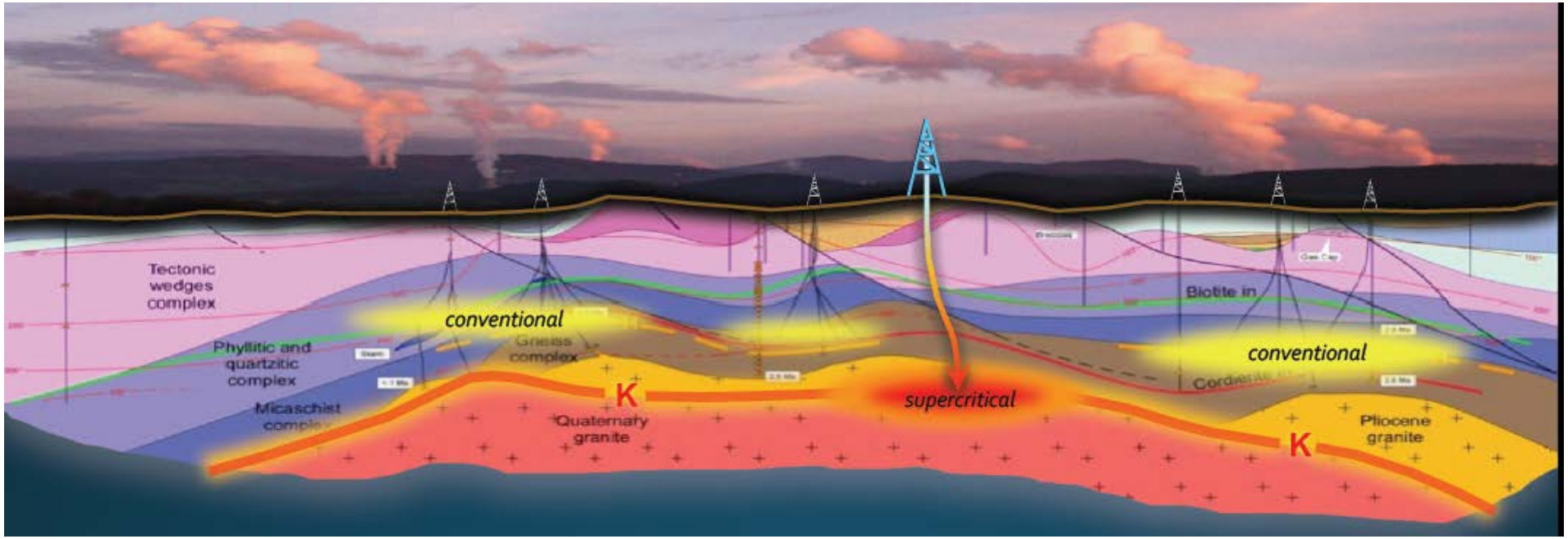
DESCRAMBLE project

ETIP

Brussels 14/11/2017

Green Power

Summary



Drilling down to a new frontier of the geothermal development:

the deep supercritical fluids

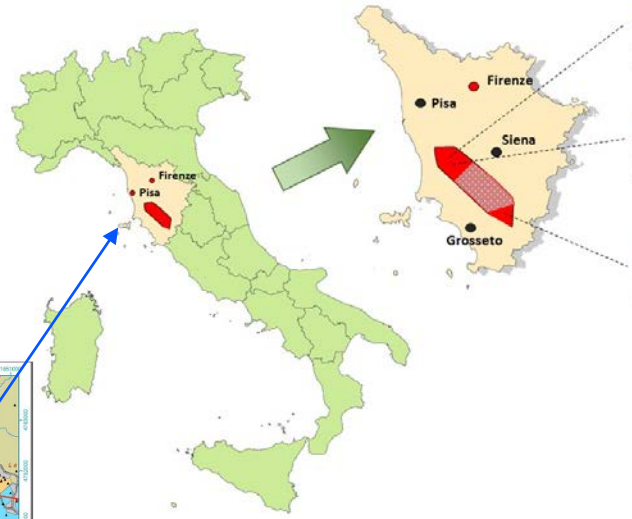
Summary

The “Drilling in dEep, Super-CRitical AMBient of continentaL Europe” (**DESCRAMBLE**) project proposes to drill in continental-crust, super-critical geothermal conditions, and to test and demonstrate new drilling techniques to control gas emissions, the aggressive environment and the high temperature/pressure expected from the deep fluids.

The project will improve knowledge of deep chemical-physical conditions for predicting and controlling critical drilling conditions. Drilling operations are now on going to deepen an existing well in Larderello (Tuscany, Italy), Venelle_2, from its previous depth of 2.2 km down to 3 km. The DESCRAMBLE project is be partly supported by EU H2020 funds.

The final purpose of the project is the chemical and thermo-physical characterization of the steam reservoir. The Venelle_2 well will not be converted in a production well.

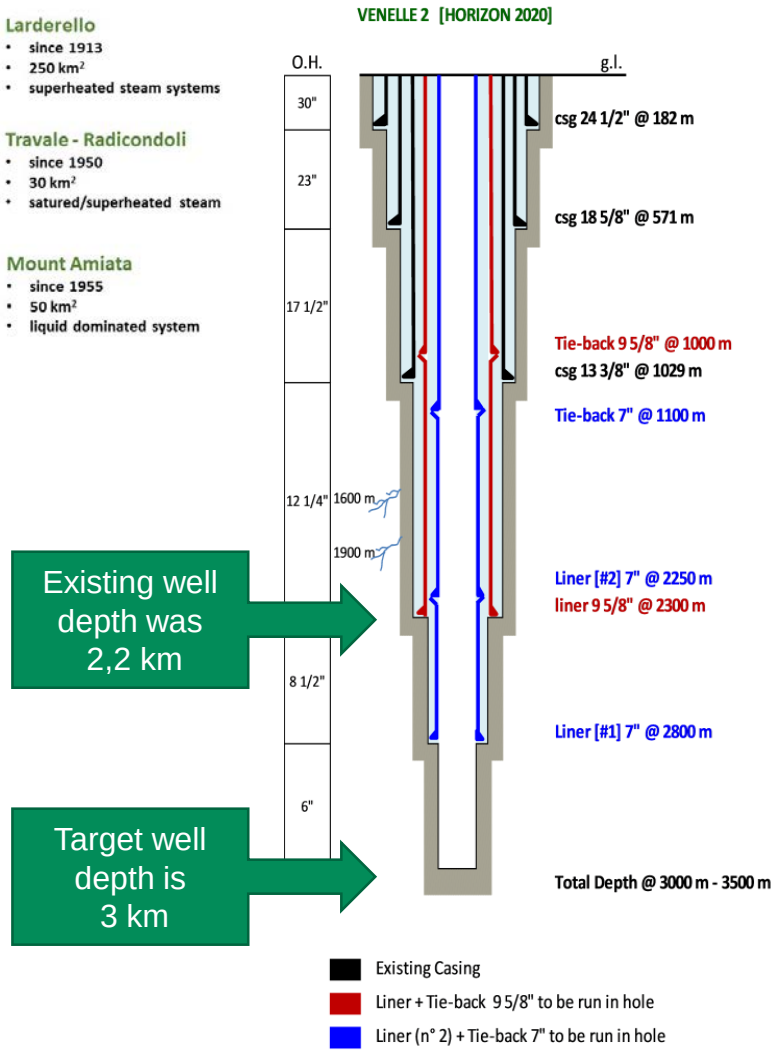
Location and main characteristic



Larderello
- since 1913
- 250 km²
- superheated steam systems

Travale - Radicondoli
- since 1950
- 30 km²
- satured/superheated steam

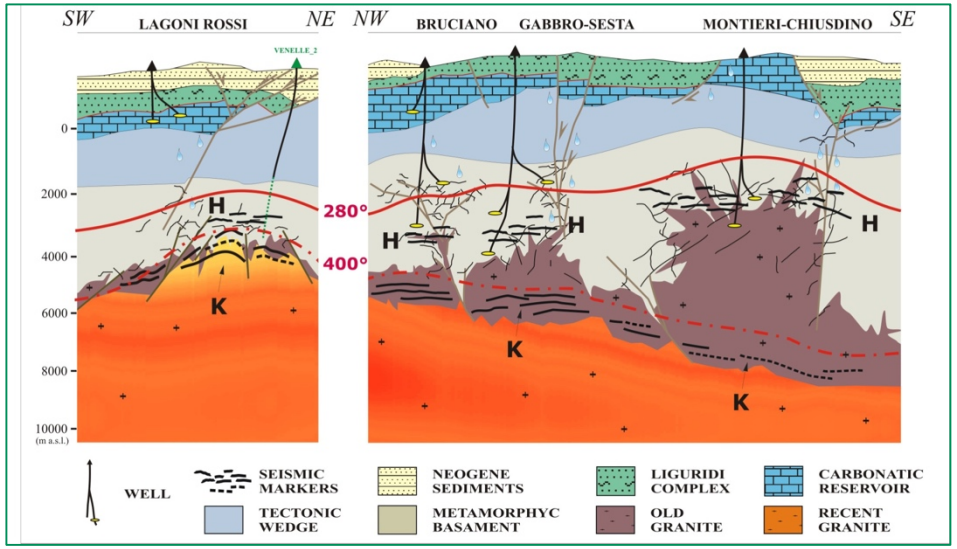
Mount Amiata
- since 1955
- 50 km²
- liquid dominated system

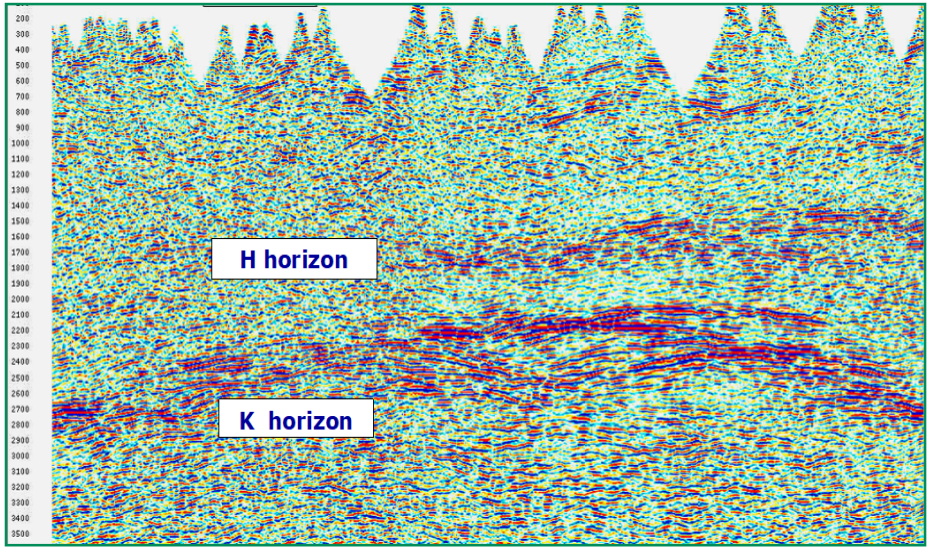


Location of the Venelle_2 well, Larderello, Tuscany, Italy

Scientific background

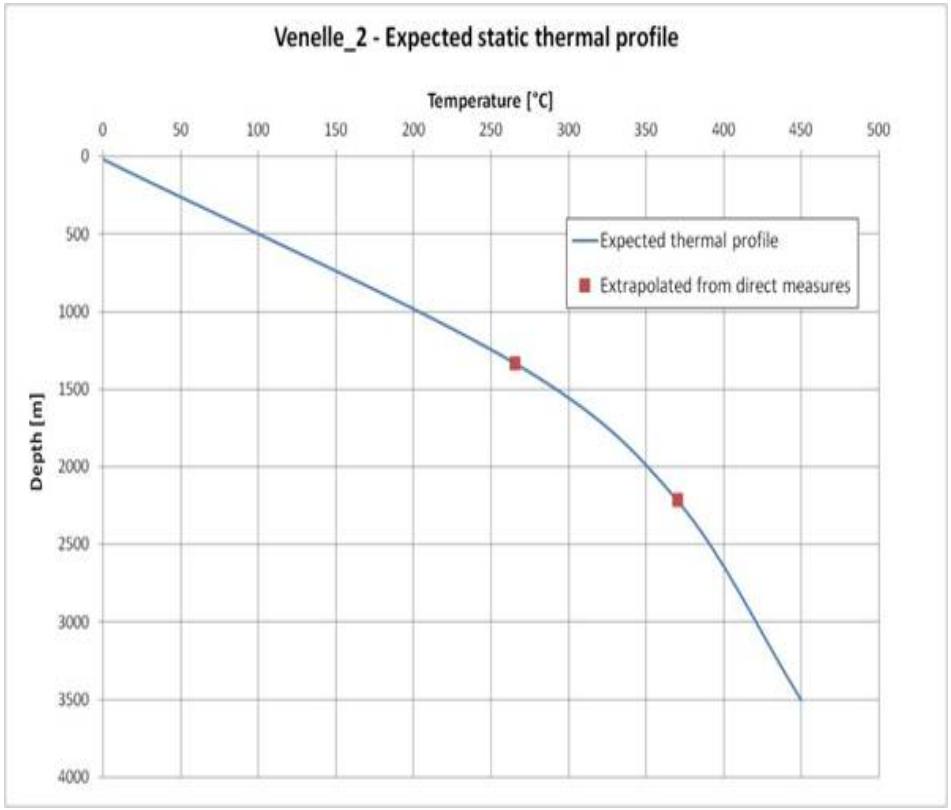
K Horizon represents a seismic marker which may be associated with overpressured fluids at supercritical conditions





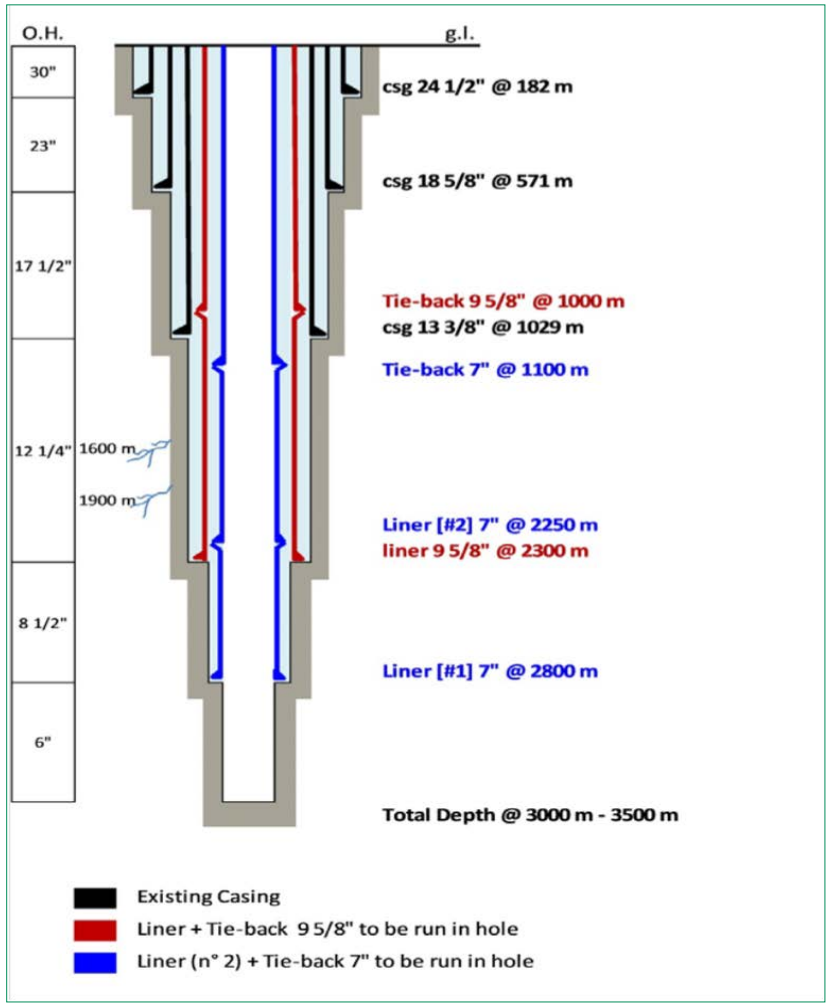
Drilling the K horizon will open possibilities of exploiting deep supercritical fluids that could be hosted in the recent granites,
with a new development phase for the Larderello field.

Thermal expected profile



- Geopressurized systems → 450 bar at 3500 m of depth..
- Above the K horizon → 35÷40 bar can be assumed.
- Higher concentrations than in typical geothermal fluids of :
  - ✓ Gas (CO_2, H_2S, etc., typical gas/steam ratio in deep reservoirs is 5÷10%)
  - ✓ Hydrochloric acid (in this case possibly higher than 100 ppm in the condensate)
  - ✓ Hydrogen fluoride (normally not present in geothermal fluid)
  - ✓ Hydrogen sulfide
  - ✓ Hydrogen and methane.

Well profile and casing string



EXISTING CASING (VENELLE 2)

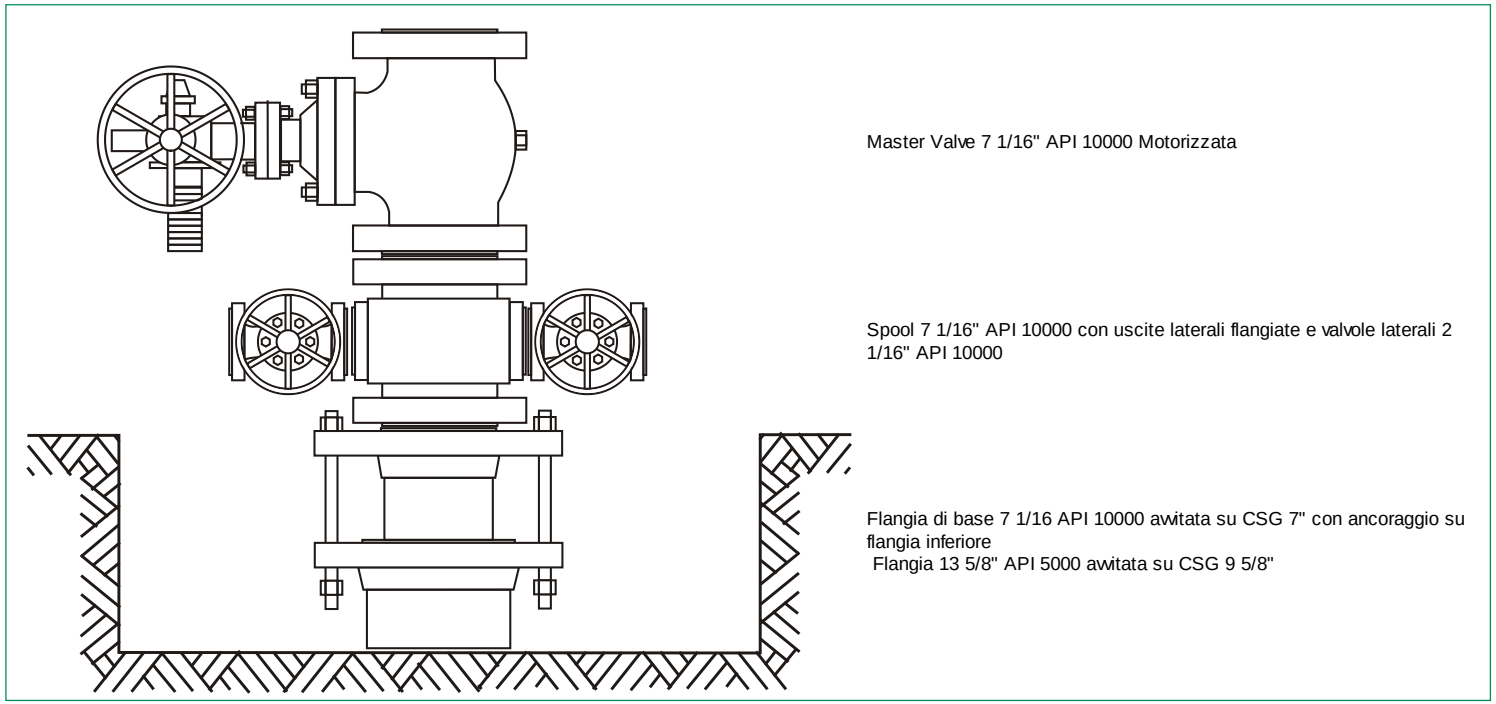
Diametro	Grado acciaio	Peso nom.	Spessore	Drift		Connessione
				API	Special	
24 1/2"	J55	133 #	12.71 mm	23.125"	-	Tenaris ER
18 5/8"	J55	96.5 #	12.32 mm	-	17.500"	Tenaris ER
13 3/8"	L80 (*)	68 #	12.19 mm	12.259"	-	Tenaris ER

(*) = 0 - 100 m Steel Grade L80 13%Cr

CASING (planned)

Diametro	Peso nom.	Spess.	Drift	Sp. Drift	Grado	Conness.	Profondità		Descrizione	Note
inches	lb/ft	mm	inches	inches	**acciaio**		da m	a m		
9 5/8"	43.5	11.05	API	-	L80	TSH ER	0	1000	Casing	
9 5/8"	43.5	11.05	API	-	L80	TSH ER	1000	2300	Liner	
7"	32	11.506	-	6	TN125SS	TSH BLUE	0	1100	Casing	OK per t > 80°C
7"	32	11.506	-	6	TN125SS	TSH BLUE	1100	2250	Liner intermedio	OK per t > 80°C
7"	29	10.36	API	-	T95	TSH BLUE	2250	2800	Liner profondo	Full Sour

Well Head



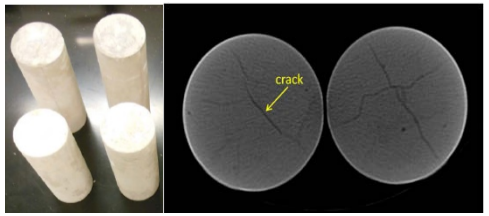
Well Head Equipments suitable for HP (450 bar) HT (450 °C) conditions have been selected.
According to API and ASME regulations, well head selected materials (Ys = 60 Ksi) are subject to derating because of high temperature, therefore well head equipments will have 10000 Psi rating.

Cementing

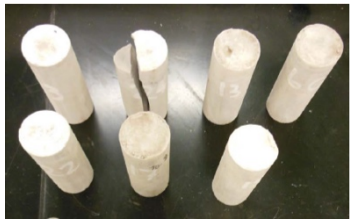
Laboratory testing performed in order to define the best cement blend for high temperature application (up to 450°C). Three kinds of blend have been tested at Halliburton laboratory:

- Geotherm (Cement class G + 40% BWOC silica)
- Cement class G + 70 % BWOC silica
- **Thermalock®**

Geoterm™ / 40% silica after 7 day exposure to 450°C



Geoterm™ / 70% silica after 7 day exposure to 450°C



Thermalock after 7 day exposure to 450°C

***TEST OUTCOME*:** Thermalock® is the most suitable cement blend for this temperature

Cementing

Thermalock® blend has been modified to improve its mechanical properties. The tests have shown that curing at high temperature (250°C) does not affect negatively the strength and the integrity of the cement.

The optimization of the rheological properties is reached using specific additives.

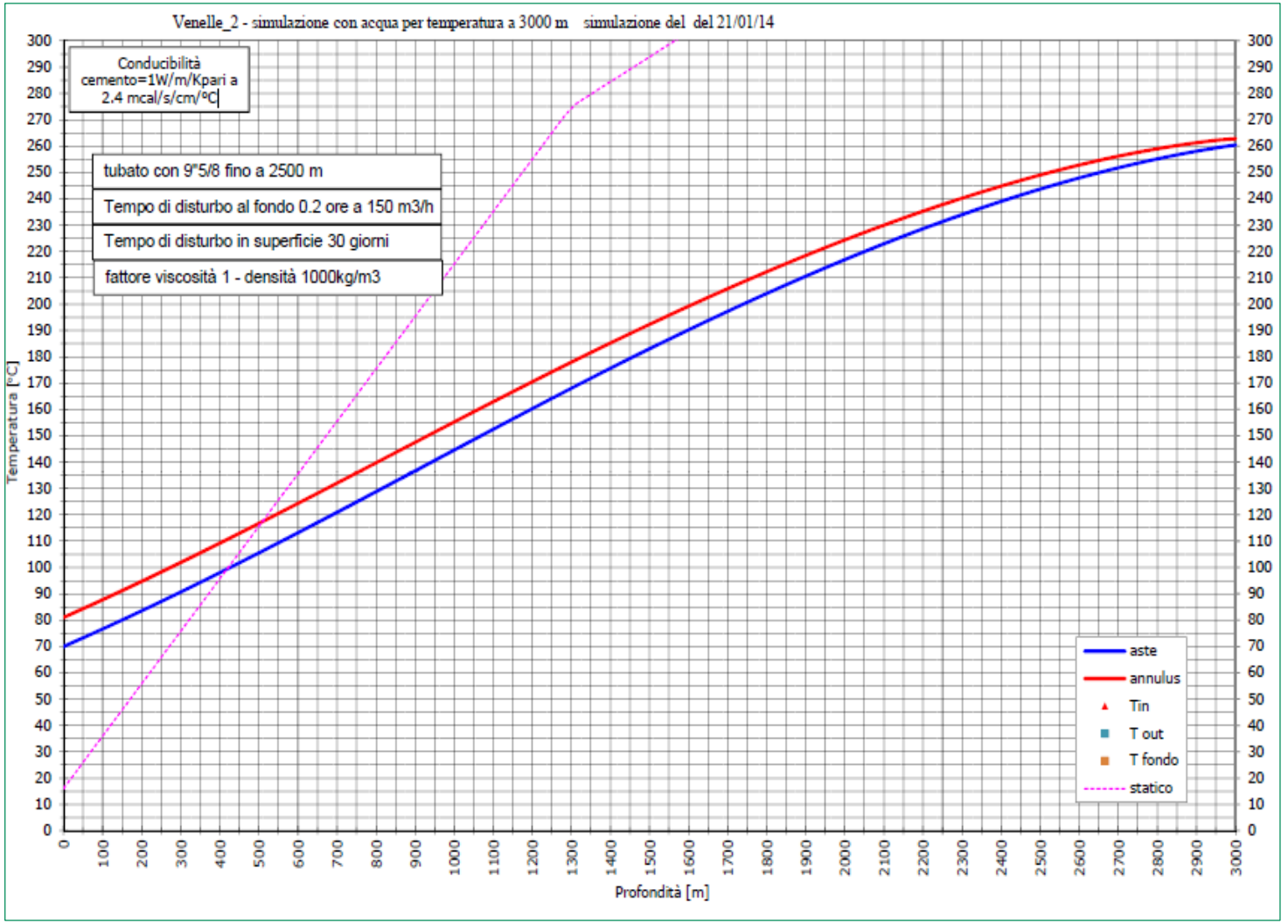
Tests performed:

- Uni-axial, Tri-axial and Brazilian tests (after curing the sample at 371°C and 310 bar for 7/28 days)
- Thermal & fluid properties
- XRD/XRF
- Permeability test

Drilling fluids

Bentonite, conventionally used in fresh water based drilling fluids cannot deliver proper rheological and water loss properties at temperatures above 150°C.

For this reason, mud with sepiolite has been chosen for the deep phases (8 ½” and 6”).



Rock bits

Rock bits commonly used in our geothermal drilling have three cones rolling on bearings.

The high temperature expected in K horizon can lead to failures because of the fast decay of elastomeric parts (Rubber and Kevlar).

- Stinger bit has been selected as the best option
- No bearings subject to fast decay in high temperature
- Successfully tested in the area

Advanced well monitoring

Mud logging system

- Geology master log from cuttings
- Monitoring drilling parameters (ROP, RPM, Torque, Flow in/out, T in/out)
- Collecting and analyze gas from mud: Total gas, CO_2, H_2, H_2S, CH_4 and He through a micro TCD+GC

Advanced well monitoring

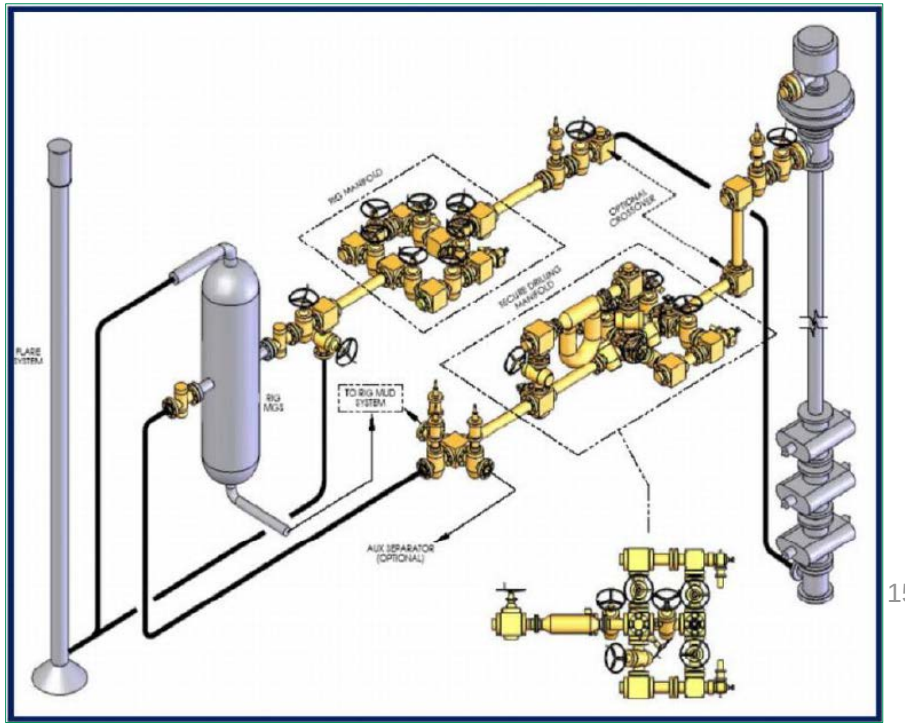
Cooling system

- High temperature expected of the drilling fluid coming out. Cooling system needed to keep the fluid temperature in a range that maintain the rheological properties of the fluid itself and keep the drilling operation safe.

Advanced well monitoring

Managed pressure drilling

- Mitigation of the risks related to the uncertainty regarding the pore gradient and the fracture gradient
- Real time control of the annular pressure and of the wellbore parameters while drilling
- Closed-loop circulating system



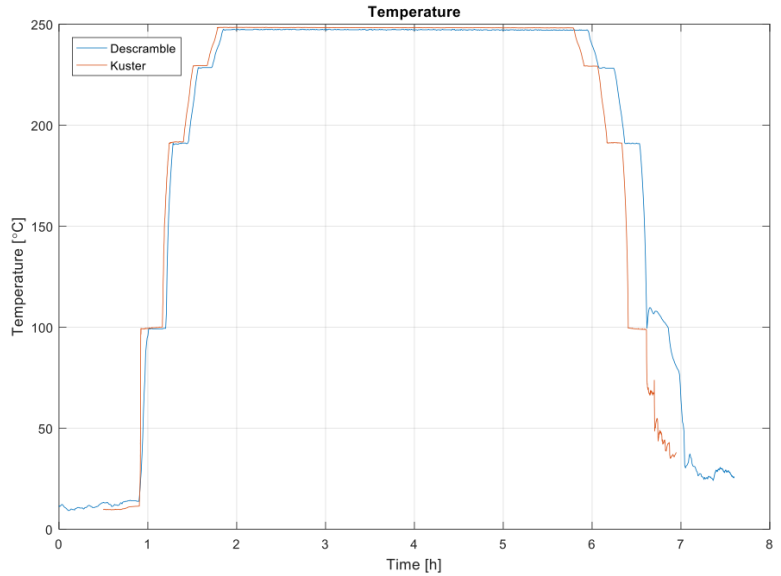
New designed T&P logging tool

A new tool for measuring temnperature and pressure at supercritical conditions has been designed and developed by SINTEF

Main features:

- Electronics, sensors and batteries operate within the range 10-200 °C
- Metal seal and pressure housing can withstand 450 bar/450 °C
- 6 hours maximum downhole recording time at 450 °C

The measurements with the DESCRAMBLE tool in Lumiera 1 has good correlation with the measurements done with the Kuster K-10 in the same well



Update from drilling operations

Drilling operations started at the end of April, after rig moving on early spring.

The first drilling phase (12 ¼”) started in the old well from 1054 m down to 2470 m (9 5/8” casing shoe at 2459 m).

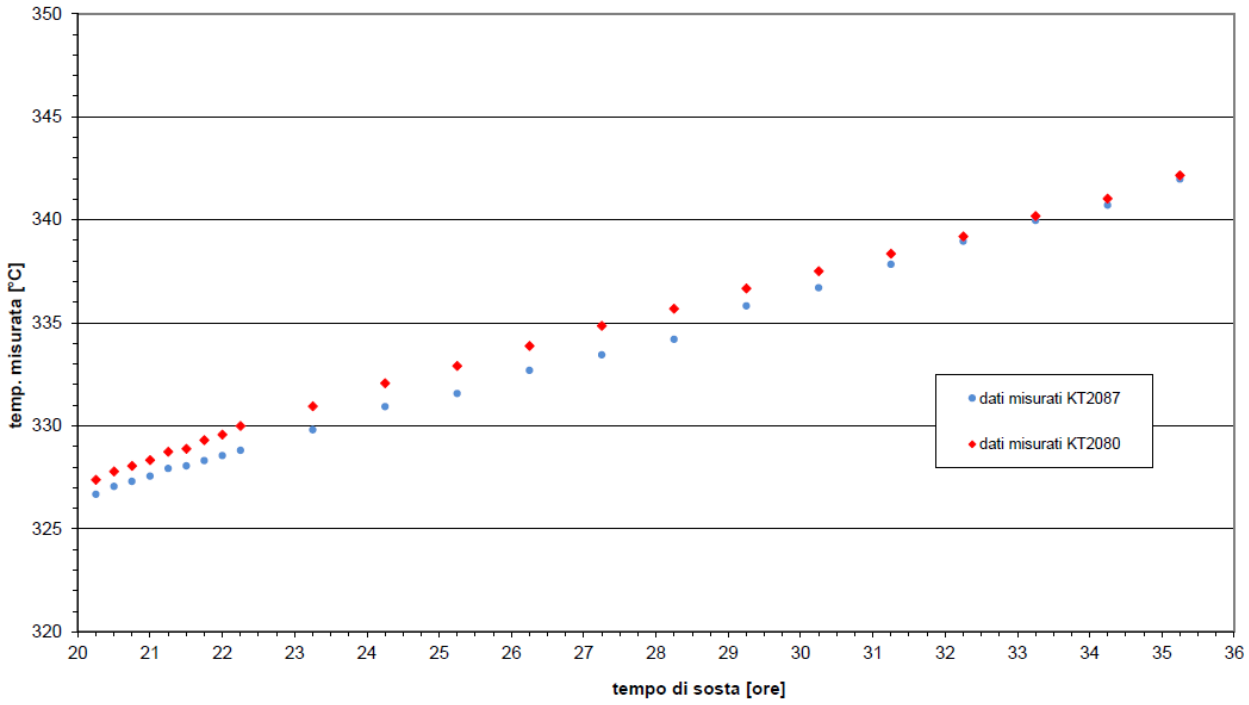
The following drilling phase (8 ½”) reached a depth of 2600 m, where a leak off test (LOT) was performed to ensure that the lithology (phyllites) would withstand a pressure of 450 bars, as expected in the target. The casing 7” have been run and cemented in three steps, liners plus tie-back.

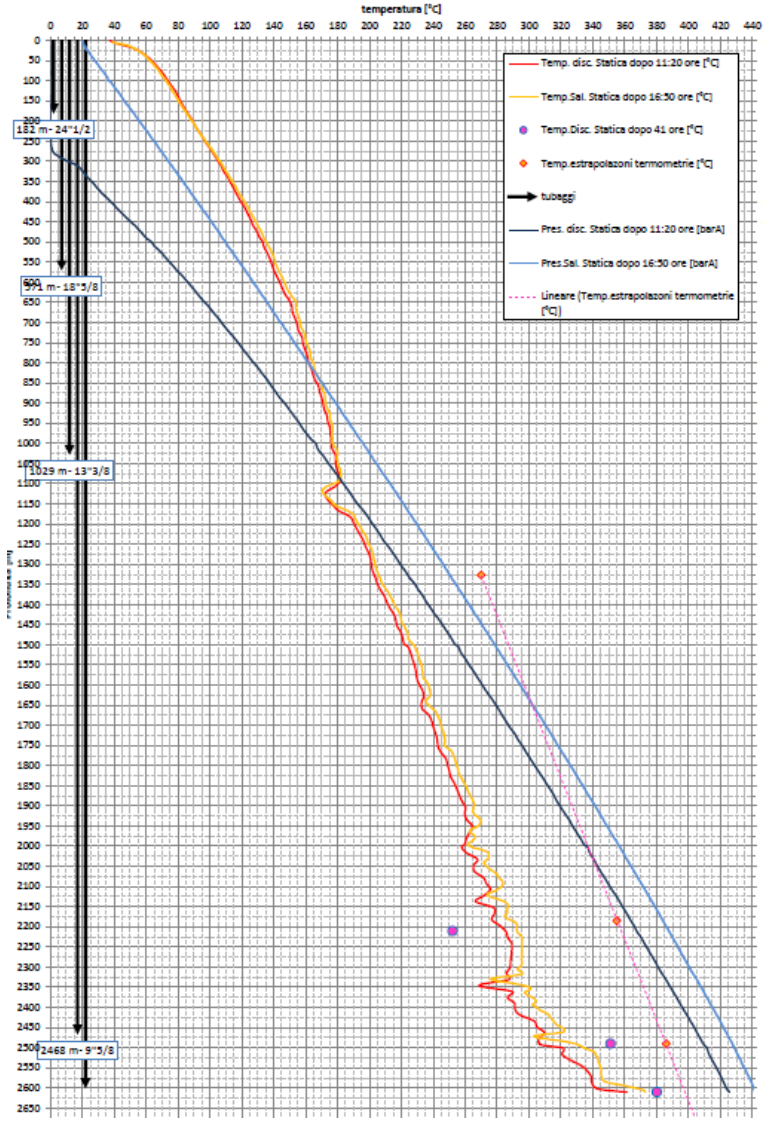
A major problem occurred during cementing operation of the second 7” liner, the upper part of the liner has been milled out and replaced.

For all cementing operations of the 7” casings, a new slurry for very high temperature has been developed together with Halliburton, starting from their product **Thermalock®.**

Drilling is now @ 2720 m (6” phase).

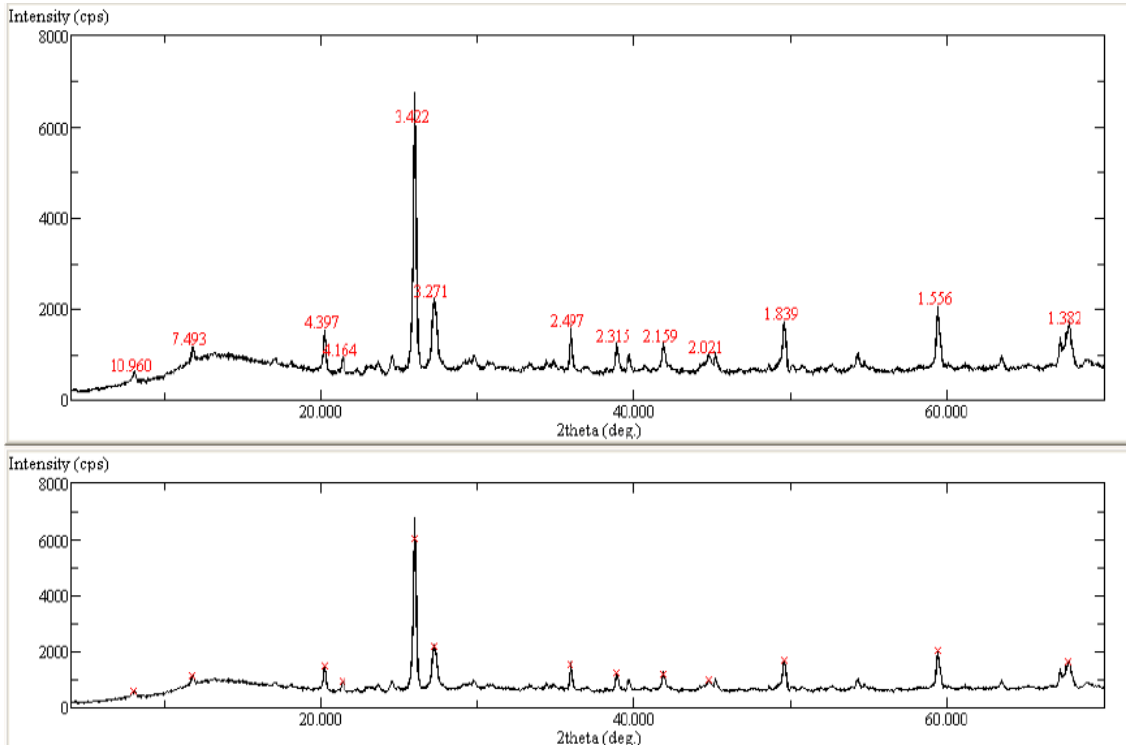
Update from drilling operations





Temperature log @ 2487 m : extrapoled temperature 387 °C
Temperature log @ 2600 m: measured temperature ≈ 380 °C

Update from drilling operations

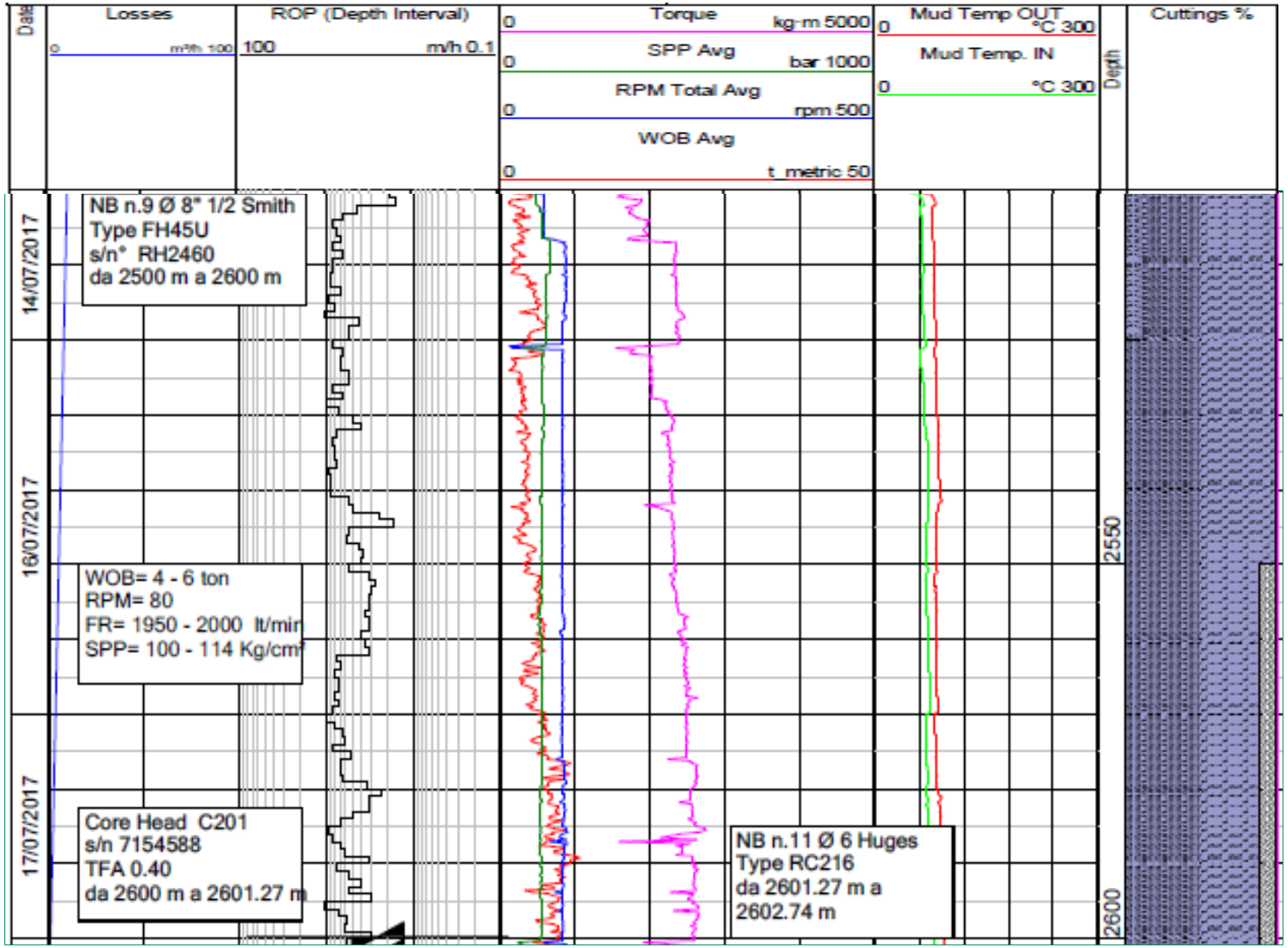


XRD on core @ 2600 m

Coring @ 2600 m

Lithology: Phyllites, minor Quarzite (10-20%)

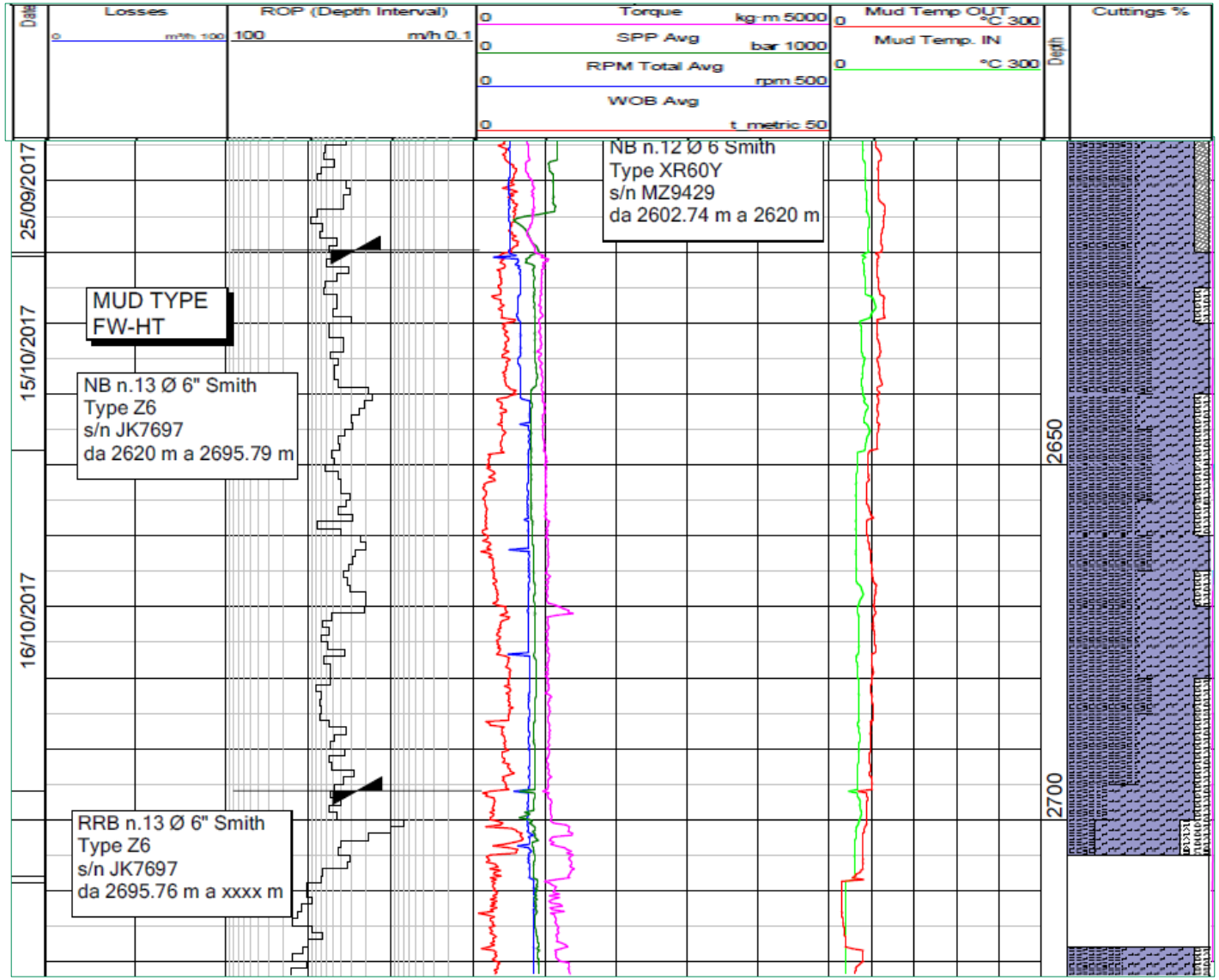
Drilling parameters 8 ½" phase



Drilling 8 ½ phase

- Average drilling parameters:
  WOB 4-6 t, RPM 80, Q 2000 l/min
- Avegare ROP ≈ 7 m/h
- Roller cone bit

Drilling parameters 6" phase



Drilling 6" phase

- Average drilling parameters:
WOB 2-5 t, RPM 90, Q 1000 l/min
- Avegare ROP ≈ 5 m/h
(up to 12 m/h)
- Positive results from stinger bit, rate of penetration comparable with the previous phase
- Losses at 2708 m, drilling with water from 2708m to 2721 m.

Criticalities

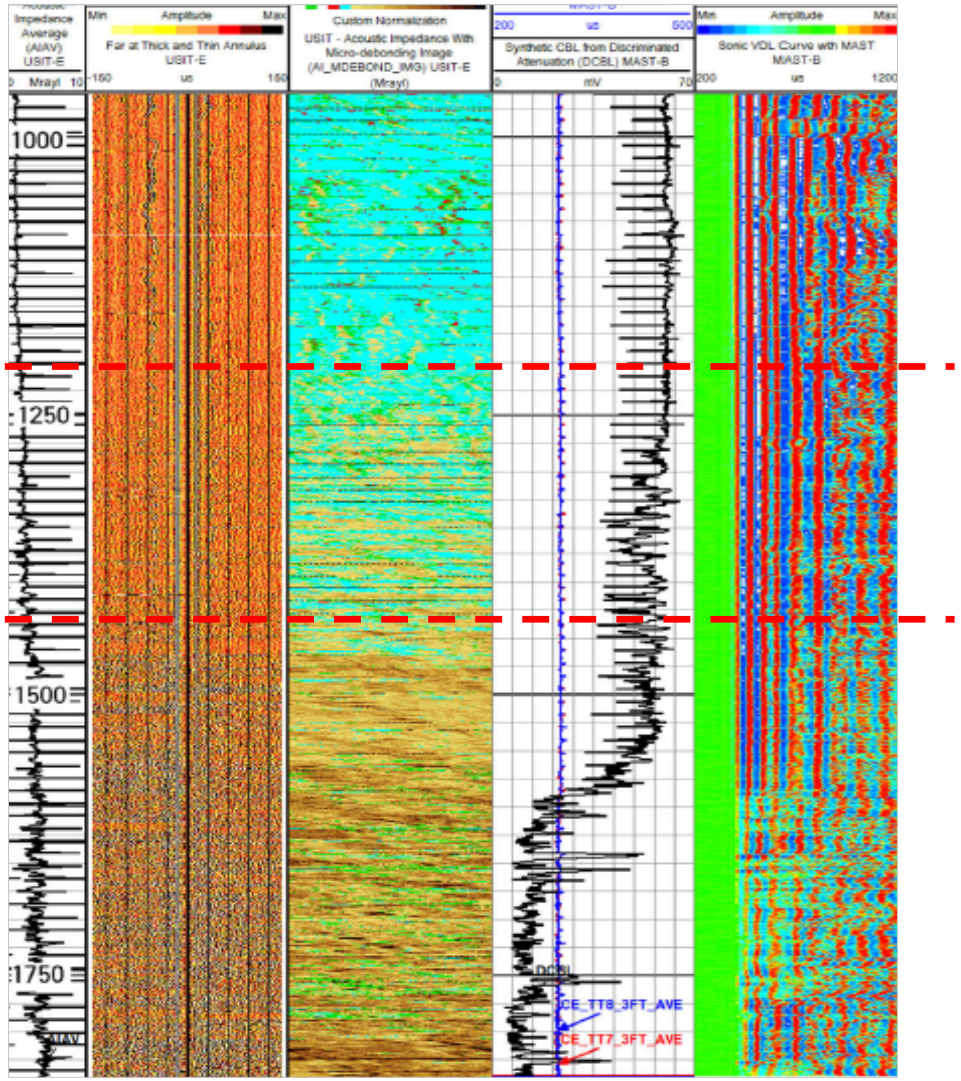
FLUID PROPERTIES								
Sample From		FL ✓	Pi	FL ✓	Pit	FL ✓	Pit	
Time Sample Taken		06:30		15:00		23:45		
Flowline / Suction Pit Temperature	°C	75	58	68	46	71	56	
Depth - M.D.	m	2600		2638		2648		
Depth - T.V.D.	m							
Weight	sg / ppg	1,50	12,5	1,50	12,5	1,50	12,5	
Fann 600 / 300 rpm	@ 50 °C	55	48	46	39	44	35	
Fann 200 / 100 rpm	@ 50 °C	43	40	33	30	32	31	
Fann 60 / 30 rpm	@ 50 °C							
Fann 6 / 3 rpm	@ 50 °C	28	27	23	21	26	25	
Marsh Viscosity	sec/L @ 46 °C	59		57		57		
Apparent Viscosity	cp @ 50 °C	27,5		23		22		
Plastic Viscosity	cp @ 50 °C	7		7		9		
Yield Point	g/100cm2 @ 50 °C	20,5		16		13		
Gel 10 sec / 10 min	g/100cm2 @ 50 °C	12,5	14,0	12,0	13,5	13,5	15,0	
Gel 30 min	g/100cm2 @ 50 °C	38		35		35		
LSR YP (Yeld Stress)	lb/100ft2 @ 50 °C	26		19		24		
SAR*100 (Shape Ratio)	@ 50 °C	66		70		81		
n / K	- / lb*secn/100ft2 @ 50 °C							
API Filtrate	mL/30 min @ 36 °C	42,0		43,0		45,0		

- Difficulties in obtaining the required rheological conditions for the mud due to the very high temperature at bottom hole (T > 400 °C); as a consequence the drilling string was stuck several times.
- Mud gelation after few minutes with no circulation, difficulties in pipe connection

Update from drilling operations
Criticalities

- As a consequence of a forest fire in the well pad area, execution of a complex 35 days remedial job. The major impact was on the extra circulation time during the 7” liner cementing job, with a severe malfunctioning of the one way valves on the cement pumping line, as a consequence of the long high temperature exposition of the equipment in the bottom hole, with the consequence of bad cementing of the liner and the requirement of removing and milling part of the casing and placing into operation a new one.

Update from drilling operations
Criticalities



CBL- USIT log highlighted a section of bad cementing. Two casing cuts (dashed lines in the figure) @ 1205 m and 1407 m. Pulling out of the second section was not possible, as a consequence about **200 m of casing have been milled out**

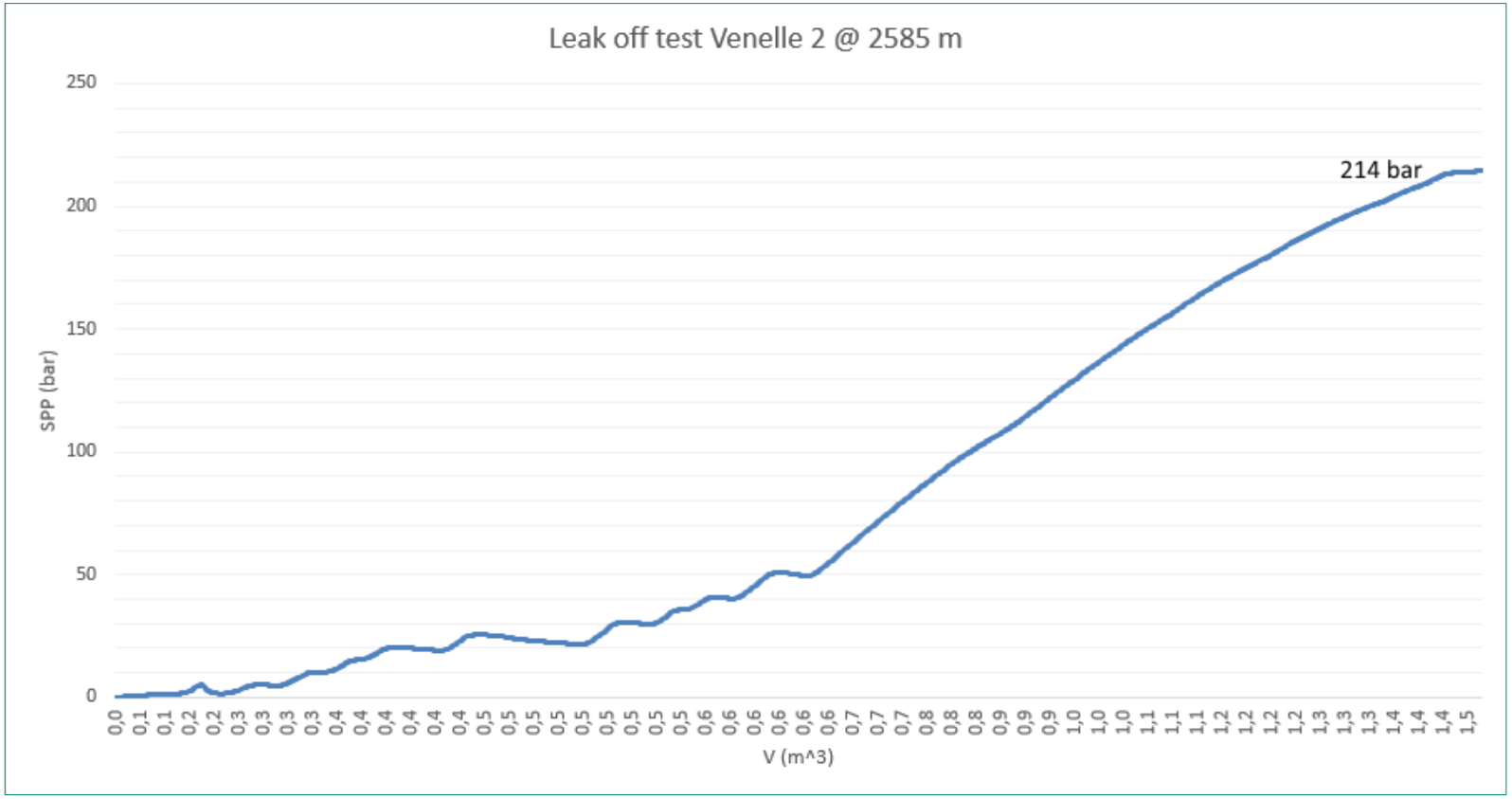
Conclusions

- Drilling operations still ongoing (6” phase). Some delays mainly due a remedial job on the last casing section (7”)
- Main criticalities from temperature at bottom hole. Extra time for circulating to cool down mud, difficulties to maintain optimal rheological properties of the mud

THANK YOU

The research leading to these results has received funding from the European Union's Horizon2020 Research and Innovation Program under grant agreement No 640573
(Project DESCRAMBLE)

Back up



- Leak off test (LOT) @ 2585 m using a sweallable packer for open hole formation.

  Mud density 1.15 s.g., downhole pressure 515 bar