GeoTHERM expo & congress

A multifold increase in drilling performance using combined hydro-jet and percussion drilling: case study from ORCHYD project

Dr. Laurent Gerbaud
Scientific Coordinator - ORCHYD
ARMINES/ MinesParisTech

ARMINES MINES ParisTech PSL Imperial College London SINTEF UNIVERSITY OF PIRAEUS RESEARCH CENTER DRILLSTAR INDUSTRIES CHINA UNIVERSITY OF PETROLEUM

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006752

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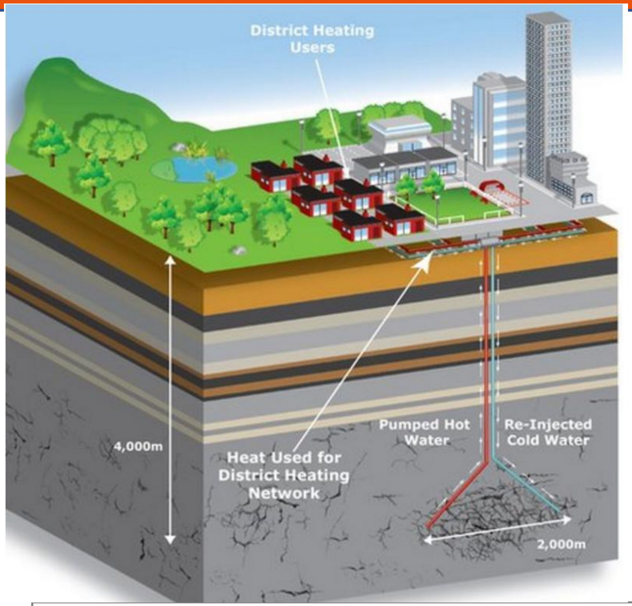
Problem statement

<u>Focus area:</u> Deep geothermal reservoirs (>4 km)/ hard rocks



Challenges:

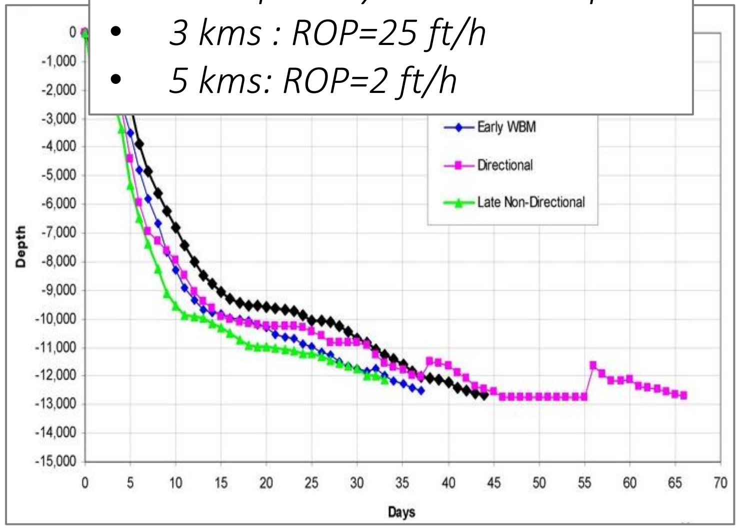
- Hard rocks (granite, gneiss …)
- Low drilling speed (ROP) with traditional rotary techniques
- High investment (drilling) costs

Typically, in deep and hard crystalline rocks:

ROP	: 1-2 m/h
Roller cone bit lifetime	: 50h
Length drilled/ bit	: <50m (many trips to replace worn bits)

ROP collapse beyond 3 kms depth :

- *3 kms : ROP=25 ft/h*
- *5 kms: ROP=2 ft/h*



(BP data, Louisiane)

Goals:

ETIP recommendation/2030 : 15-30% reduction of the unit cost of well construction (€/MWe)

- ROP increase from 1-2 m/h to 4-10 m/h
- Cutting drilling costs by 65 %

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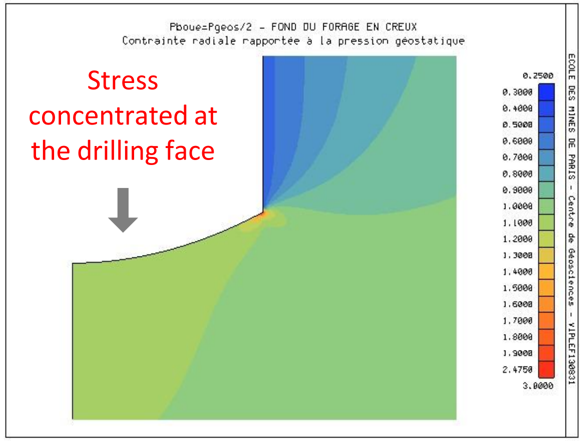
ORCHYD: Approach

A process of "Self-Relief Drilling (SRD)"

Conventional bottom-hole configuration



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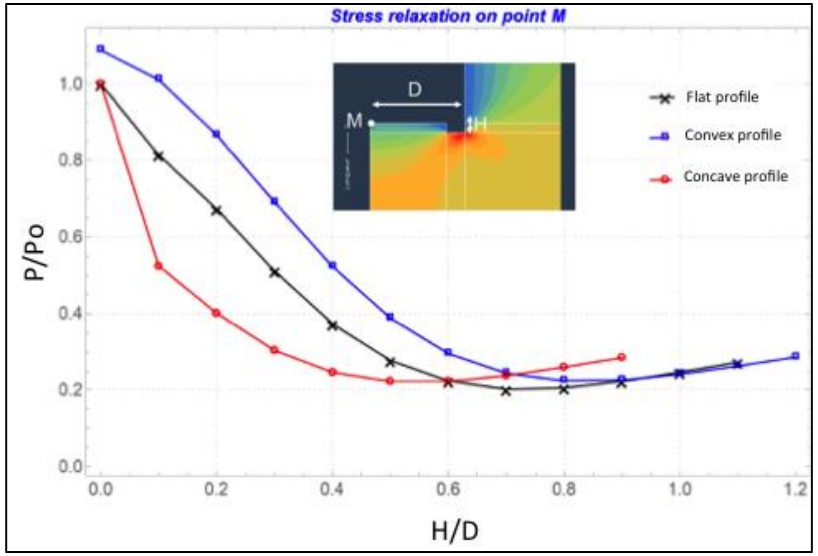
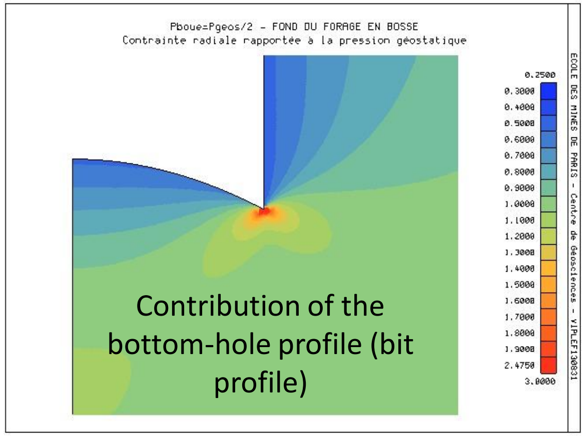
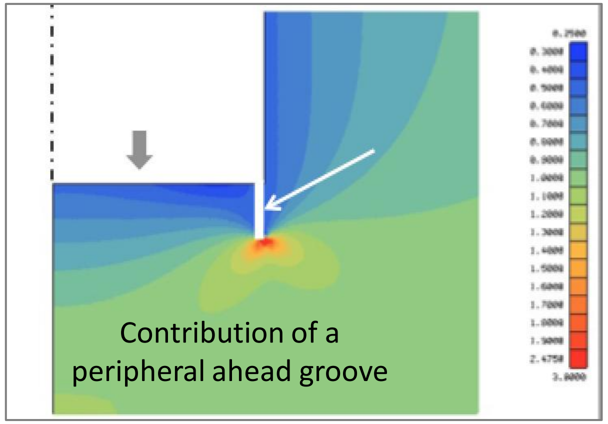
- Demonstrate/optimise the SRD concept
- Develope prototypes
- Implement prototype in BHA
- Set-up & operate full-scale pilot laboratory drilling tests



Modified bottom-hole configuration





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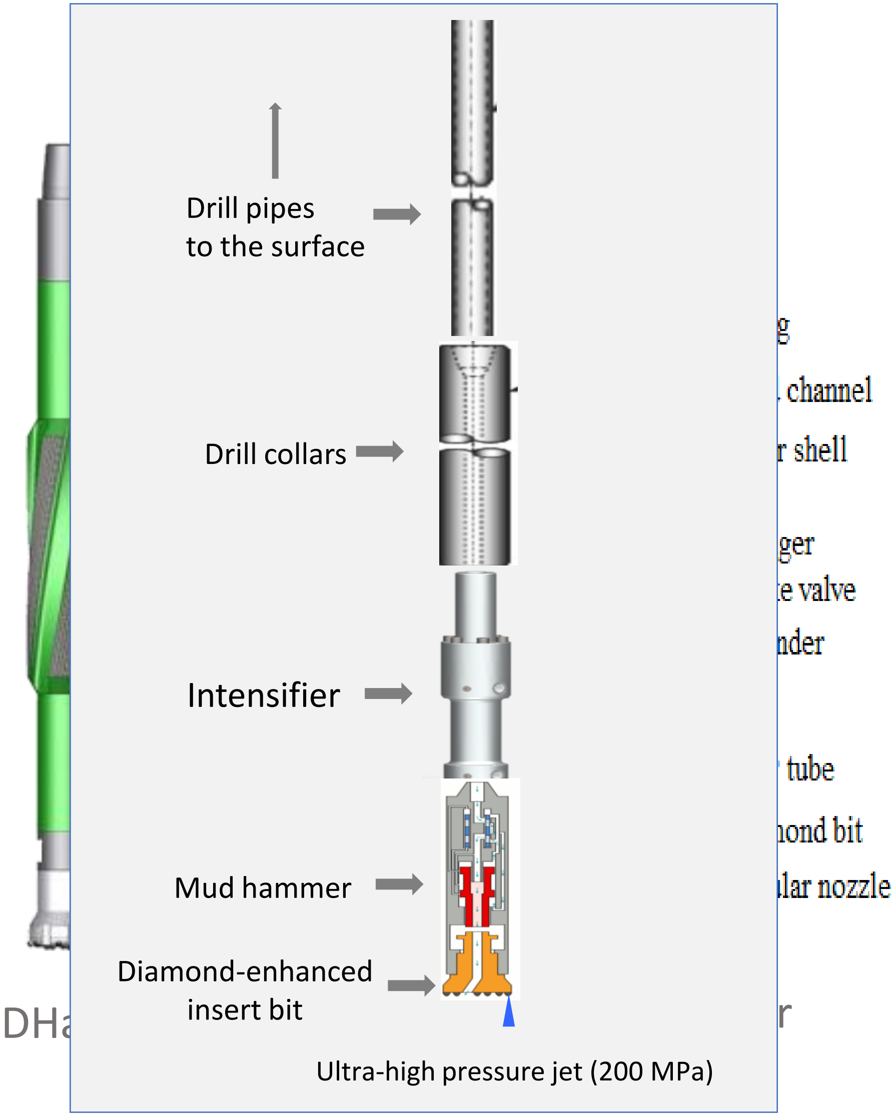
ORCHYD: Technical prototype



MUDHammer: Hydraulic (fluid) -> Mechanical (high-power percussion)

+ Diamond-enhanced-insert hammer bit

Intensifier: Mechanical (axial vibrations) -> Fluid (high pressure jet)

Current stage: the high-pressure water jet is delivered directly from a pump

ORCHYD approach : optimization of 3 main processes

WP4

1- Stress Release Process : maximise stress release
Best bottom-hole geometry :

- ❑ **drilling face/bit profile ?**
- ❑ **Groove depth ?**

WP5

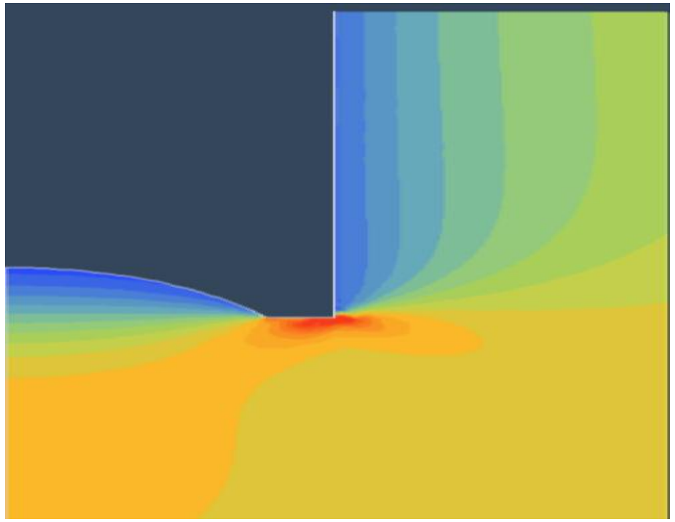
2- Jetting process : maximise the groove depth

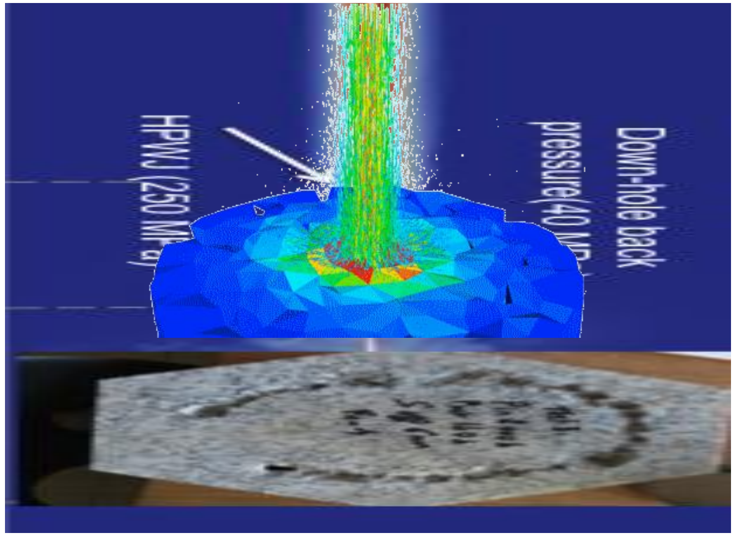
- ❑ Optimal HPWJ parameters (Pressure, nozzle, SD, ..) ?
- ❑ Feasibility of in-hole HPWJ production system (intensifier) ?

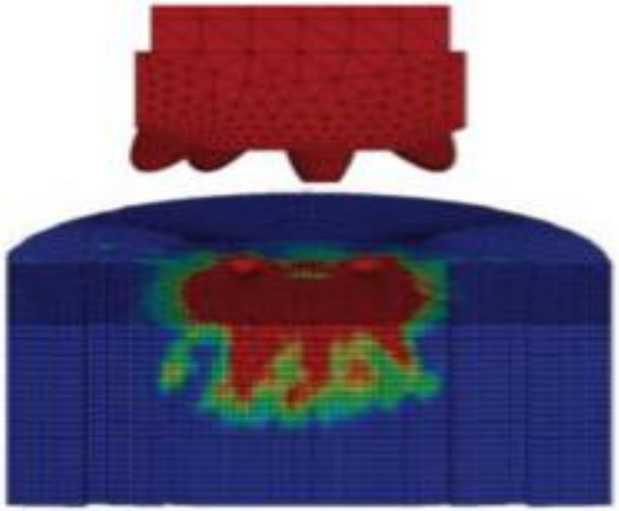
WP6

3- Percussive drilling process : optimize Bit-Rock interaction (maximise ROP ; optimal vibrational response)

- ❑ Best bit design (cutters, set-up, profile) ?
- ❑ Optimal drilling parameters (WOB, percussion, fluid, …) ?

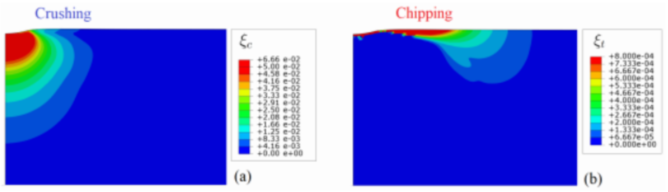


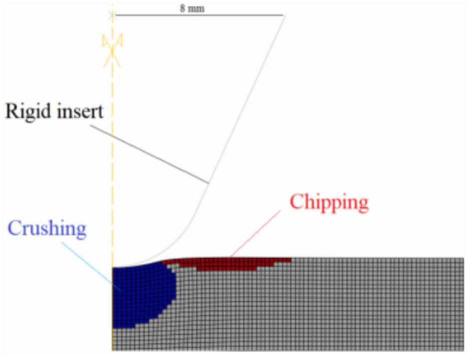




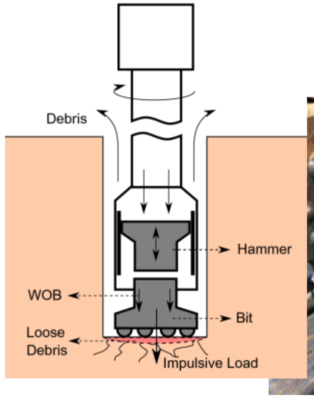
WP4 - Optimization of the stress release process while drilling

Numerical modeling

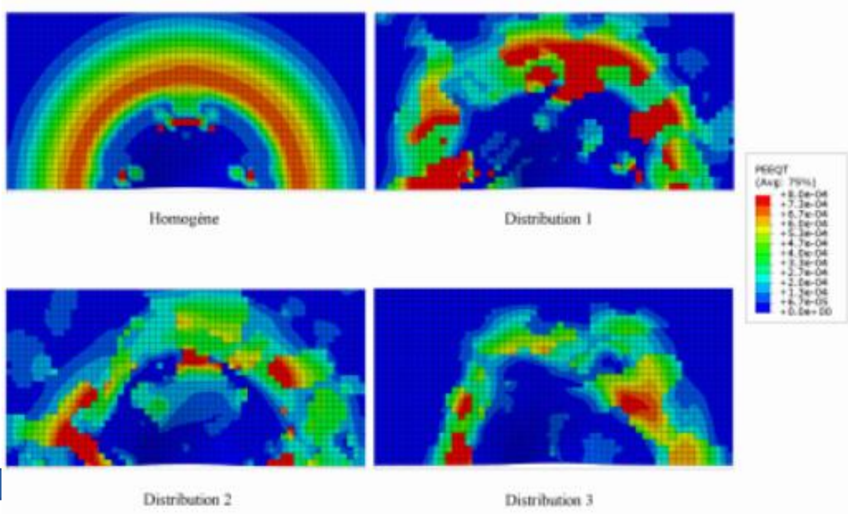




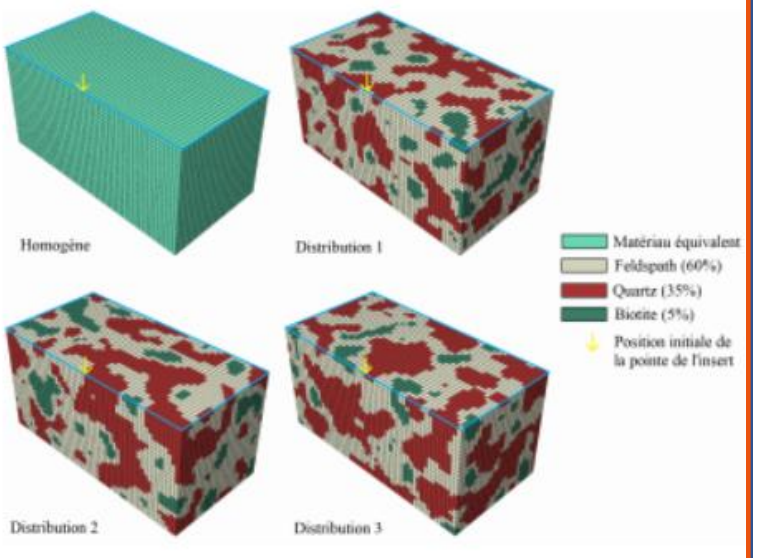
Crushed and chipped volumes identification.



Numerical modeling



- **Effect of rock heterogeneity**



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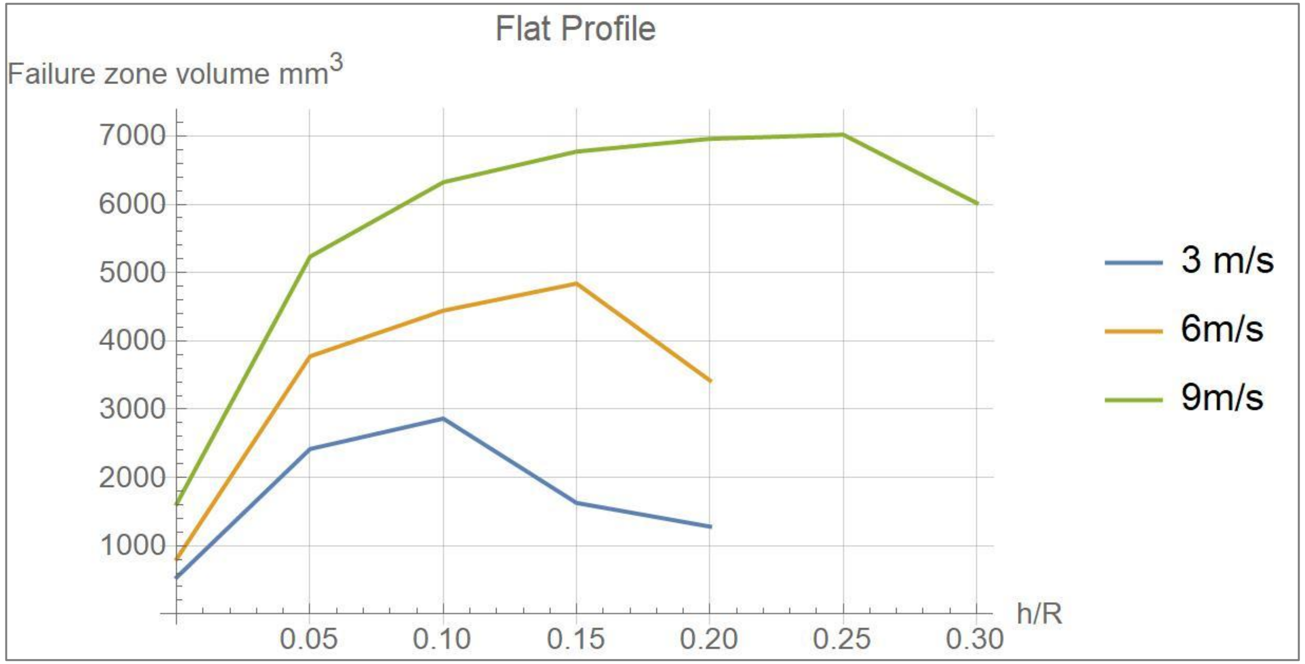
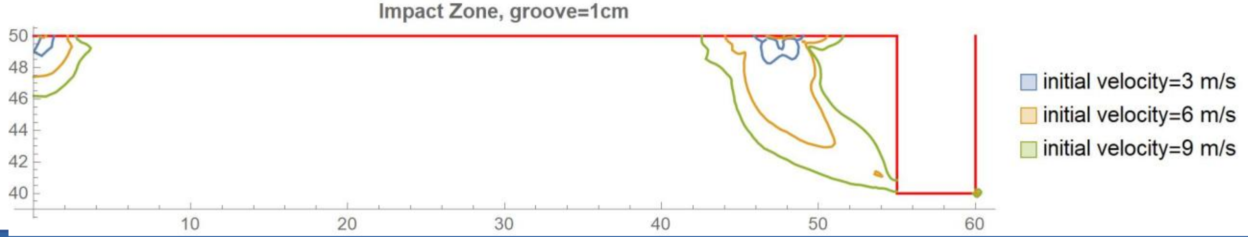
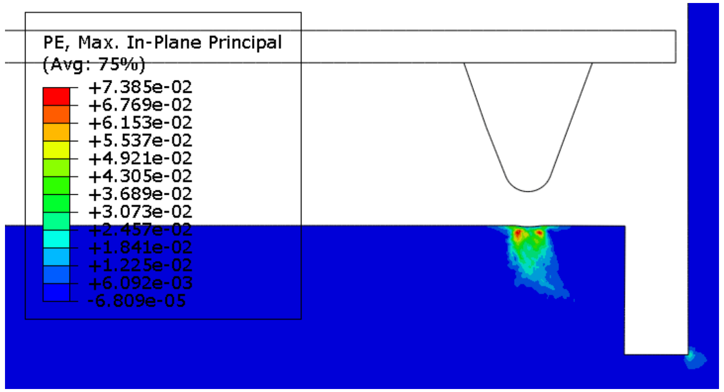
Implicit method: Contact velocity effect

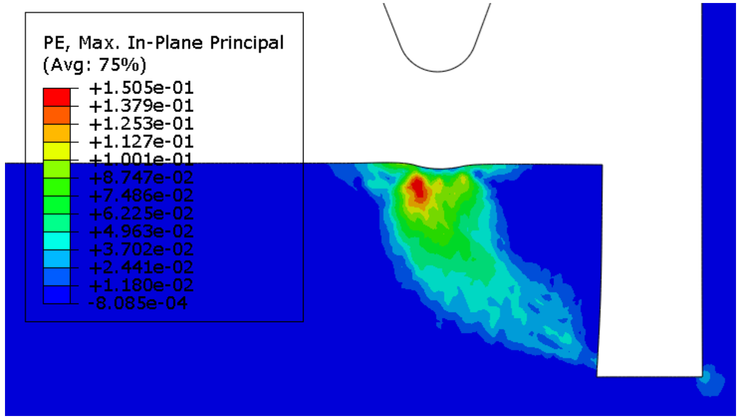


The h/R ratio (groove depth to hole radius) has a similar trend as within static analysis where an optimum point is obtainable according to the initial velocity (Impact energy).

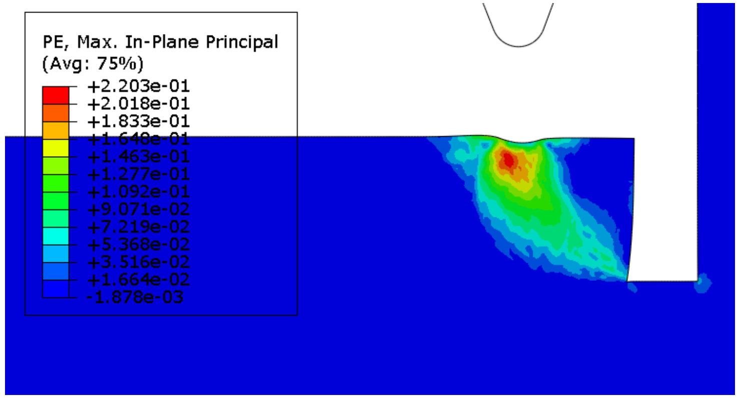




3 m/s



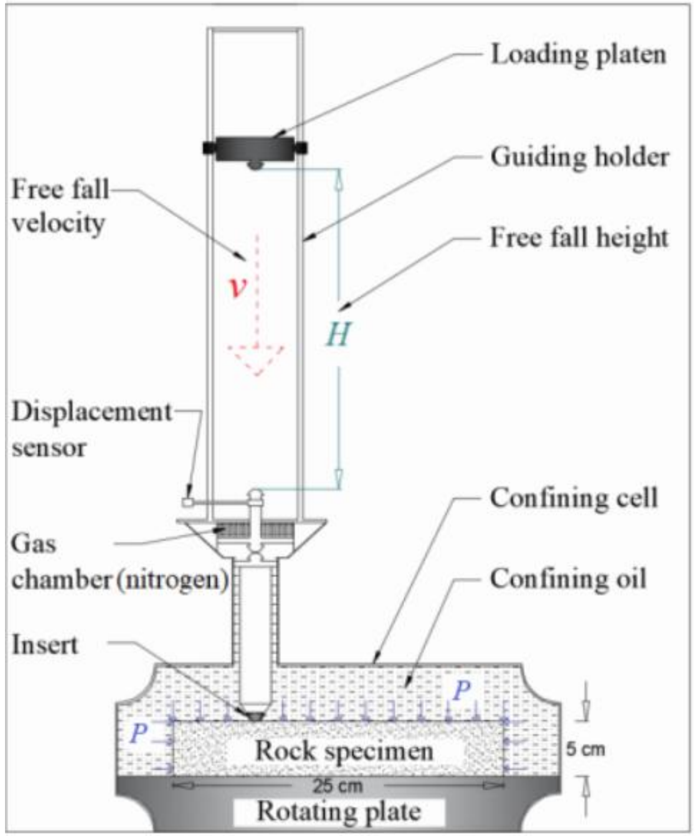
6 m/s

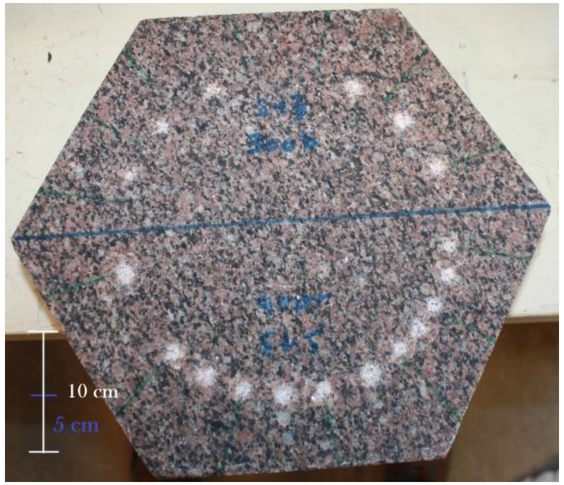


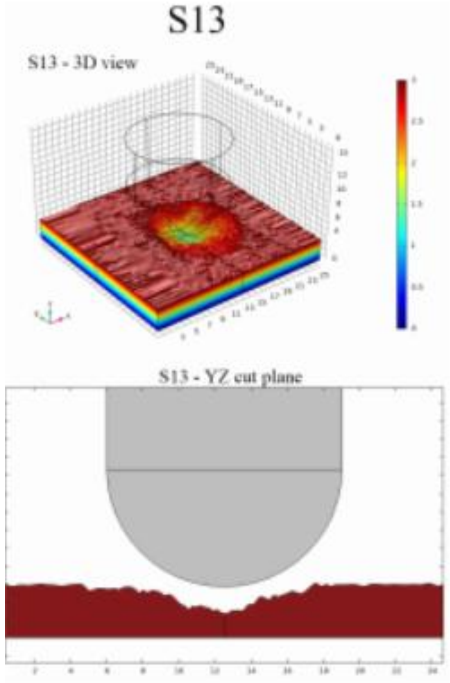
9 m/s

➢HAMMER BIT: OPTIMISE INSERT LAY OUT

- **Experimental approach**







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➢HAMMER BIT: OPTIMISE INSERT LAY OUT

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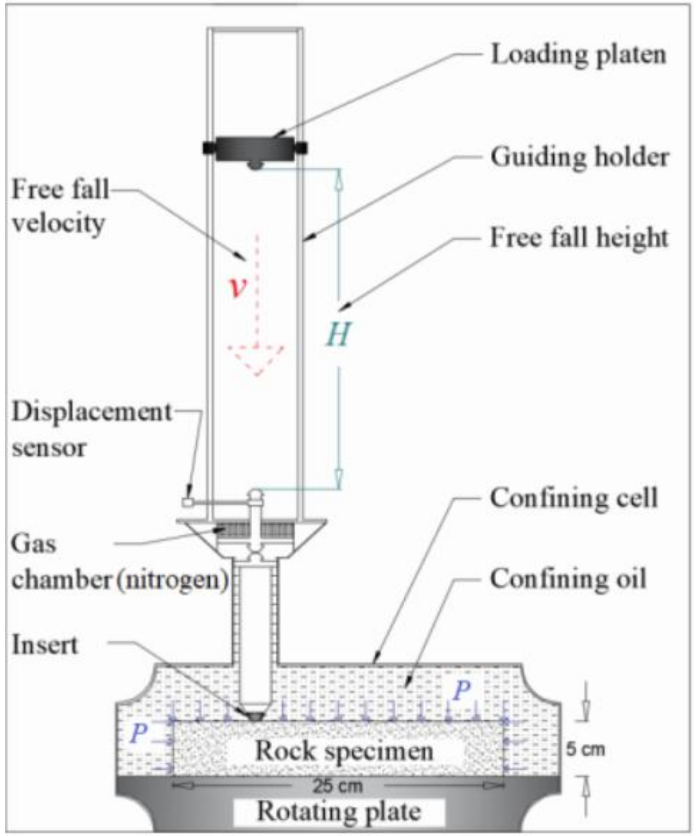
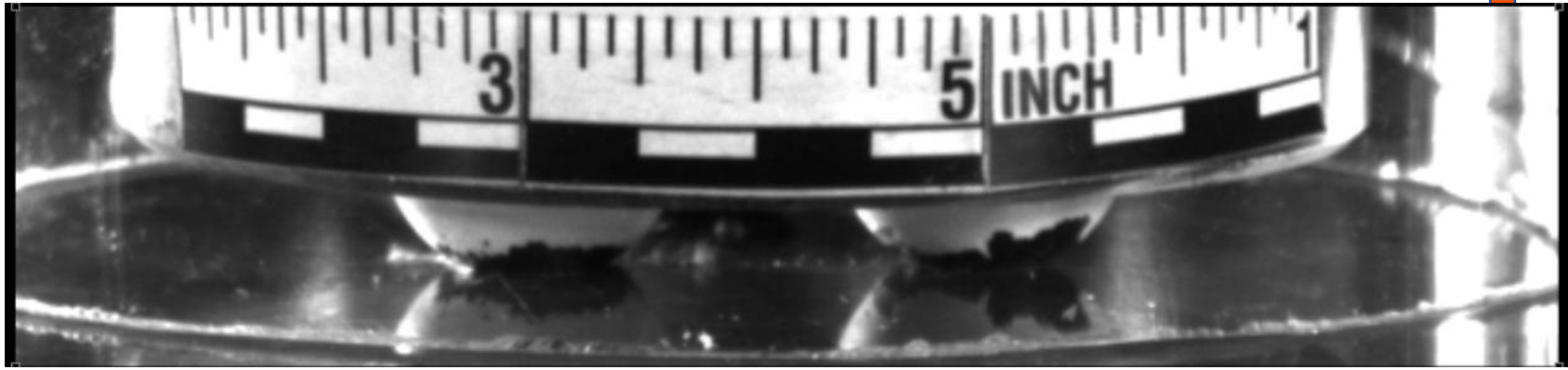
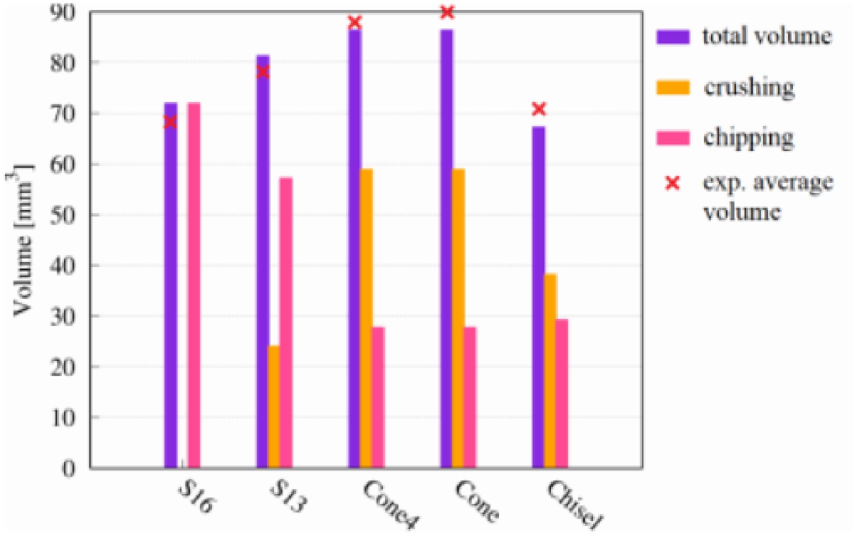
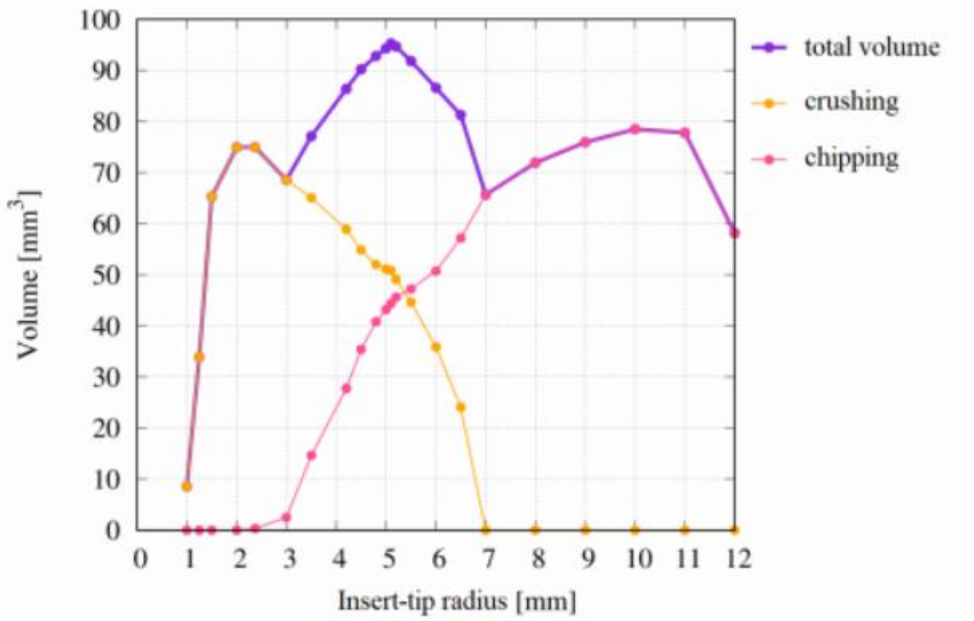




➢HAMMER BIT: OPTIMISE INSERT LAY OUT

- **Main results: Volume drilled**





➢HAMMER BIT: OPTIMISE INSERT LAY OUT

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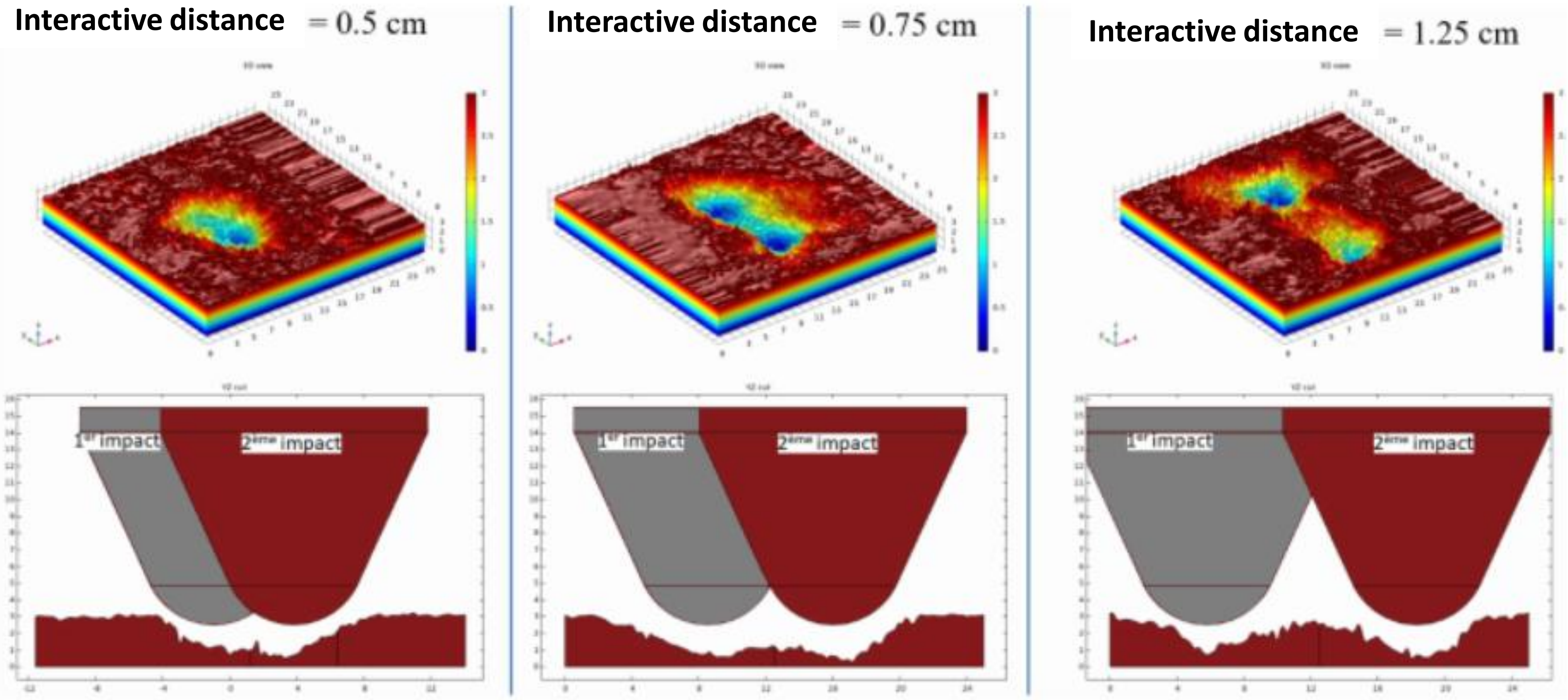
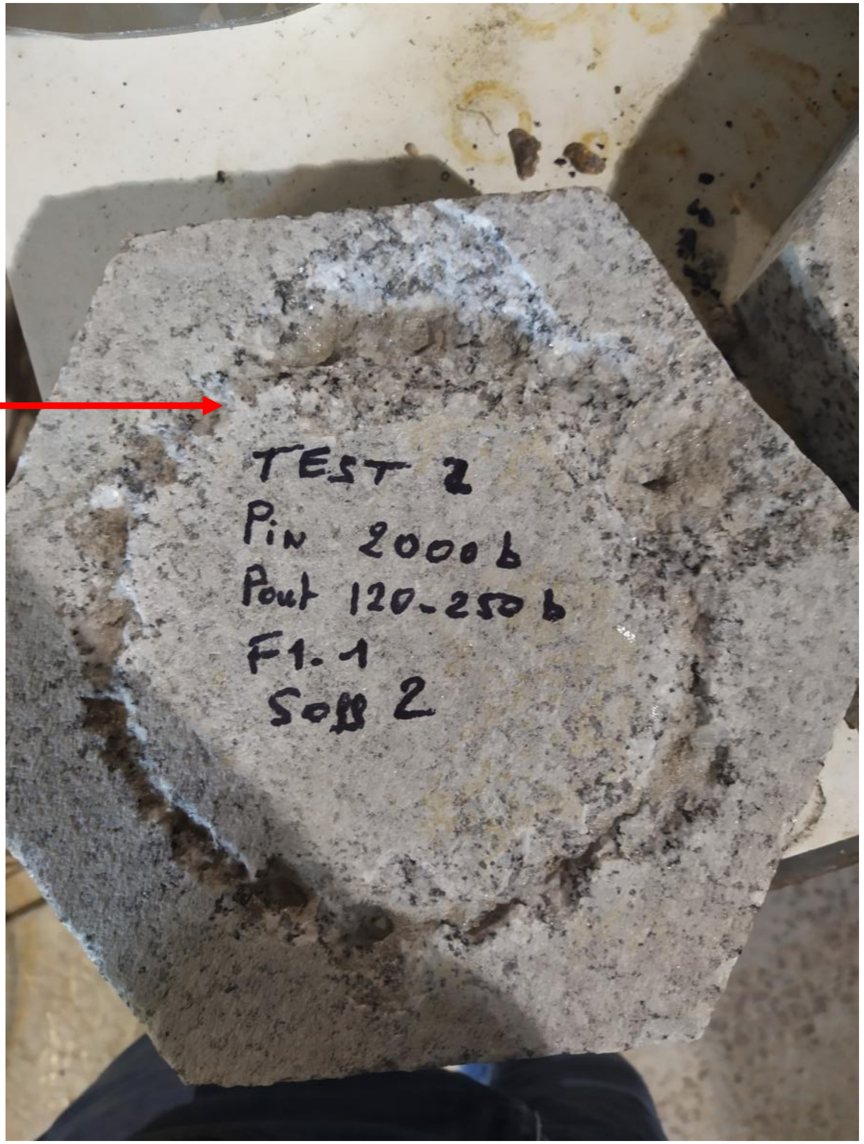


Rock sample and preparation

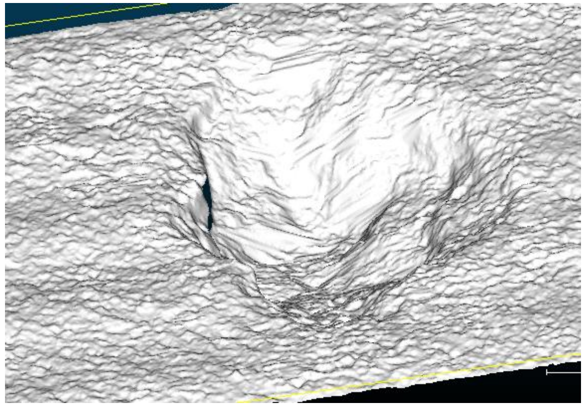
Table 1: Characteristics of the studied **Sidobre** granite

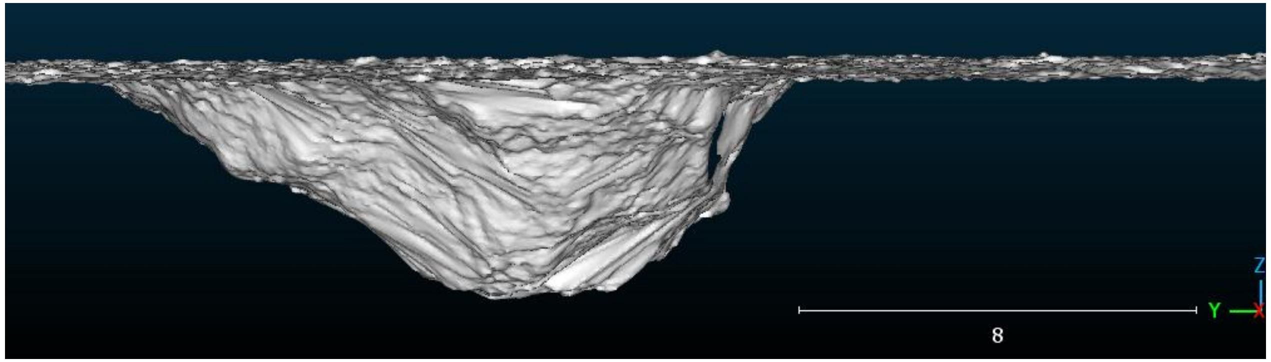
Density	**2635 kg/m^3**
Sound velocity	5600 m/sec
Young modulus	60 GPa
Poisson ratio	0.25
Uni-axial Tensile Strength (UTS)	8 MPa
Uni-axial Compressive Strength (UCS)	**150 MPa**
Cohesion	25 MPa
Friction angle	55 deg

groove created using HPWJ



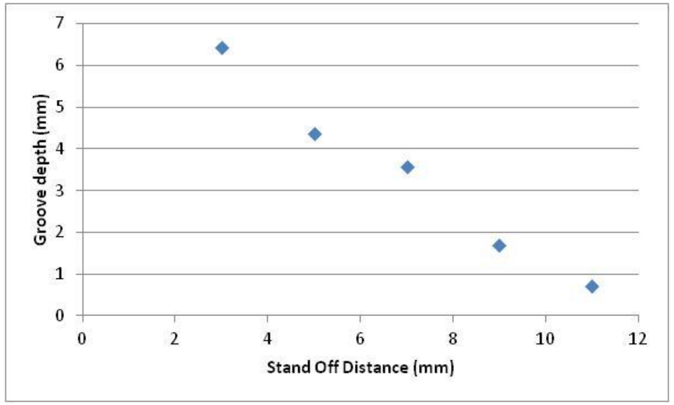
WP5: HPWJ Non Traversing Test





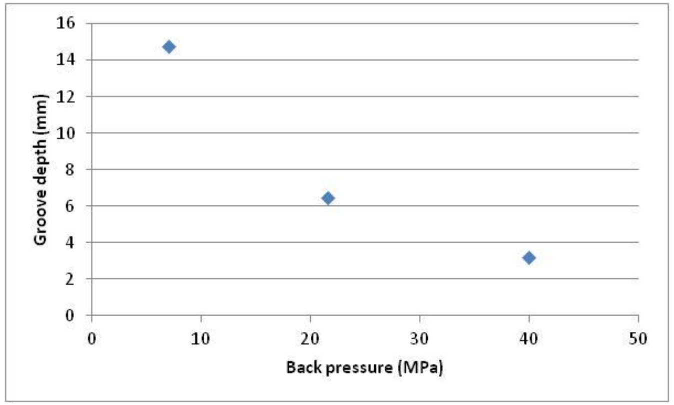
Sidobre, Injection Pressure = 240 MPa, Back Pressure = 20 Mpa, Nozzle F1, Diamètre 1 mm, SD = 4 mm

Stand Off Distance



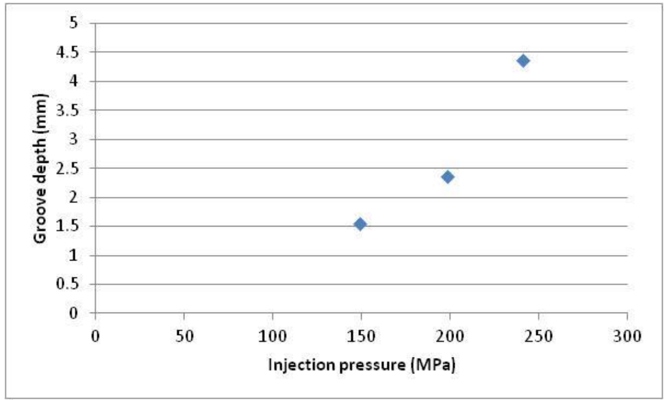
Sidobre, Injection Pressure = 240 MPa, Nozzle F1, Diamètre 1 mm, injection time 20s Back pressure = 20 MPa

Back pressure



Sidobre, Injection Pressure = 240 MPa, Nozzle F1, Diamètre 1 mm, injection time 20s, Stand Off = 5 mm

Injection pressure



Sidobre, Back Pressure = 20 MPa, Nozzle F1, Diamètre 1 mm, injection time 20s, Stand Off = 5 mm

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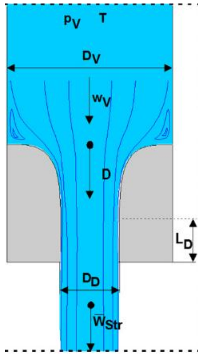
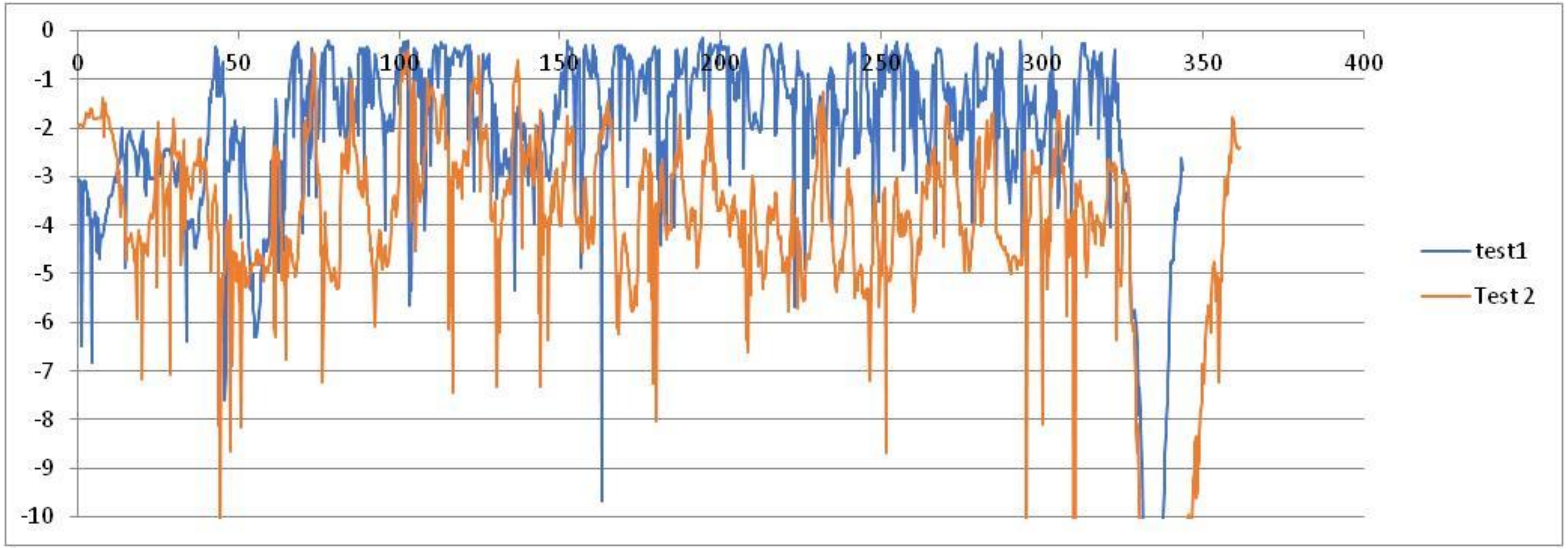
Parametric study

Nozzle type

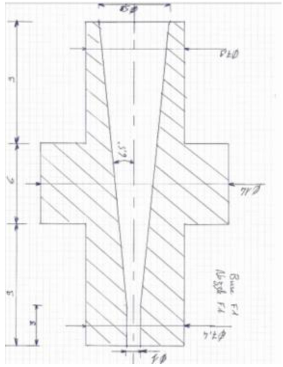
F21 Ceramic





Sidobre, Injection Pressure, = 200 MPa, Back Pressure = 20 MPa, Diamètre 1 mm, Rotation speed = 20 RPM, SD = 5 mm

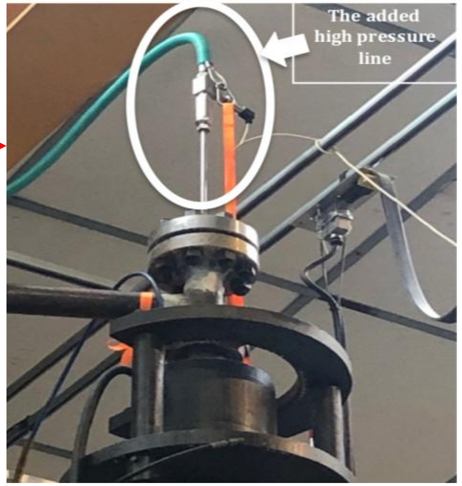
F1

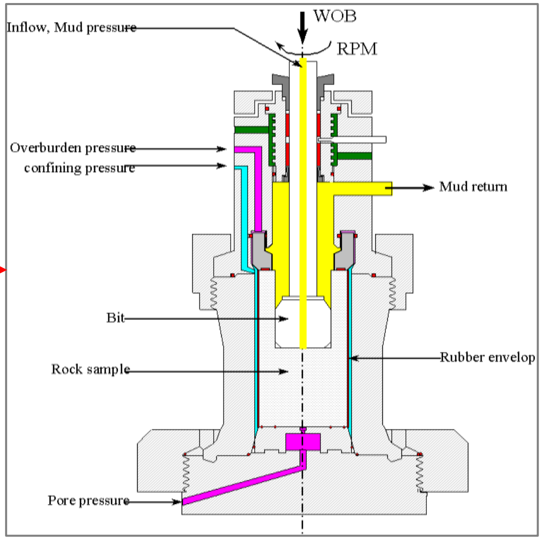


Experimental setup: ARMINES

Vertical drilling rig

Modification for HPWJ (connected to a HP pump)





Schematic of the cell

Hammer bit

HPWJ

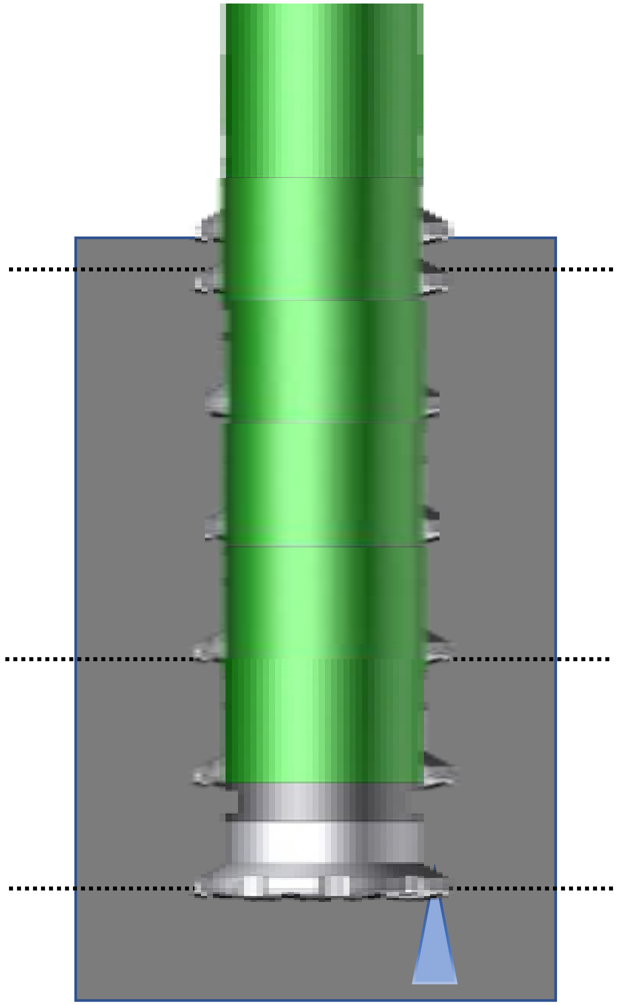
Location of rock sample (inside the confining chamber)

Operational testing snapshot

WP4.2 : Testing protocol

- ❑ Step 1: Fully engage the drill bit
- ❑ Step 2: Drill using rotary and hammer action only
- ❑ Step 3: Activate high pressure waterjet
- ❑ Step 4: Drill using rotary, hammer and HPWJ action
- ❑ Step 5: End of drilling

Input : Rock confining pressure (lateral, overburden)
Mud pressure and flow rate
Impact energy and frequency
WOB, RPM
Water Jet pressure
Output : ROP , TOB , groove depth



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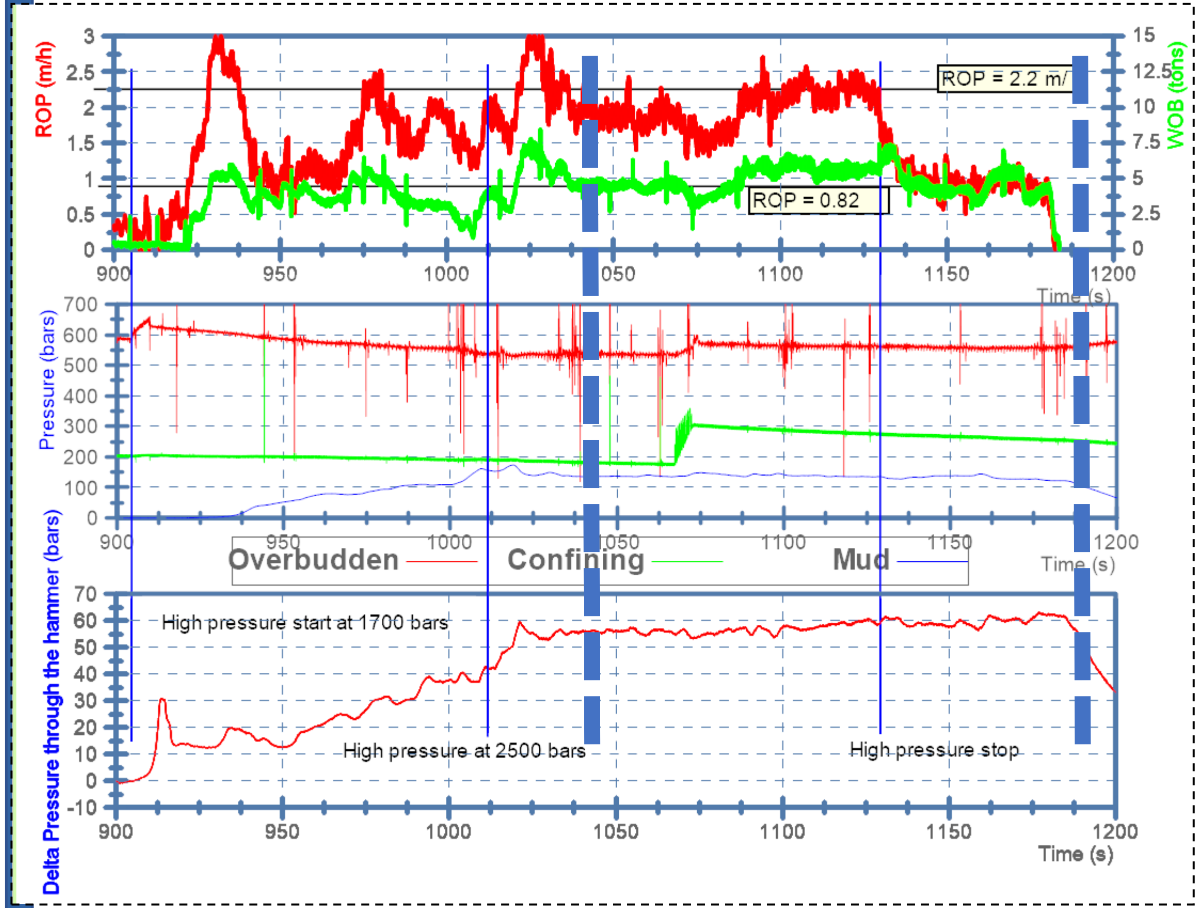
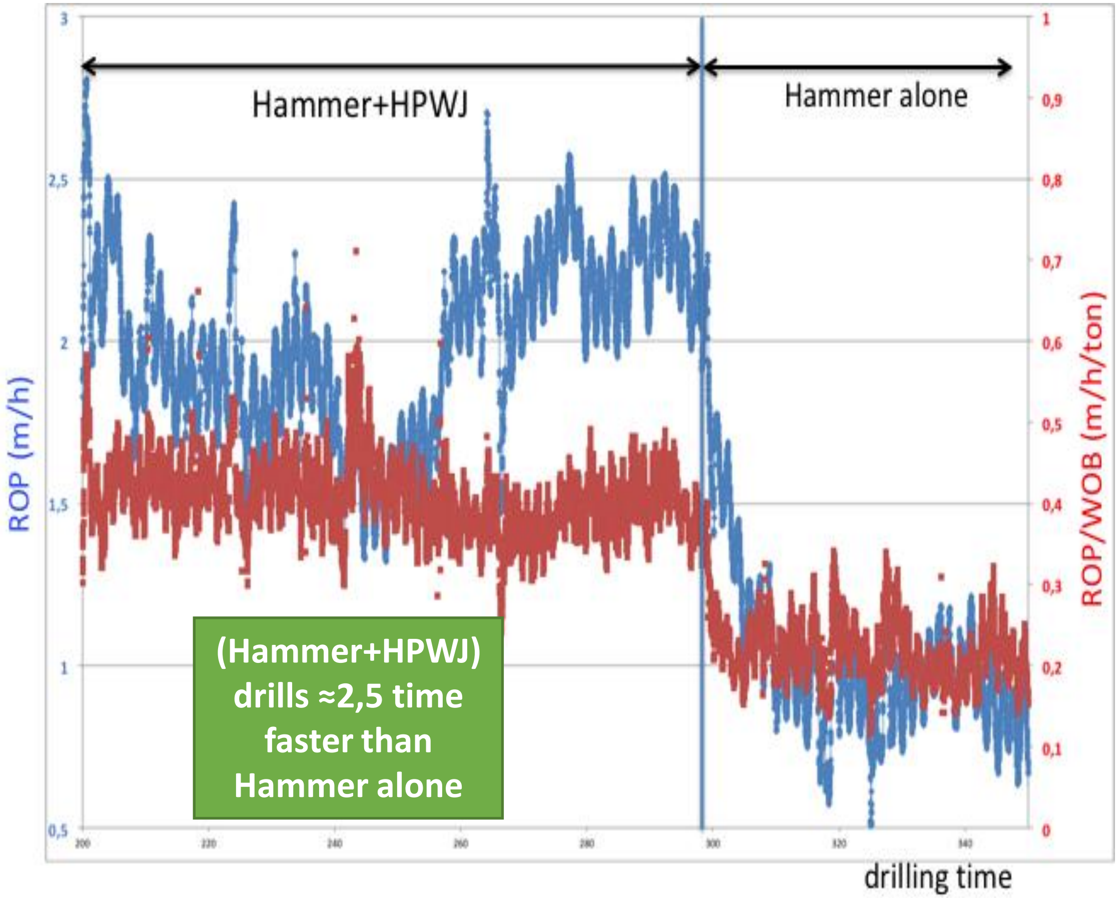
WP4.2 : Firts Results → Proof-of-concept

Data acquisition during drilling test



Drilling performances in Sidobre granite



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Conclusions

- Peripheral groove depth is one of the key improvment
- Improved insert lay out increase the drilling perfomance
- Results already show a ROP multiplied by 2.5 in Sidobre when HPWJ is used

Way Forward

- Design new prototype with the last improvment on HPWJ and percussive drilling
- Test new nozzles to increase the groove depth
- Perfomance on other type of rocks to be observed

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- Florian Cazenave and Raphaël Souchal, Drillstar Industries, France.

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ARMINES MINES ParisTech | PSL Imperial College London SINTEF

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Thank you!

Dr. Laurent Gerbaud
Scientific Coordinator - ORCHYD
ARMINES/ MinesParisTech
E: laurent.gerbaud@minesparis.psl.eu

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