Investigation of deep thermal state in buried Romagna and Ferrara fold sector

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Innovation in **GEO**thermal resources and reserves potential assessment for the decarbonization of power/thermal sectors

Study area e DB information

The database of Romagna and Ferrara folds sector is composed by 867 boreholes from BNDG and other open sources (ex: Videpi). This information can be extracted for each well:

- Type of data available (Thermal and Lithostratigraphic data);

Well data availability

- 🟢 Thermal data
- 🔵 Lithostratigraphic data
- 🟡 Thermal & Lithostratigraphic data

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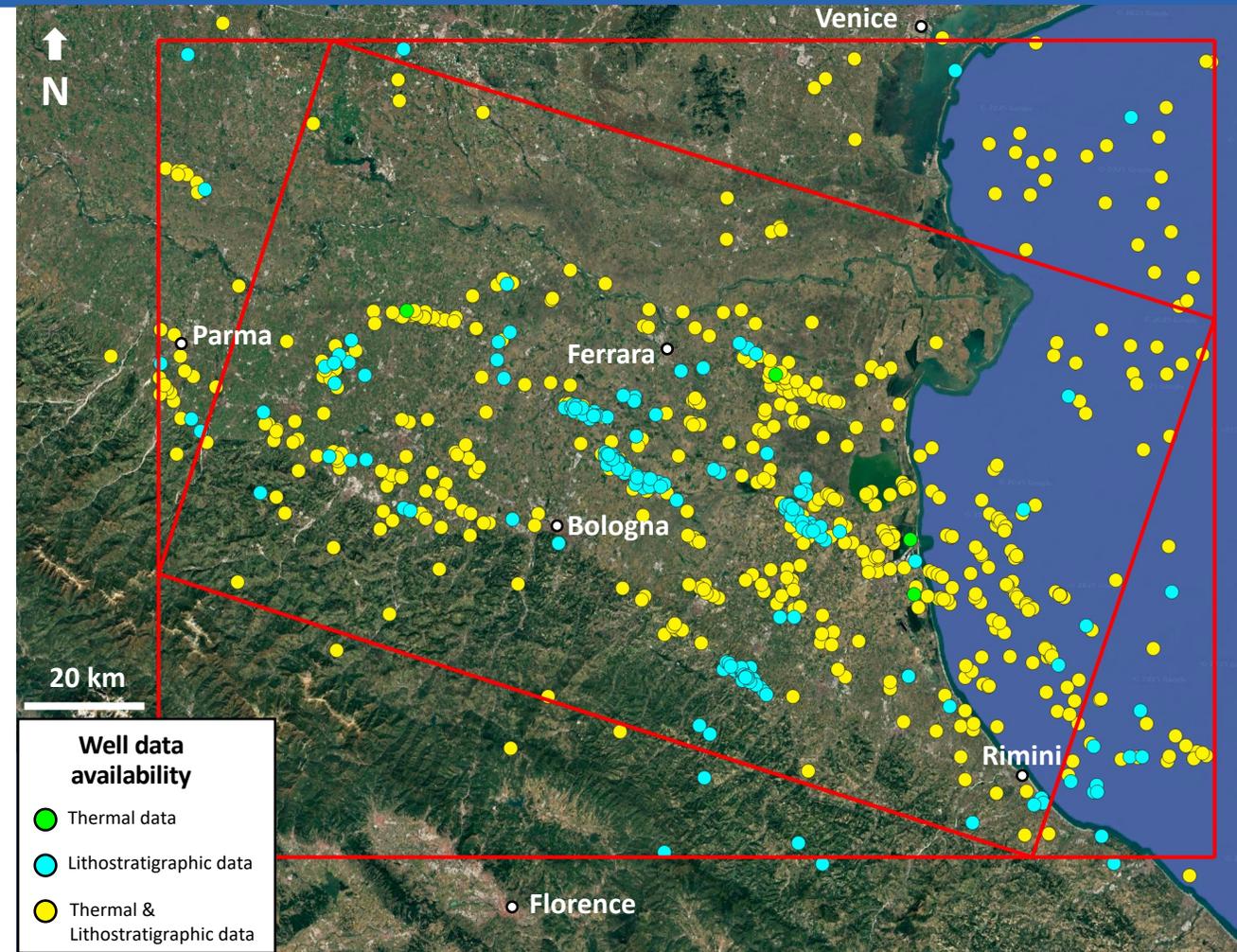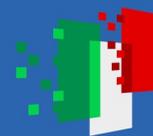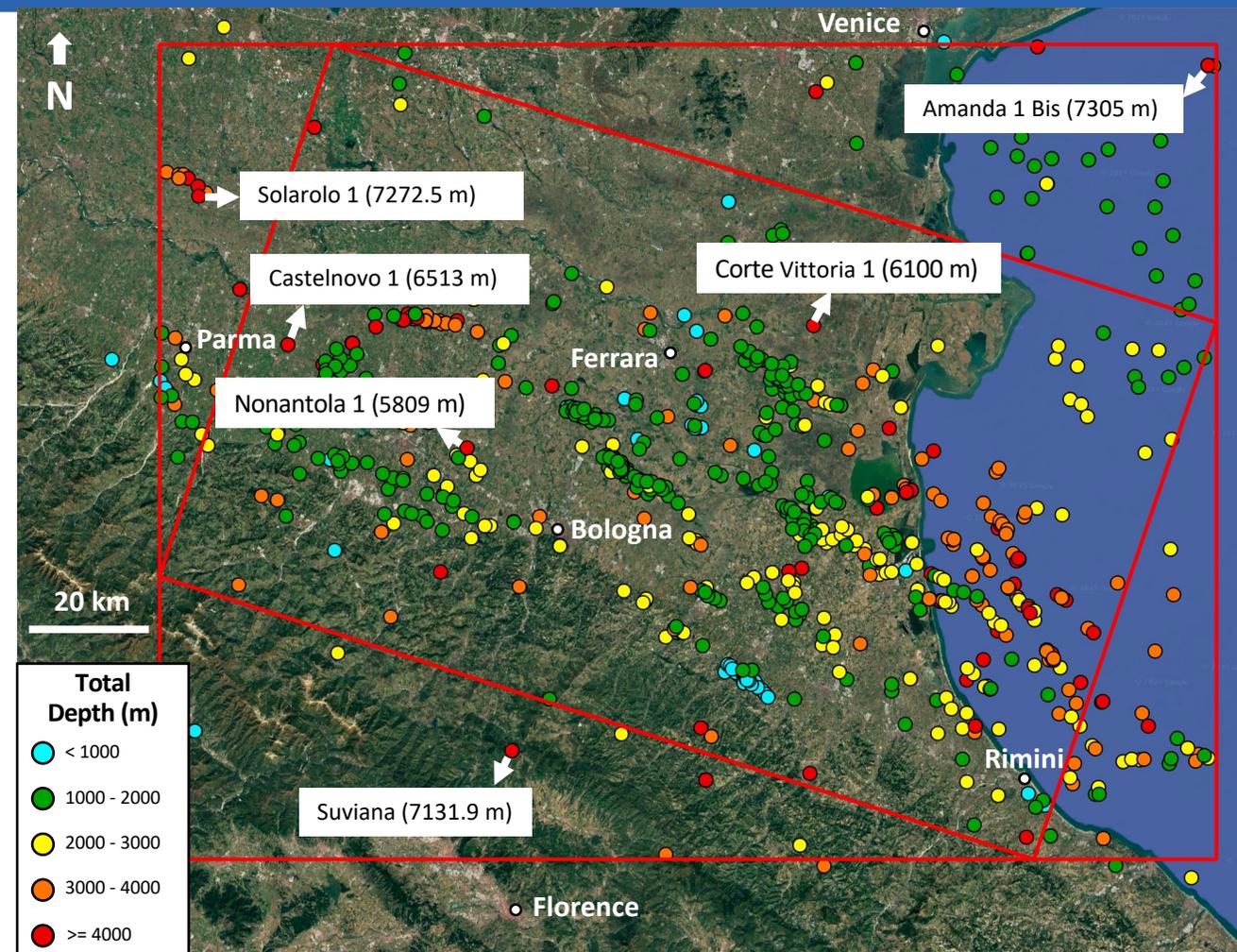
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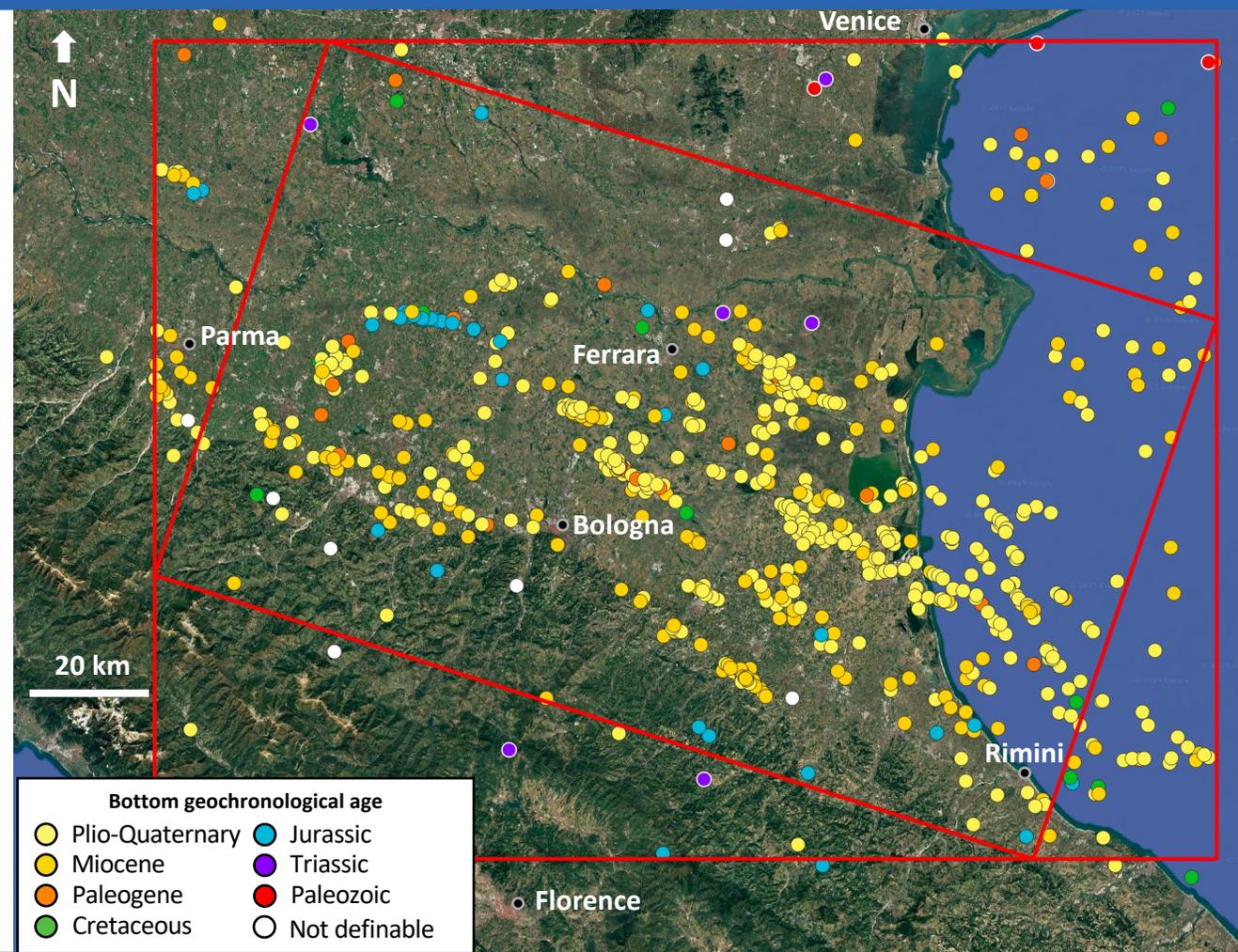
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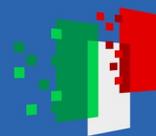
- Bottom hole geochronological age;

Bottom geochronological age
- Plio-Quaternary
- Miocene
- Paleogene
- Cretaceous
- Jurassic
- Triassic
- Paleozoic
- Not definable
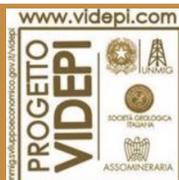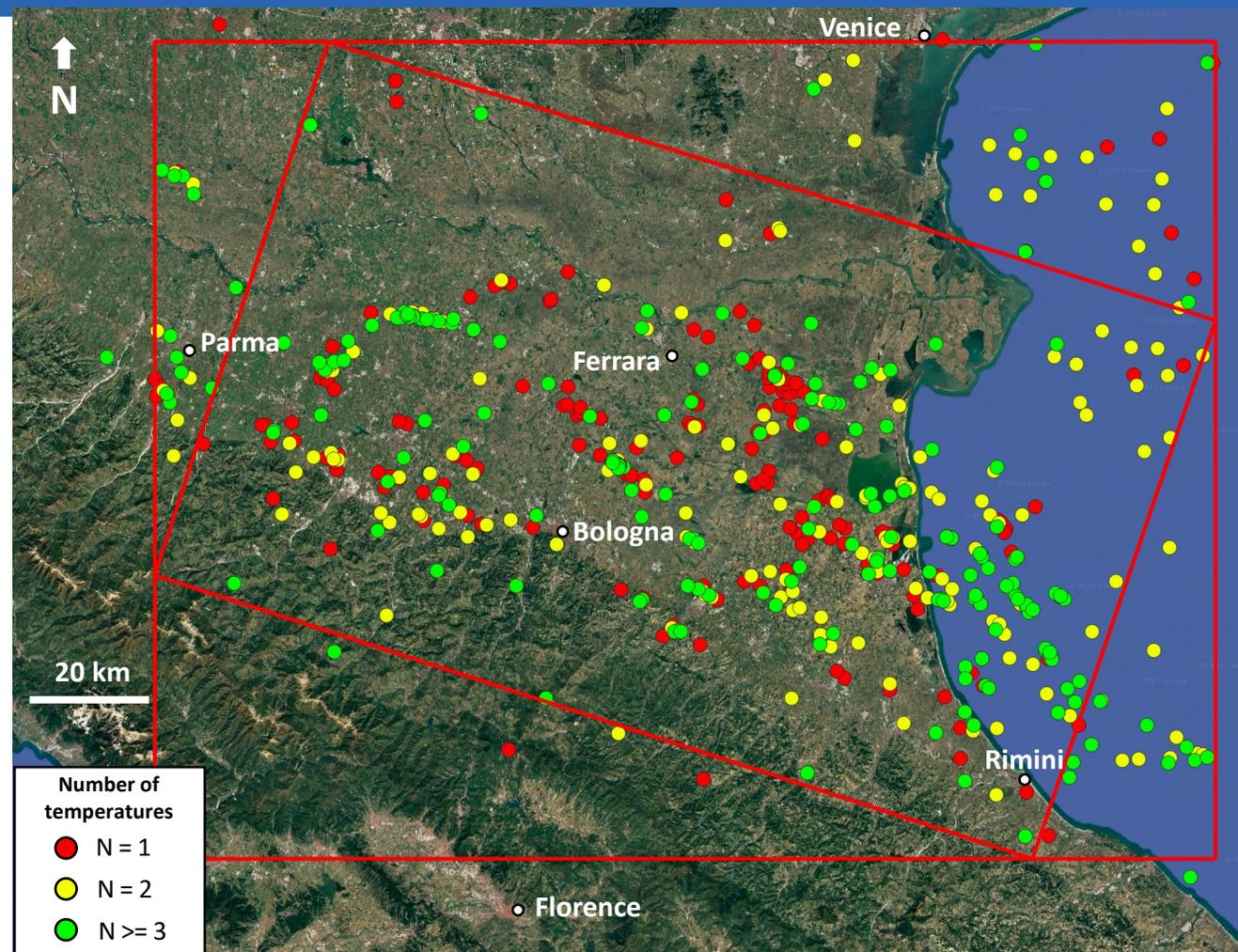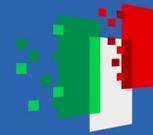
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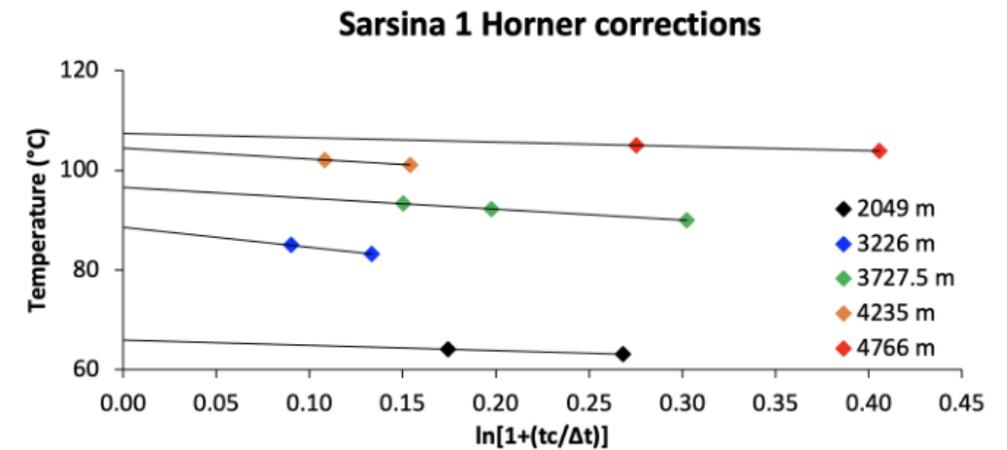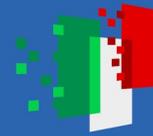
- Number of temperatures (BHT & DST).
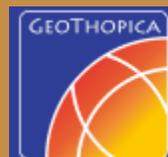
CORRECTION OF TIME-TEMPERATURE SERIES: HORNER METHOD

Horner method (1951) is based on the linear source theory:

$$BHT(t) = SBHT + \left(\frac{H}{4\pi k}\right) * ln\left(1 + \frac{t_c}{\Delta t}\right)$$

Data needed circulation mud time (t_c) and shut-in-time (Δt) to extrapolate the static bottom hole temperature (SBHT)

Sarsina 1 Horner corrections

Legend:
- 2049 m
- 3226 m
- 3727.5 m
- 4235 m
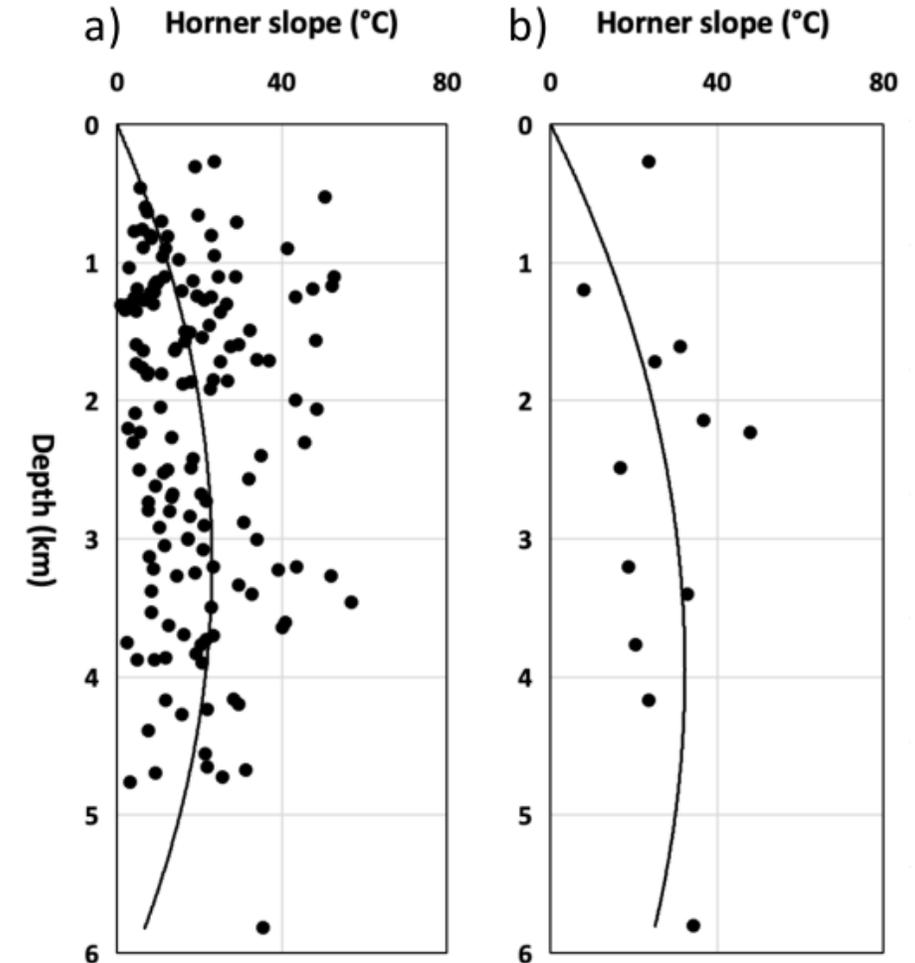- 4766 m

X axis: ln[1+(tc/Δt)]
Y axis: Temperature (°C)

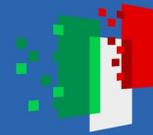## SINGLE TEMPERATURE DATA CORRECTION: EMPIRICAL LAW CALIBRATION

$$BHT(t) = SBHT + \left(\frac{H}{4\pi k}\right) * ln\left(1 + \frac{t_c}{\Delta t}\right)$$

Given that the Horner slope is proportional to the borehole heating rate, we calibrated an empirical 2nd-order polynomial function which enable us to correct the single BHT as function of t_c, Δt and depth (z).

$$\Delta T = (14.6z - 2.3z^2) * ln\left(1 + \frac{t_c}{\Delta_t}\right)$$

InGeo project calibrated the empirical correction formula using 153 Horner slope data (a) improving the previous correction calibrated by only 12 Horner slope data (b).

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DST underestimation: Joule-Thompon effect

The underestimation of DST results (ΔT) is mainly due to the presence of free gas in the reservoir. When gas moves into the well, pressure differences cause it to expand and temperature reduction.

The equation to calculate the real formation temperature is:

$$T_f = T_i + \Delta T = T_i + \mu_{JT} * \Delta P$$

μ_{JT} is the Joule-Thompson coefficient:

$$\mu_{JT} = \frac{1}{C_p}\left[\frac{T}{\rho^2} * \frac{\left(\frac{\partial p}{\partial T}\right)_\rho}{\left(\frac{\partial p}{\partial \rho}\right)_r} - \frac{1}{\rho}\right]$$
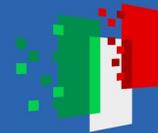
DST underestimation: Joule-Thompon effect

To better analyse the variation of the underestimation in pure methane (CH_4 100%) reservoirs, the evaluation of dependency on reservoir temperature (T_res), reservoir pressure (P_res), and pressure drawdown (ΔP) is .
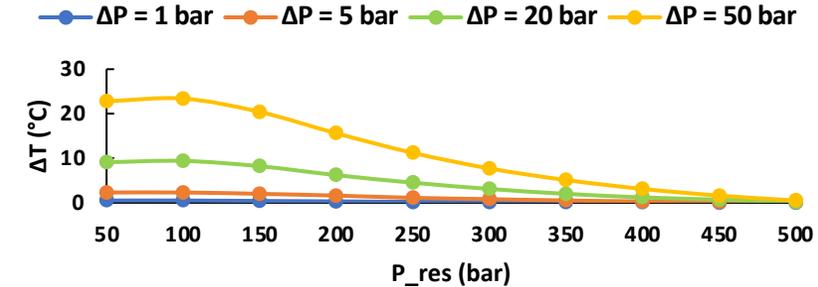
The investigated parameter ranges are consistent with typical methane reservoir conditions:
- T_res = 25-125 °C;
- P_res = 50-500 bar;
- ΔP = 1-50 bar.

Reservoir pressure (P_res) = 100 bar

Reservoir pressure (P_res) = 300 bar

Reservoir pressure (P_res) = 500 bar
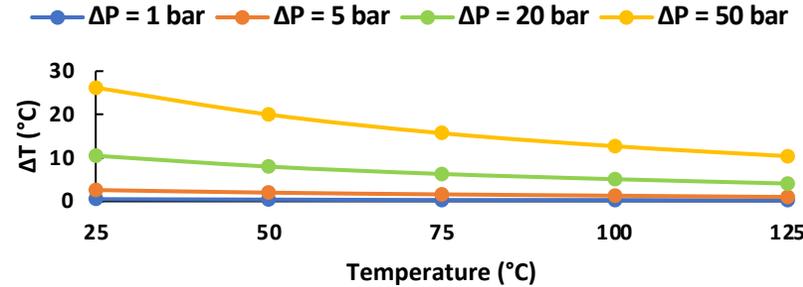
Reservoir temperature (T_res) = 35 °C
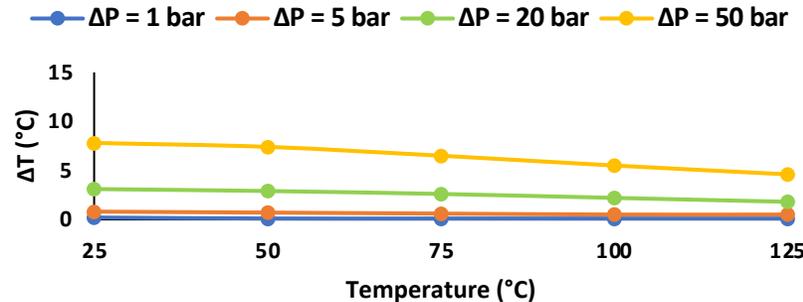
Reservoir temperature (T_res) = 75 °C

Reservoir temperature (T_res) = 115 °C
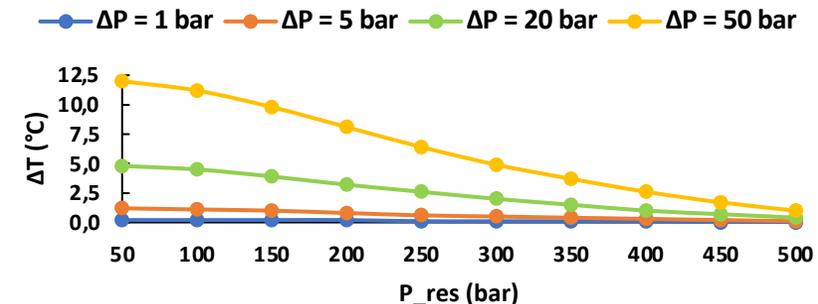
# DST underestimation: Joule-Thompon effect Portoverrara 1 case study

Portoverrara 1 well is located approximately 25 km from Ferrara. In the end-well report, available on the Videpi website, production test data are reported. The variation of bottom-hole pressure (BHP) enables the calculation of DST underestimation for each flow rate (Q) applied during the test.
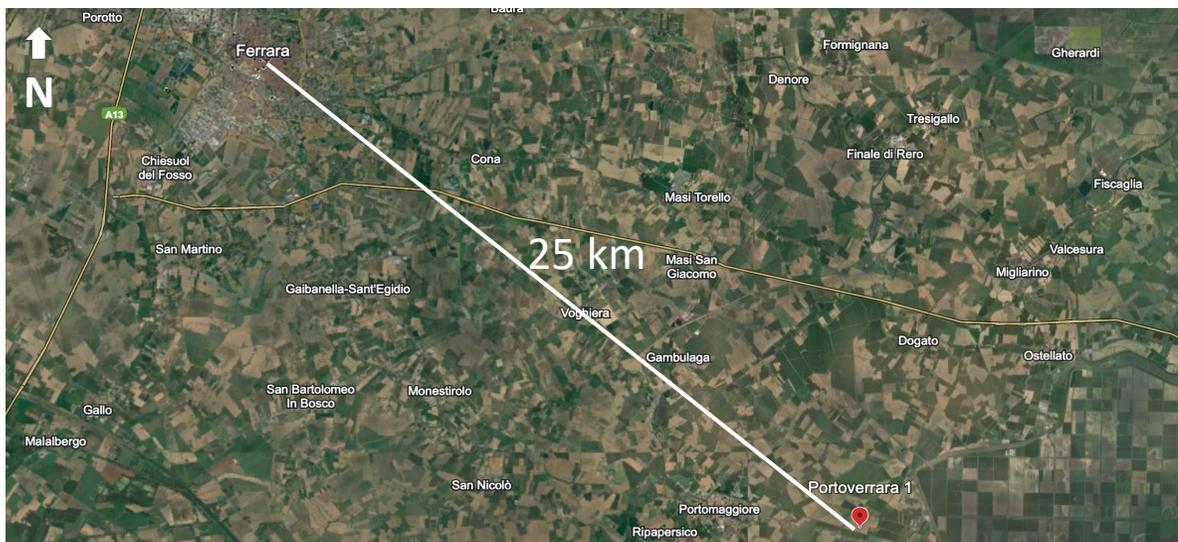
Intervallo aperto alla produzione (5.2.1958).
m. 832 – 866,50 (q. 827 – 861,50).
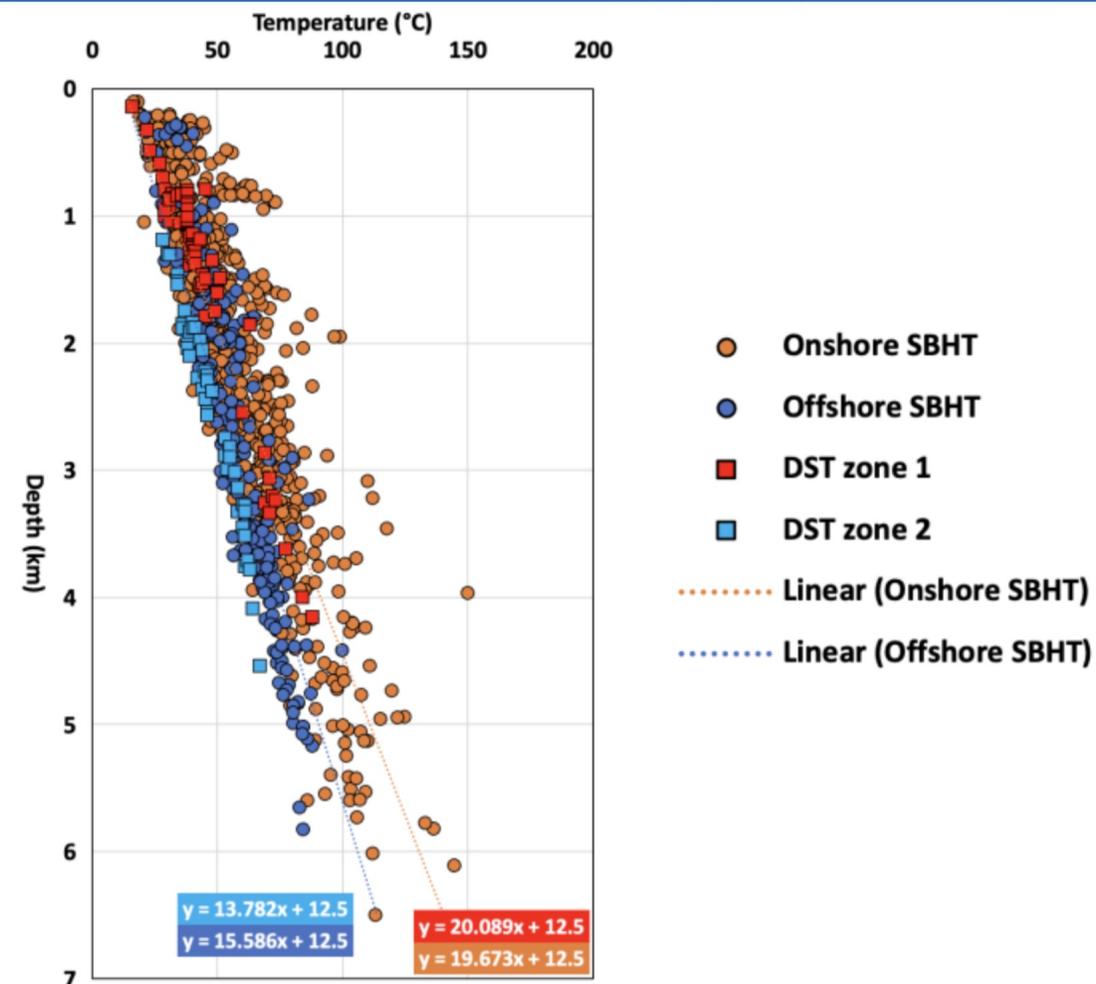
Pressioni a fondo pozzo:

In erogazione		a pozzo chiuso		Portata	
Ø 4 mm.	89,08 atm.	89,98	atm.	750	mc/h
" 5 "	88,58 "	89,28	"	1215	"
" 6 "	85,41 "	89,28	"	1830	"
" 7 "	85,41 "	89,28	"	2080	"

ΔT Portoverrara 1
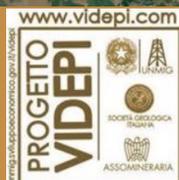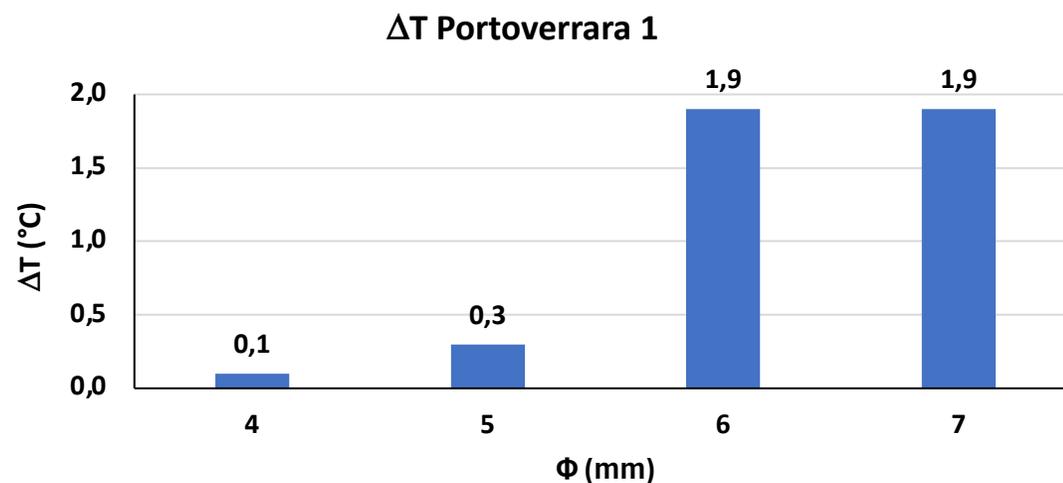
FINAL DATASET

The final dataset was create using all corrected data (SBHT and DST). The gradient comparison between SBHT data and DST data of two different thermal regimes show a good agreement.
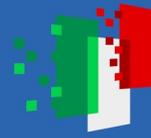
GRADIENT MAP
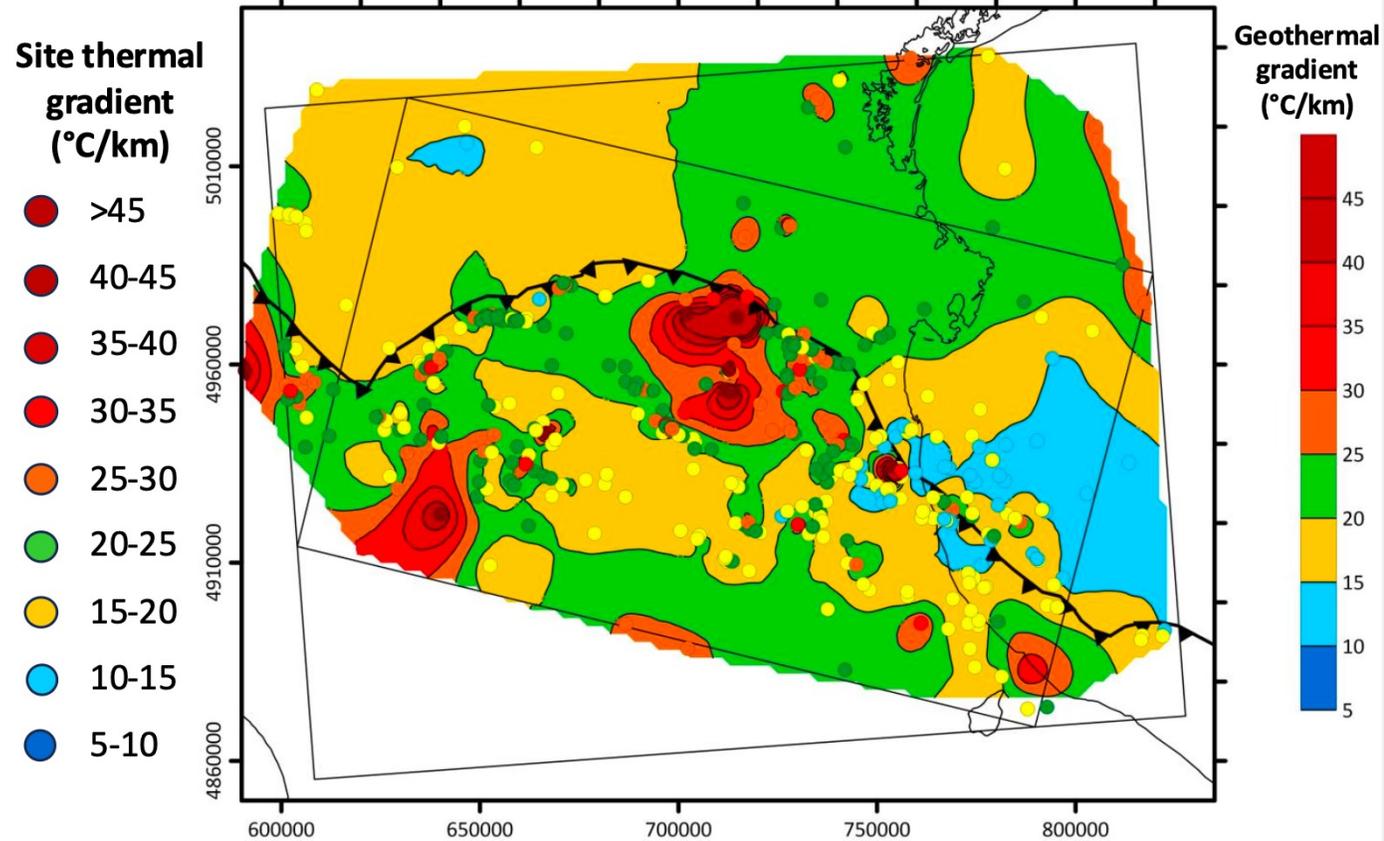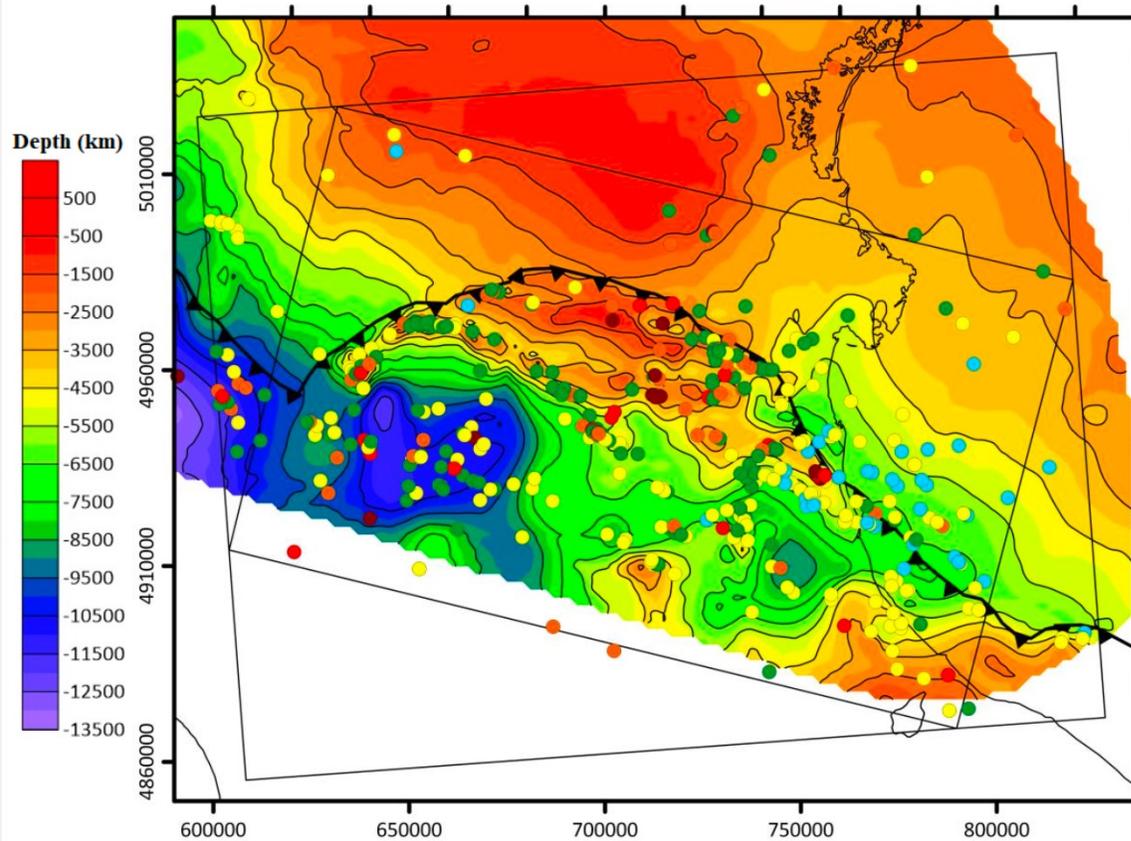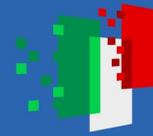
CONCLUSIONS

- DSTs data show two different thermal regimes (onshore and offshore) in the study area.

- Horner slope is useful to generate an empirical law for the correction of single BHTs data.

- DST underestimation arises from the presence of free gas in the reservoir. The magnitude of this effect is primarily controlled by P_res and ΔP, while T_res plays a secondary role.

- A positive thermal anomaly was recognised in culmination of overthrust.

Thanks for your attention

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