porosity following a linear relationship.



Dry TC range from 2.4 W/(m K) of carbonates (limestone) to 3.5 W/(m K) of metasandstones. Overall, dry TC decreases with increasing porosity. The geometrical mean model is in accordance with the measured data.



For air-TC = 0.025 W/(m K) and adopting the geometric mean model for dry-TC, the rock's solid matrix TC is estimated. TC_{matrix} is sensitive to the type and proportion of mineral phases. High TC values (metasandstones) are due to the Quartz. The carbonate-TC slightly increases as function of grain density as dolomite fraction increases at the expense of the calcite fraction.



Preliminary relationships between two or more petrophysical parameters can be calibrated for our study area. Of interest is to investigate functions that link thermal conductivity to seismic velocity. For metasandstones and carbonates a linear relationship can be highlighted.

Carbonates → TC(VP) = 0.2 x VP [km/s] + 1.7 [W/(m K)]

Metasandst → TC(VP) = 0.2 x VP [km/s] + 2.3 [W/(m K)]