EINSTEIN TELESCOPE

Preliminary technical prefeasibility assessment based on Aubel's borehole results

XIV ET Symposium | Maastricht

ENGINEERING SERVICES BY TRACTEBEL ENGINEERING & AMBERG ENGINEERING

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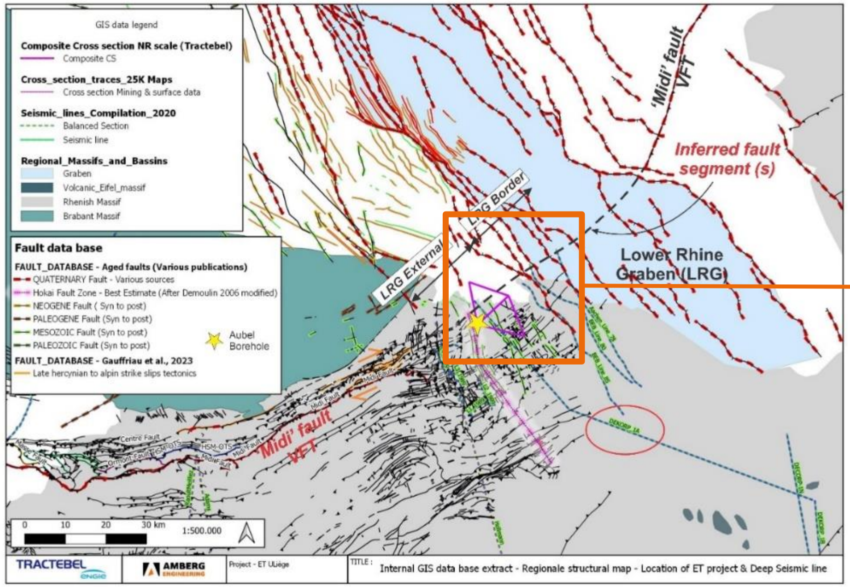
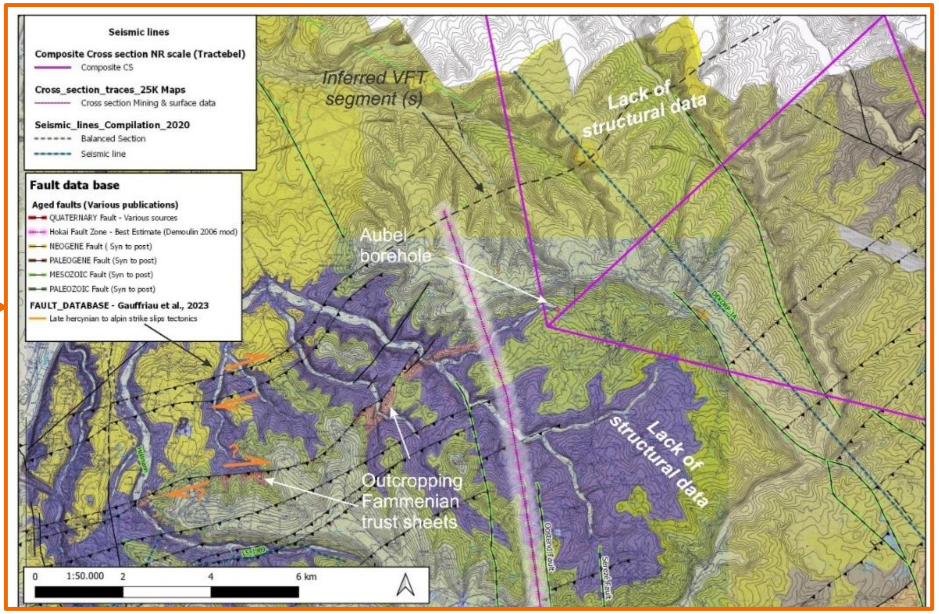
Borehole Aubel : Stratigraphy and tectonics

Near Regional geological map



Site Scale geological map



- Aubel borehole is in Paleozoic basement ➔ the Famennian sandstone series
- This sandstone tectonic sheet outcrops on the hanging wall of a main trust to the west of the site.
- At the site scale, there is lack of structural data ➔ Geological, structural conditions and, consequently, the rock mass characteristics are poorly defined

Ground interpretation results from borehole Aubel

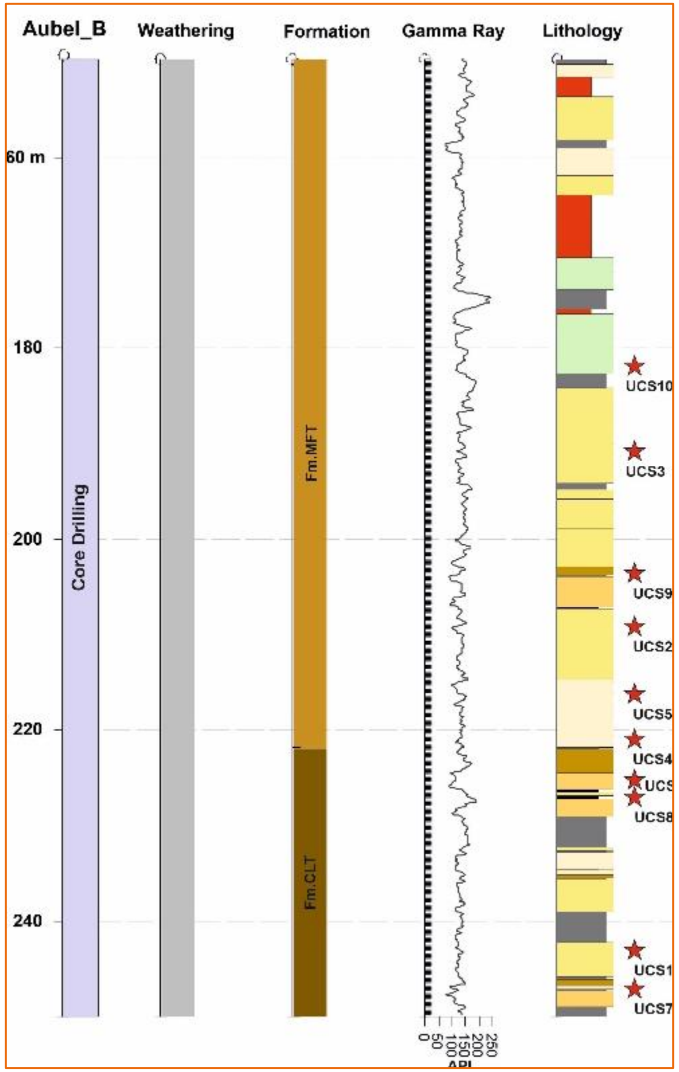
Borehole Aubel : *Lithostratigraphy*

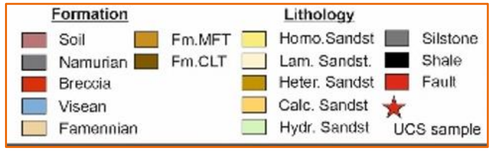
Eight lithological facies were recognized :

1. The first four lithological facies correspond to medium-coarse grained sandstones:
   - GH: Homogenous sandstone
   - GL: Laminated sandstone
   - Gi: Heterogeneous sandstone with clayey component in the rock matrix (black spots, clayey pebbles...)
   - GHC: sandstone with calcareous component (HCl reaction)
   - A particular sandstone facies (HGH) is identified corresponding to a hydrothermal alteration of sandstones with a greenish aspect

2. Two darker fine-grained materials are observed with siltstone (Slt) and clayey level with calcareous component (ARG)

3. A fault breccia facies at 2 levels: 152 and 164 m





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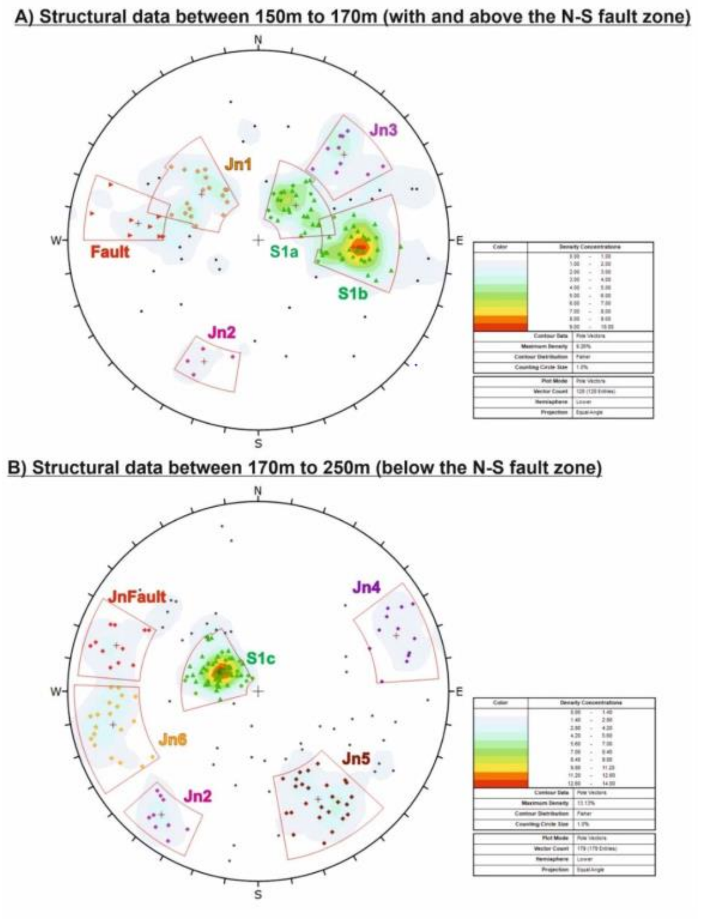
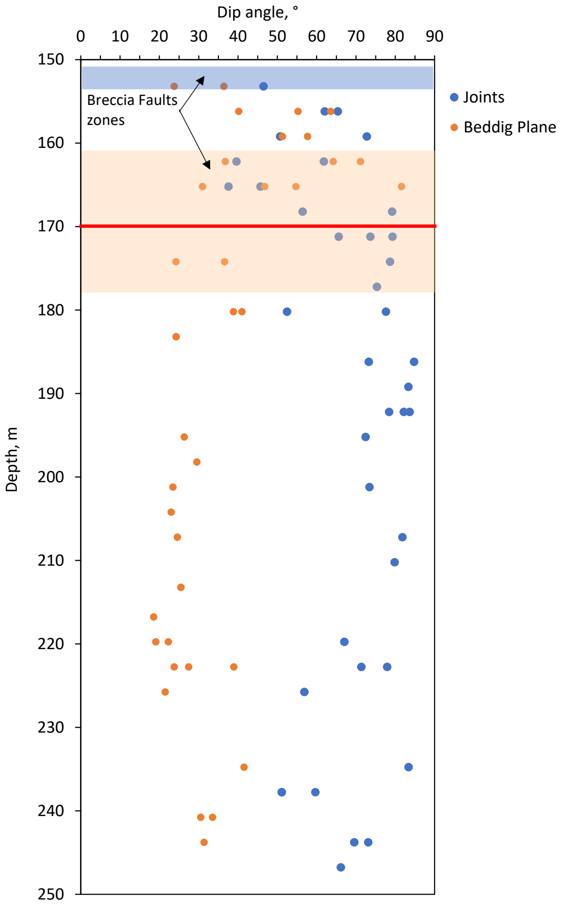
Aubel Borehole: *Joints identification*





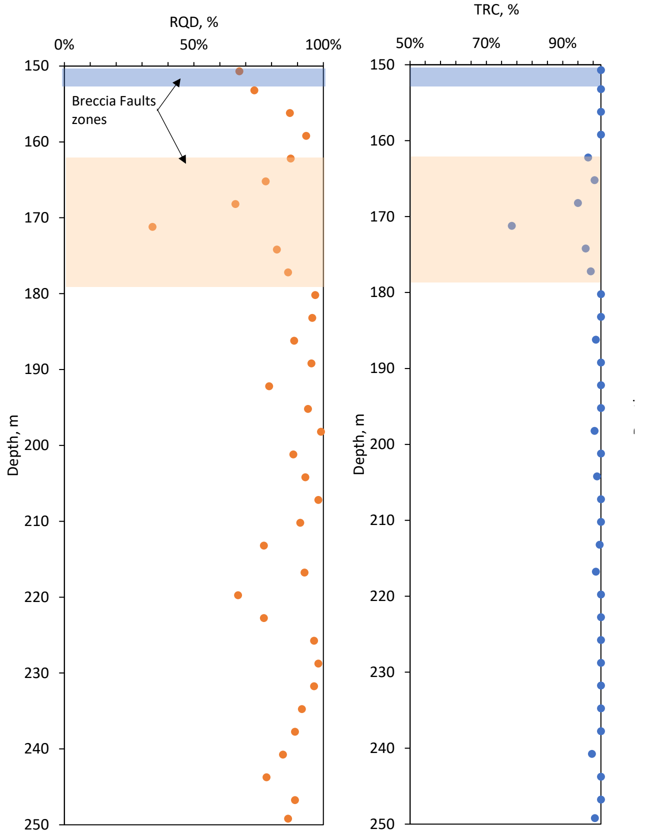
Two structural domains were identified separated by the N-S Fault zone :

1. The structural domain above the N-S Fault zone is composed of:
   - three sets of fractures/joints (Jn1, Jn2, Jn3) with a dip angle varying between 38 to 72°
   - One fault orientation (Fault: N09-70E)
   - two subsets representing the stratigraphical variation approaching fault-drag fault structure (S1a : N126-30SW and S1b : N185-60SW)
2. The structural domain below the N-S Fault zone is characterized by:
   - Four fracture sets (Jn2, Jn4, Jn5 and Jn6) with a dip angle from 56 to 83° (subvertical joints)
   - One fracture set associated to the fault (Jn-Fault)
   - One well-constrained set corresponding to the stratification (S1c: N28- 24SE) with a dip angle varying between 20 to 41° (subhorizontal)

Ground interpretation results from borehole Aubel

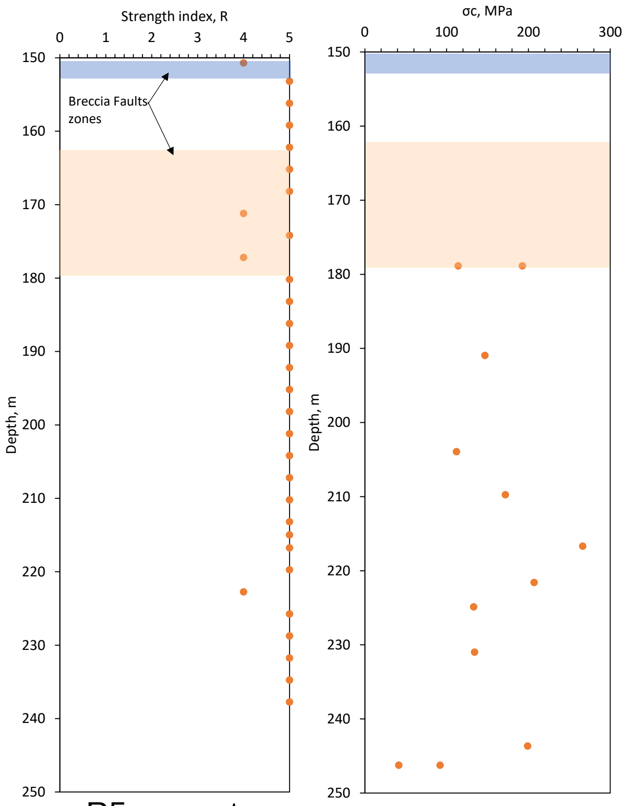
Evaluation results

Rock characteristics



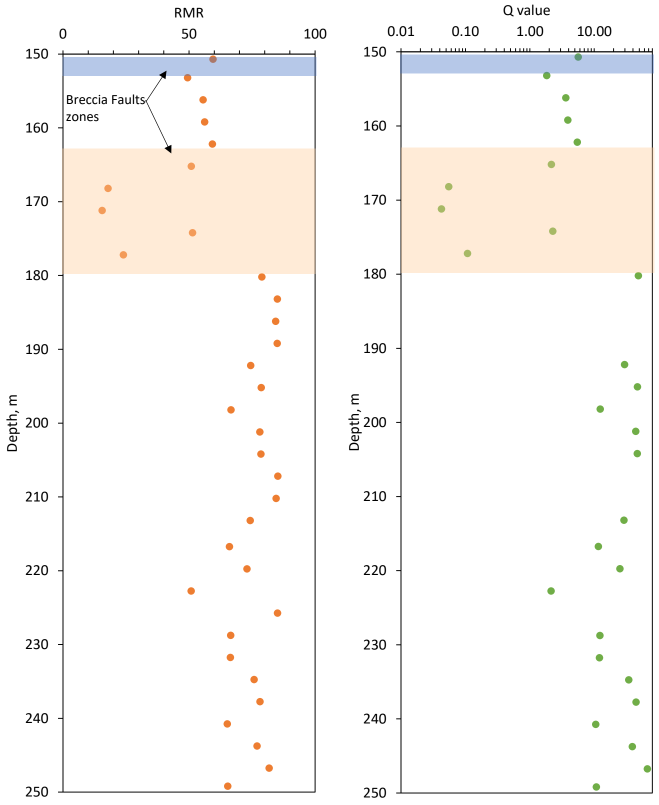
- RQD > 67%
- Good rock quality
- Lost core in fault zones only

Mechanical Properties



- R5: very strong
- σc > 100 Mpa to 266 Mpa
- Medium to hard rock

Rock Classification



- RMR mostly 65-82
  ➔ Good rock
- Q-value > 10 for 65% of the borehole length

Ground interpretation results from borehole Aubel

- Stratigraphy and tectonics
- Lithostratigraphy
- Joints
- Engineering parameters for construction assessment

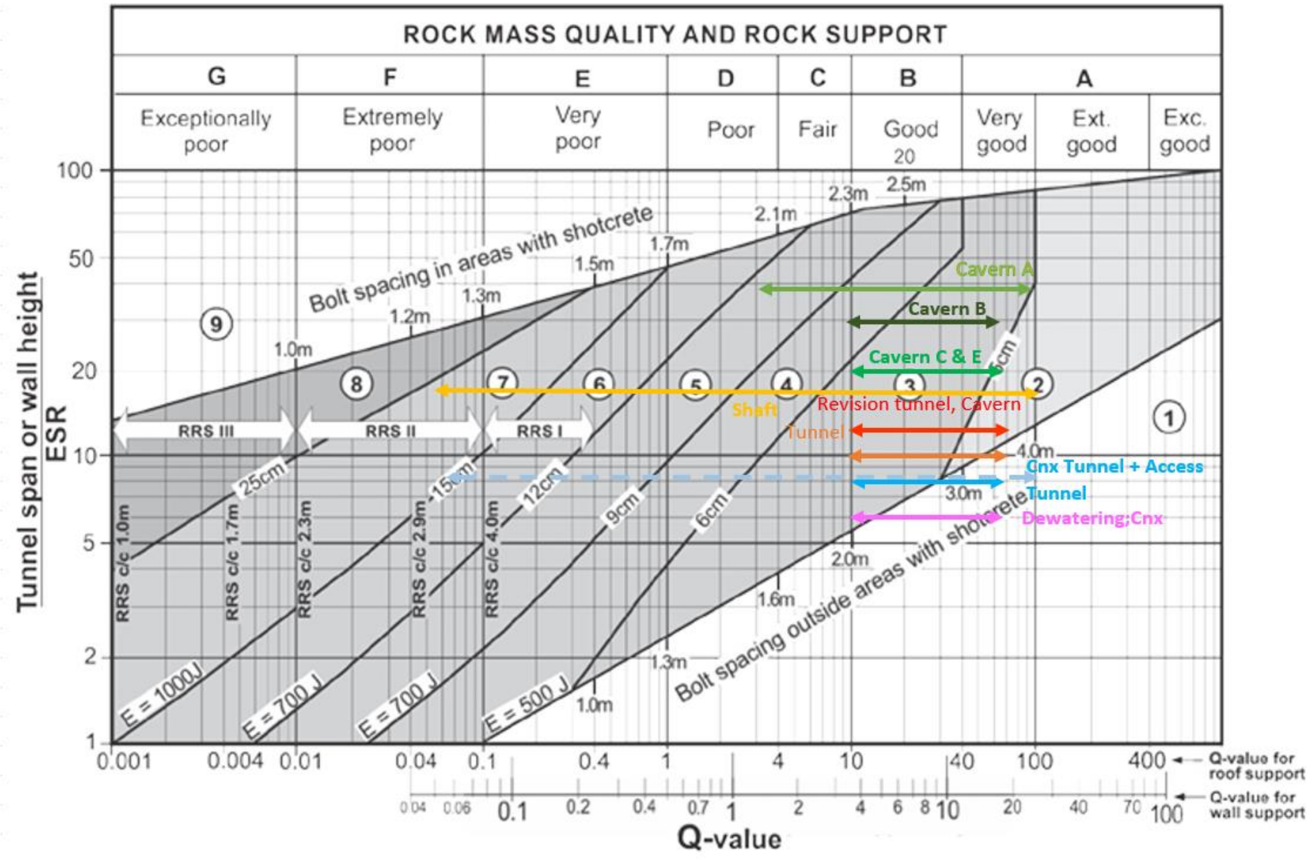
Subsurface conditions assessment for Aubel

- Reference layout feasibility assessment
- Design & construction assessment for for tunnel, caverns & shafts

Conclusions

Ground interpretation results from borehole Aubel

Evaluation results



Project Element	ESR	Eq. dimension (m)	Q-system range	Support requirements for vault
Tunnel	0.8	10	10-66	Shotcrete thickness 5-6 cm + systematic bolting
Shaft	0.8	15	0.04 -98	Range from RRS II to spot bolting
Revision tunnel, Cavern F, G	1	12	10-67	Shotcrete thickness 5-6 cm + systematic bolting
Dewatering/ construction tunnel & connection tunnel BA	1	6	10-67	Shotcrete thickness 5-6 cm + systematic bolting
Connection tunnel BC	1	8	10-67	Shotcrete thickness 5-6 cm + systematic bolting
Access tunnel	1.3	8	0.04 -98	Range from RRS I to no support
Cavern A, Cx, D & G	0.8	38	2-96	Shotcrete thickness 9-12 cm +Bolts spaced by 2.1 m
Cavern B	0.8	31	10-66	Shotcrete thickness 6-9 cm + Bolts spaced by 2.5 m
Cavern Cy	0.8	21	10-66	Shotcrete thickness 5-6 cm + systematic bolting
Cavern E	0.8	25	10-66	Shotcrete thickness 6-9 cm + Bolts spaced by 2.5 m

Subsurface conditions assessment for Aubel

Reference layout feasibility assessment based on borehole data – Caverns

	Cavern (span> 20m) (only conventional method considered)
RQD	✓ From depth 200 to 250 m: high values of RQD (77-98%), excavation of the caverns is possible
Weathering/alteration	For cavern depth: Fresh rock ✓ Conventional method: possible in this zone with bolting and immediate support
Broken/Lost core	For cavern depth between 220 and 250 m: no broken core ✓ Conventional methods are possible
Fault Breccia/Gauge	No fault zone from 220 to 250 m: ✓ Safe cavern excavation by conventional method ✓ Cavern support & lining can be optimised, partial excavation (i.e., NATM) is possible.
Dip	Dip angle changes from 20° to 84° along the depth ✓ Bolting and immediate lateral support. Might need face support
UCS tests	✓ Very high resistance rock mass, cavern support & lining can be optimised, partial excavation (i.e., NATM) is possible.
Graphite	✓ Concrete lining immediately following the excavation of front ✓ Shotcrete at the tunnel face
Strength Index	The rock mass is strong (R4) to very strong (R5),drill and blast should be used.
Water conditions	Unknown water conditions at the depth of the caverns ✓ Monitoring water levels ✓ Pre-excavation probing ✗ Pregrouting might be required. ✗ If water inflow is confirmed, might also need post excavation grouting.

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Subsurface conditions assessment for Aubel

Reference layout feasibility assessment based on borehole data – Shafts

	Shaft
RQD	Missing values of RQD for the first 150. From 150 to 250m, 94% of the borehole length has an RQD higher than 67%. ✓ Methods like SBC or drilling jumbos could be used ✓ Concrete lining to be installed immediately following the excavation for the fault zones ✓ Lining of circular shaft could be optimised
Weathering/ alteration	Fresh to slightly weathered rock from 150- 250m ✓ Methods like SBC seem safer as no data is available for the first 150 m ✓ Conventional methods are possible when combined with hard rock excavating methods (eg. drilling jumbo)
Fault Breccia/Gauge	2 Faults zones were identified: between 151 and 153 m and the second between 164 to 170 m with an alteration zone from 170-183 m ✓ Methods like SBC are more appropriate ✓ Concrete lining immediately following the excavation in these zones
Dip	Dip angle changes from 20° to 84° along the depth with steep dip angle encountered: possible flocking, lateral support needed ✓ Methods like SBC appear to be safer ✓ Concrete lining immediately following the excavation
UCS tests	✓ The use of gripper support is possible ✓ Lining of circular shaft could be optimised ✓ The use of conventional method like Drill and Blast might apply
Strength index	✓ Drill and blast ✓ Unknown rock strength for the first 150 m, excavation method could not be generalized along the whole depth of the shaft
Graphite	✓ Methods like SBC might be safer ✓ Concrete lining immediately following the excavation
Water conditions	Unknown, the water table is at 9m below ground level which might imply the need of: Monitoring water levels Draining pipes through final lining ✗ Permanent pumping ✗ Grouting to reduce permeability

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Subsurface conditions assessment for Aubel

Reference layout feasibility assessment based on borehole data – Tunnels

	Tunnel and access/connection galleries (TBM and conventional method considered)
RQD	For tunnel depth: high values of RQD (78-89%) ✓ Open TBM or gripper TBM is adequate for tunnel's depth (estimated below 200 m) ✓ Conventional method possible in this zone
Weathering/ alteration	For tunnel depth: Fresh rock ✓ Open TBM is possible ✓ Drill and blast for connecting or auxiliary galleries of non-conventional diameter might be considered.
Fault Breccia/Gauge	At the depth of the tunnel, no fault zone were identified : ✓ For tunnel depth: open TBM is possible, no notable uncemented faults ✓ Conventional method : possible in this zone ✓ Lining could be optimized
Dip	Dip angle changes from 20° to 84° along the depth. Below 200 m , 4 families of joints identified and 1 bedding plane ✓ Open TBM possible, bolting and shotcrete layer support to ensure stability of small blocks ✓ Conventional method: Support by bolting and shotcrete layer . Might need face support
UCS tests	✓ In the depth of the tunnel: Extremely high resistance rock mass, tunnel support & lining can be optimised ✓ The use of gripper tunnel is possible ✗ Mechanical method as roadheader might not be suitable
Strength index	The rock mass is strong (R4) to very strong (R5),drill and blast should be used.
Graphite	✓ Concrete lining immediately following the excavation of front ✓ Shotcrete at the tunnel face
Water conditions	Unknown water conditions at the depth of the tunnel ✓ Monitoring water levels ✓ Pre-excavation probing ✗ Pregrouting might be required. Permanent pump sumps required, if the layout cannot be modified with inclined tunnels

Subsurface conditions assessment for Aubel

Reference layout feasibility assessment – Conclusions

Confronting the ground conditions to the construction elements	Cavern (span> 20m) (only conventional method considered)	Tunnel and access/connection galleries (TBM and conventional method considered)	Shaft
Conclusion: considering the most exclusive criteria	✓ Conventional methods could be used along with a support system of shotcrete and systematic bolting ✓ Drill and blast is suitable	✓ Open TBM ✗ Conventional method with shotcrete layer and systematic bolting ✓ Avoid profusion of water when excavating	✗ No data for the whole depth of the shaft ✓ Methods like SBC could be more appropriate ✗ Avoid profusion of water when excavating in case clay exists ✓ Concrete lining immediately following the excavation in the fault zones

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Questions round

Thank you for your attention