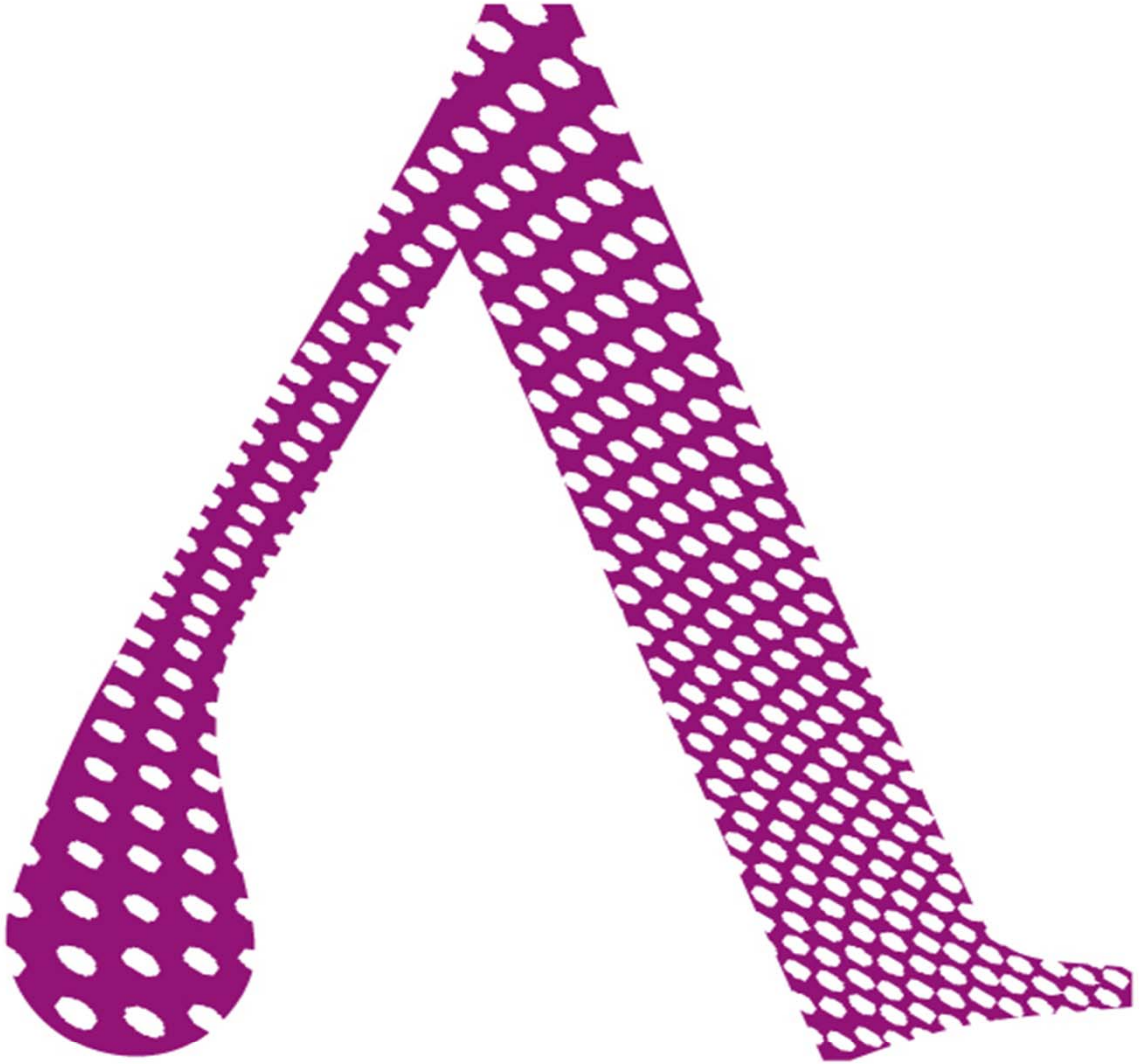


Lagvna

ROCKPLAN

LAGUNA-LBNO Design Study

(EU, FP 7 – INFRASTRUCTURE 2011-1)

ANT 11

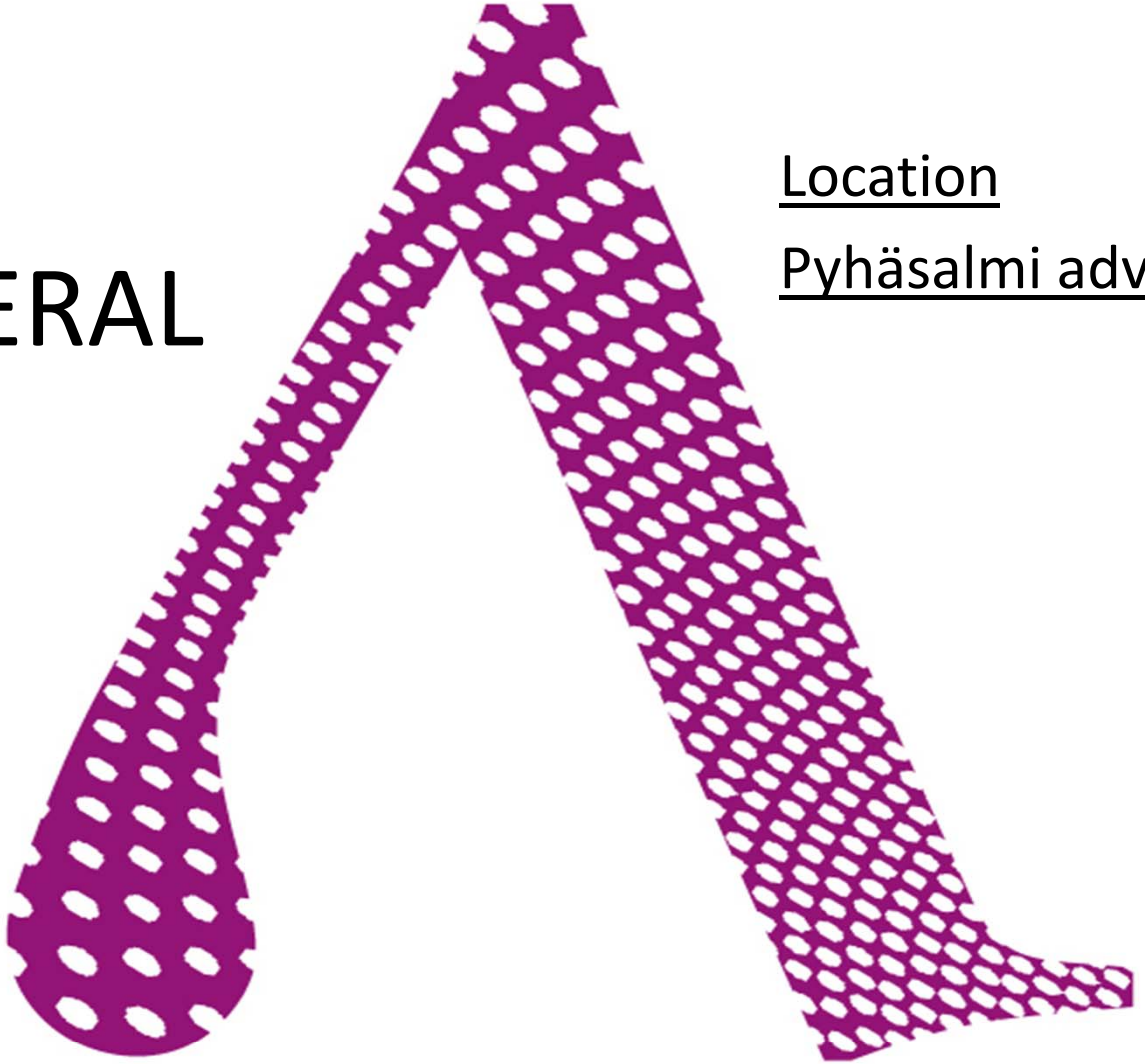
GEOTECHNICAL STUDIES FOR LENA (LIQUID SCINTILLATOR) AT PYHÄSALMI, FINLAND

ROCKPLAN

GENERAL

Location

Pyhäsalmi advantages



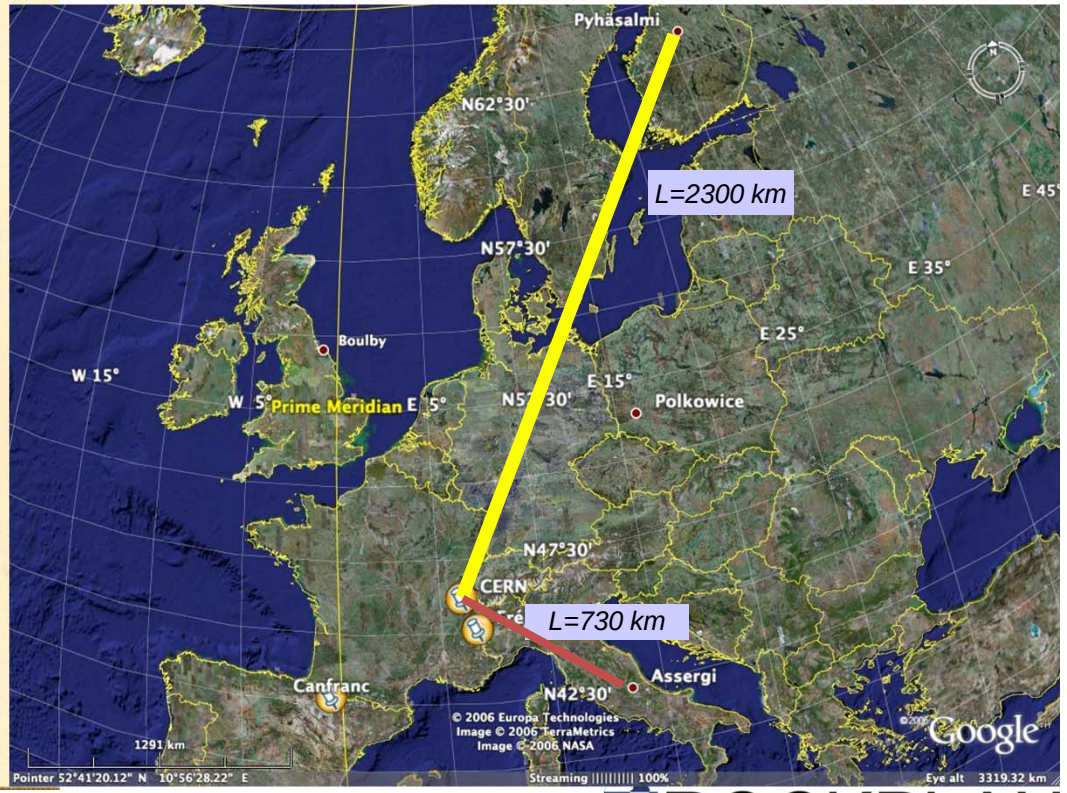
LAGUNA

ROCKPLAN

Location of Pyhäsalmi

Pyhäsalmi advantages:

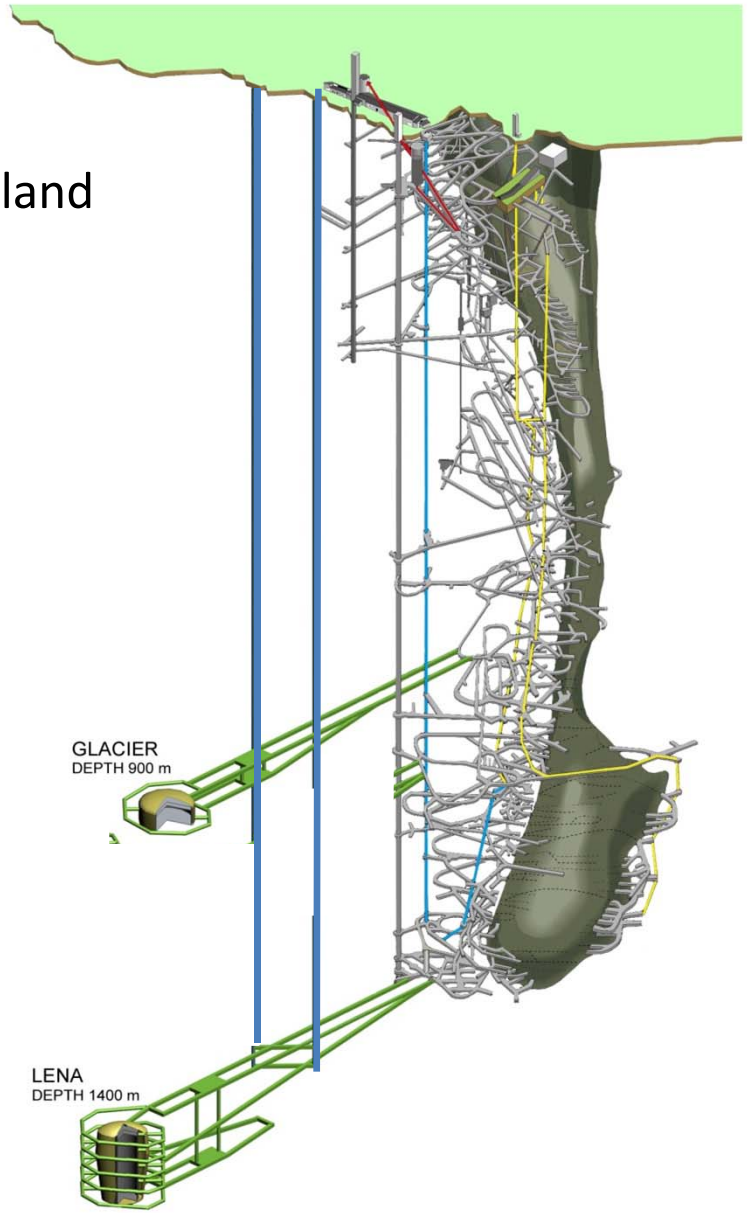
- No nuclear plants, yet
- Sufficient depth
- Long distance from CERN
- All alternatives possible



ROCKPLAN

Current alternatives studied in LAGUNA-LBNO & depth of experiments

Finland



Finland
- LIQUID SCINTILLATOR @ -1400
- LIQUID ARGON @ -900

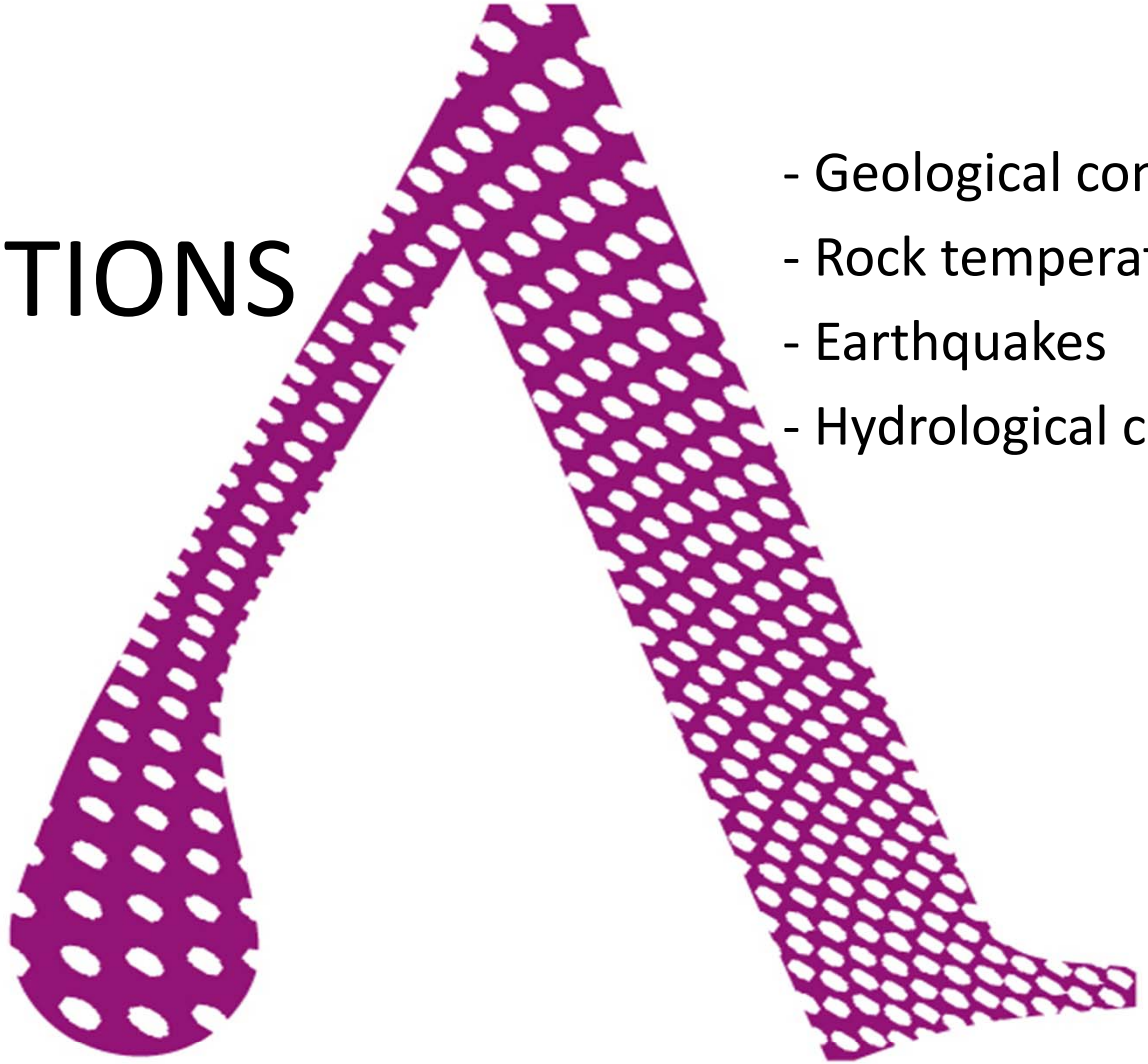
France
-WATER CHERENKOV @ -1500

Italia
- LIQUID ARGON @ -650

ROCKPLAN

ROCK CONDITIONS

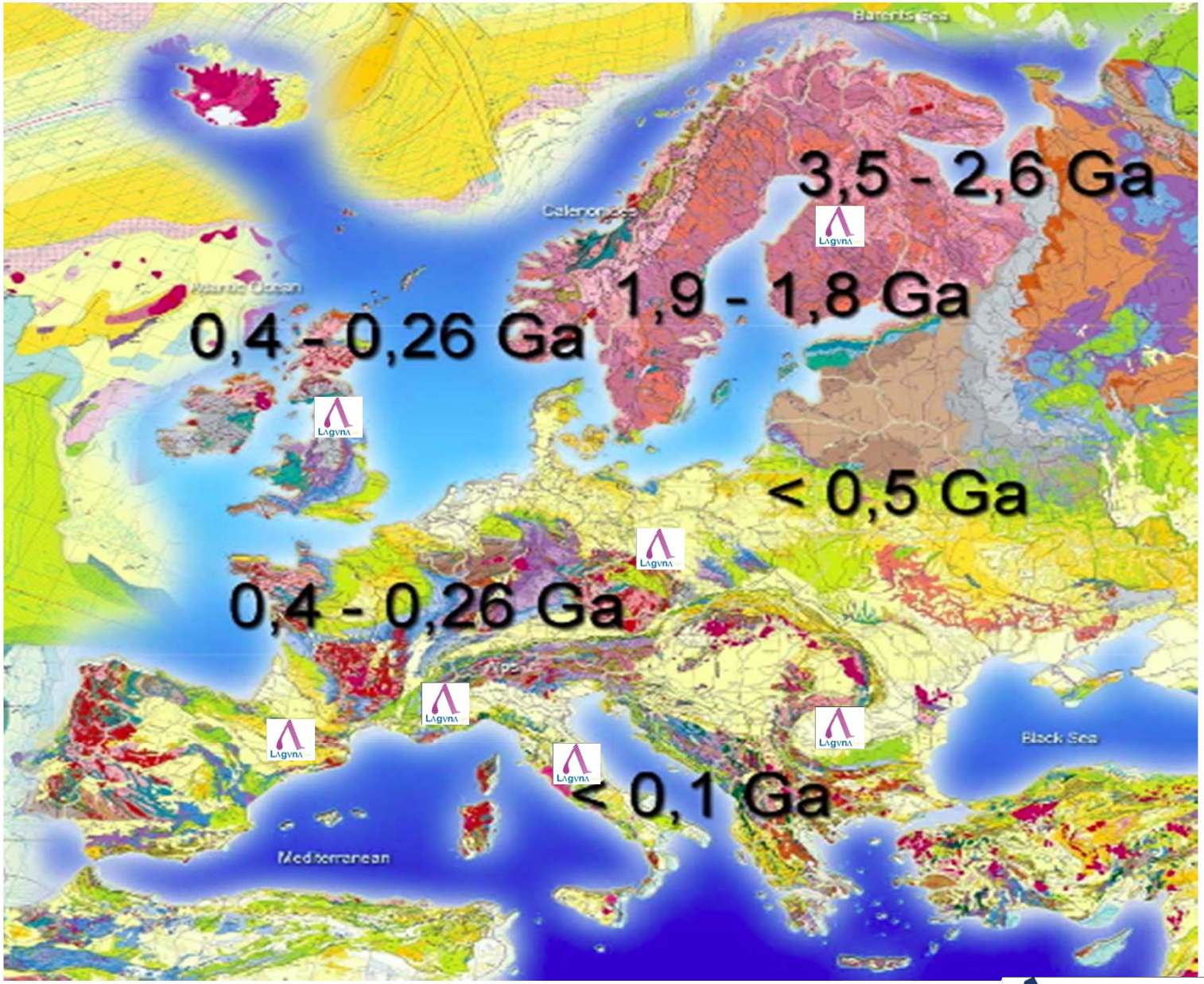
- Geological conditions
- Rock temperature
- Earthquakes
- Hydrological conditions



LAGUNA

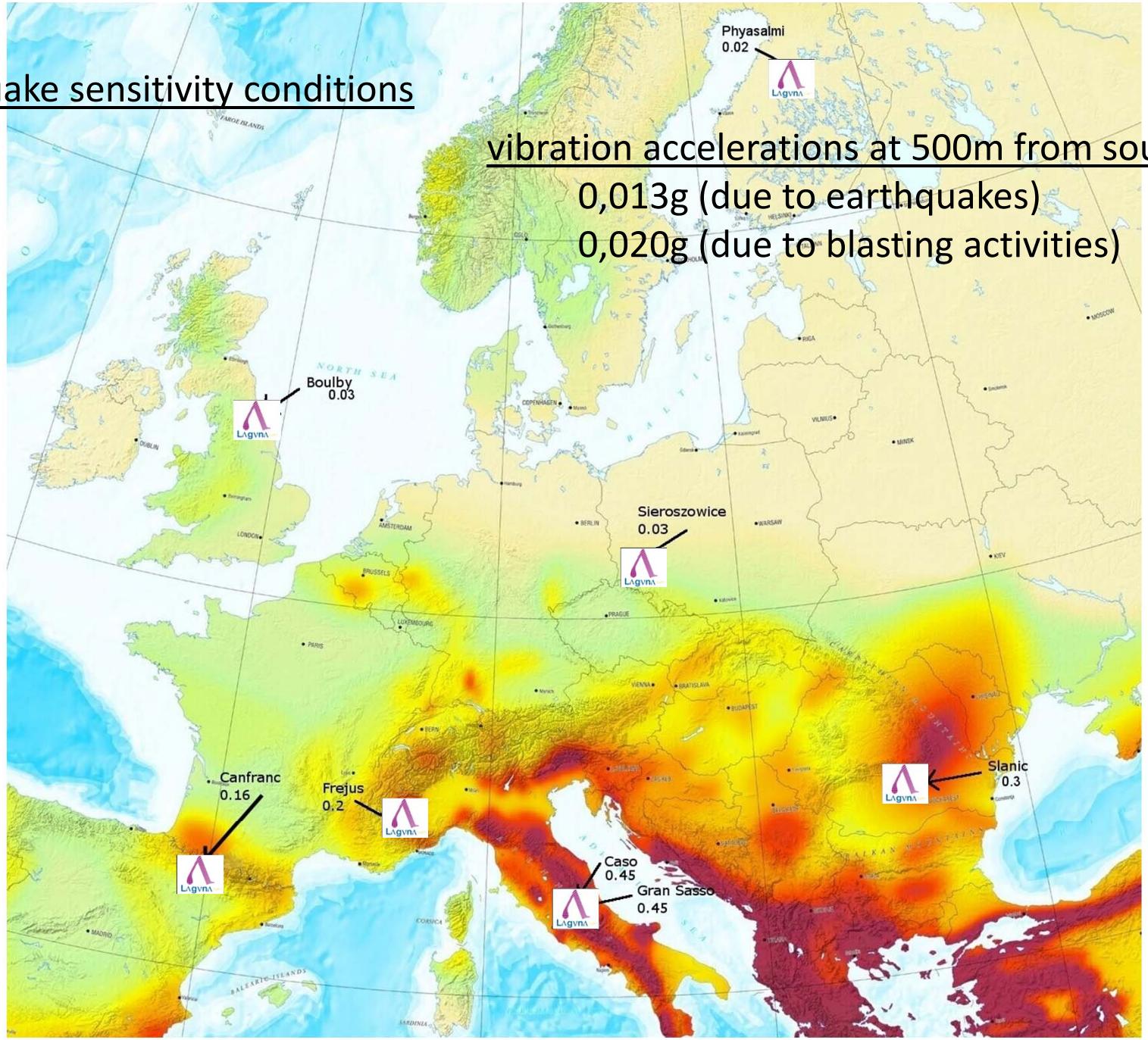
ROCKPLAN

Geology: stable (ancient) bedrock conditions



ROCKPLAN

Earthquake sensitivity conditions



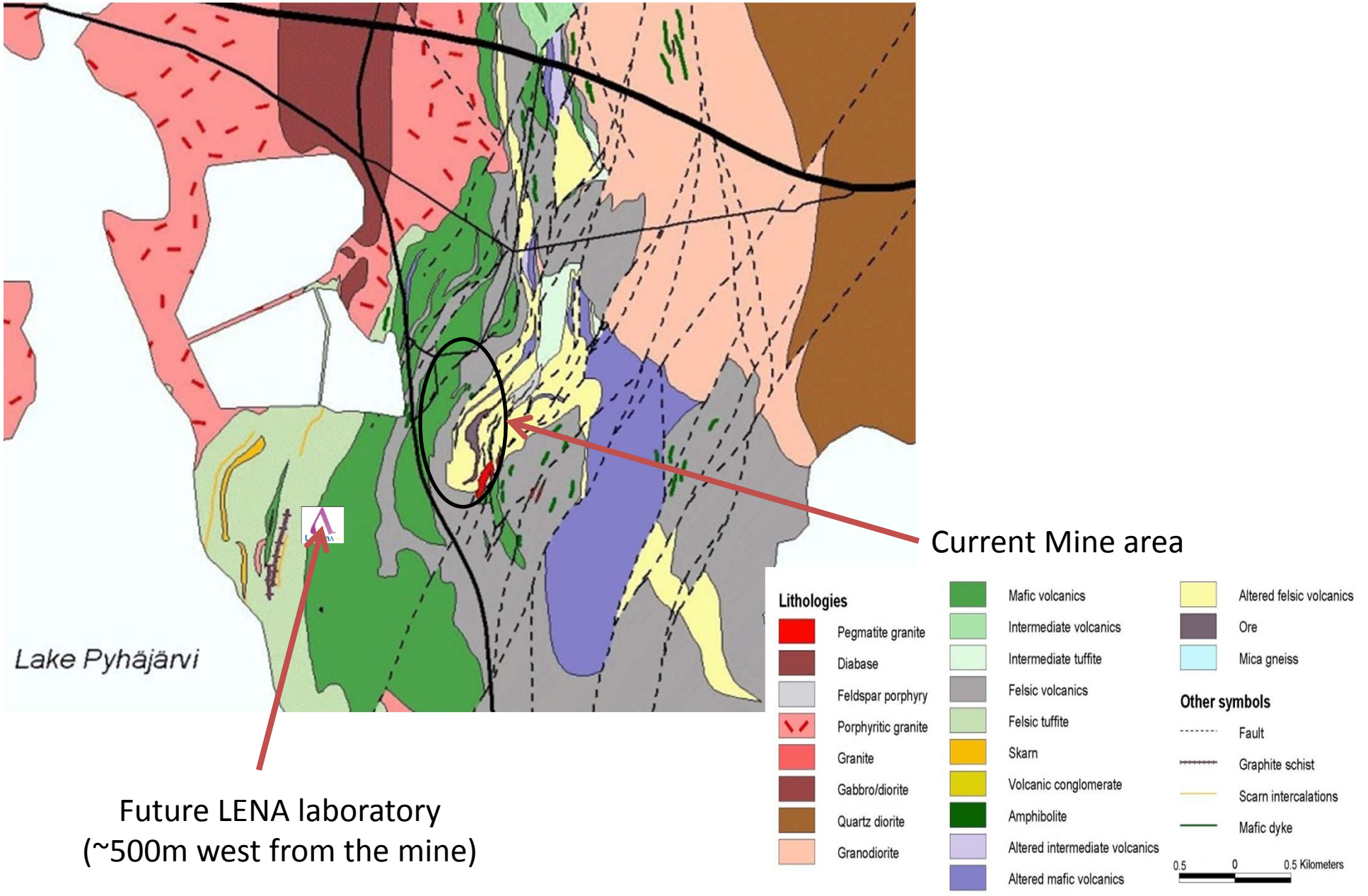
vibration accelerations at 500m from source:

0,013g (due to earthquakes)

0,020g (due to blasting activities)

ROCKPLAN

Lithological map of the Pyhäsalmi geological complex



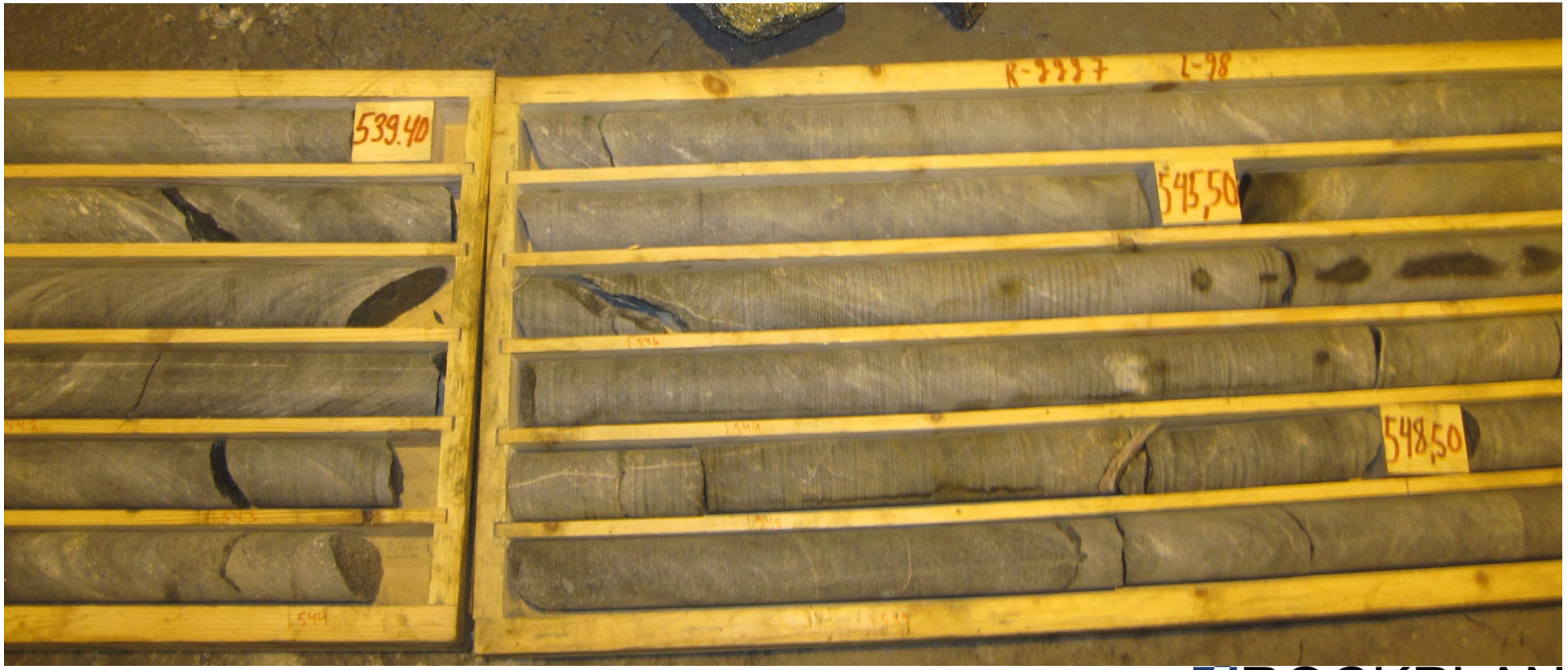
ROCKPLAN

Rock sampling at Pyhäsalmi mine (Finland)

Several boreholes executed at -1385m to -1450 level (spring 2002) for CUPP

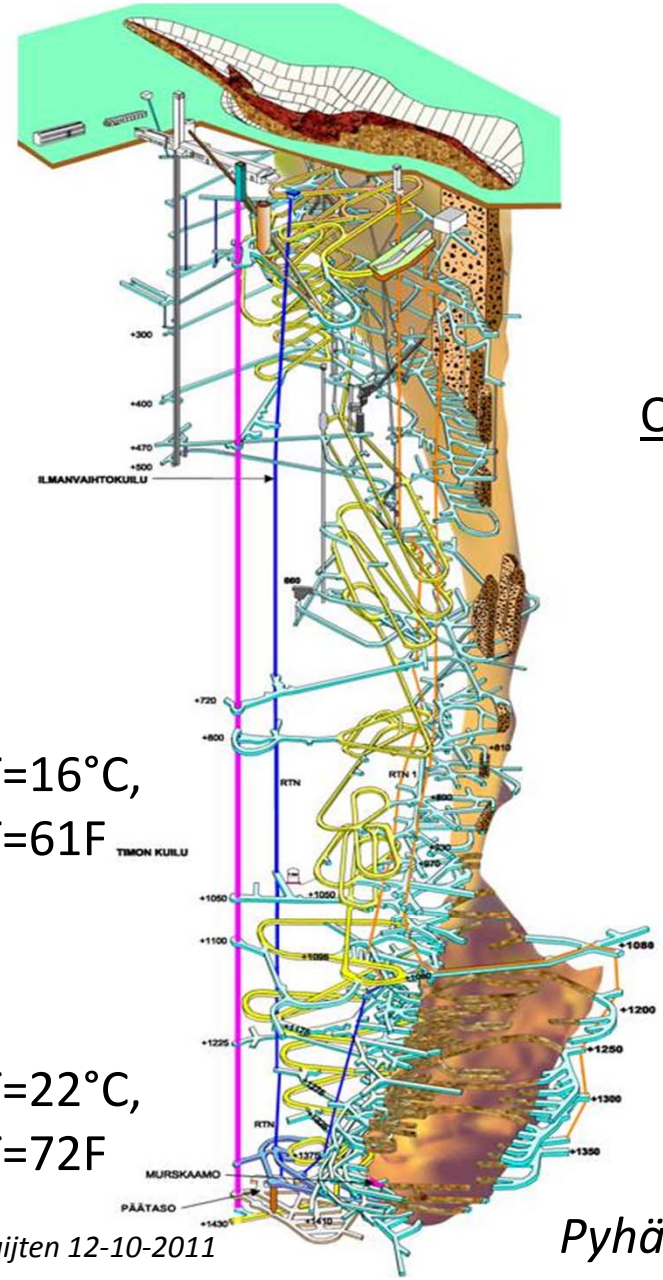
Very intact rock:
average RQD: 99.67
Joint density: 1 crack / 2m
Locally pegmatite dike encountered

Uniaxial compressive strength of intact rock is 200-250 MPa (29,000-36,000psi)



ROCKPLAN

Temperature conditions of in-situ rock



T=16°C,
T=61F

T=22°C,
T=72F

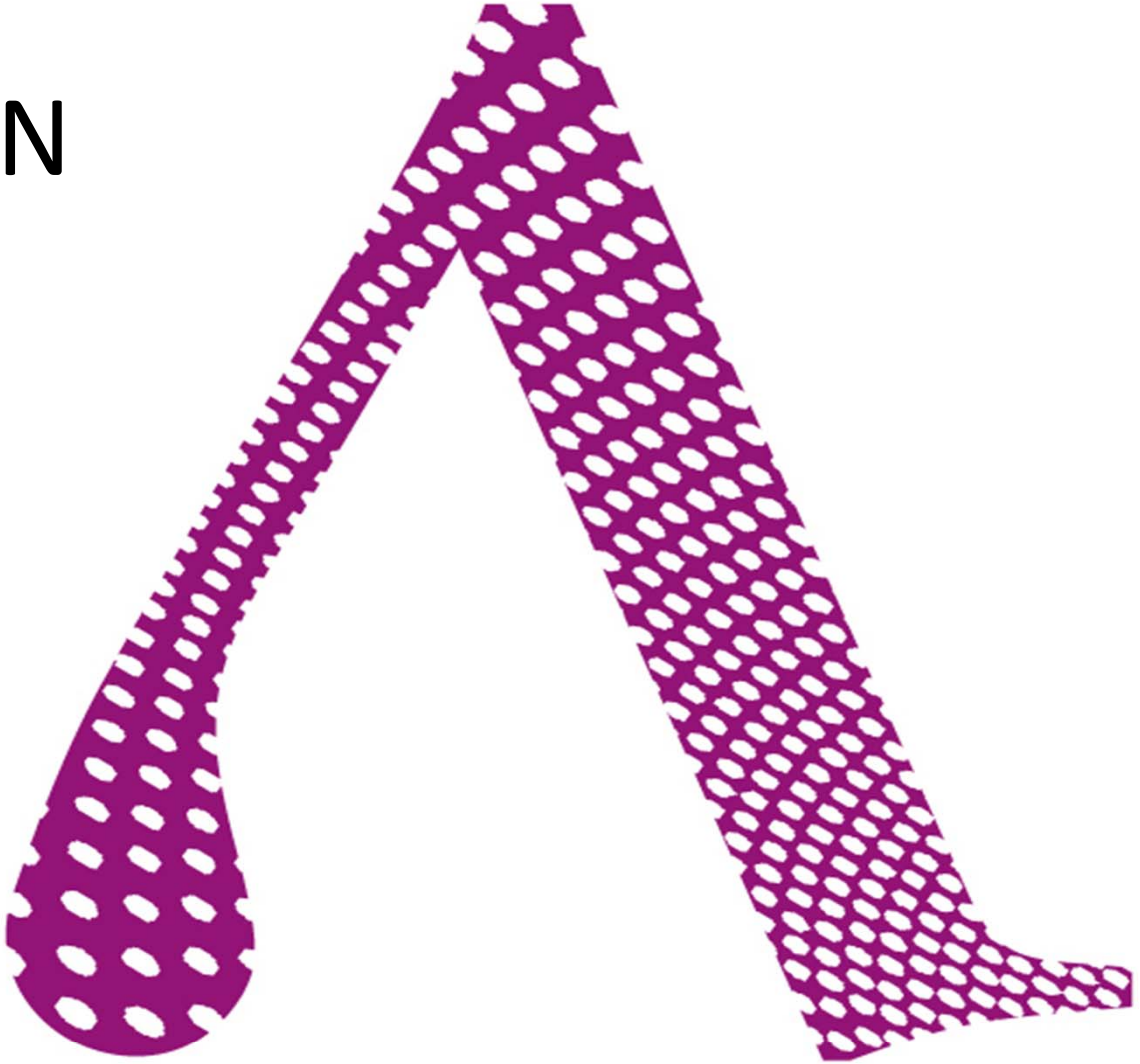
Average air temperatures at surface in Pyhäjärvi are:
-9^{o}C (Jan) ... +16^{o}C (July).
+16F (Jan) ... +61F (July).

Other conditions of in-situ rock

Very dry conditions

Ventilation precautions to reduce radon ingress
Radon content:
- in ventilated underground areas: 20 Bq/m^3
- otherwise may be tenfold

CAVERN SIZE



LAGUNA

ROCKPLAN

LENA, size in comparison

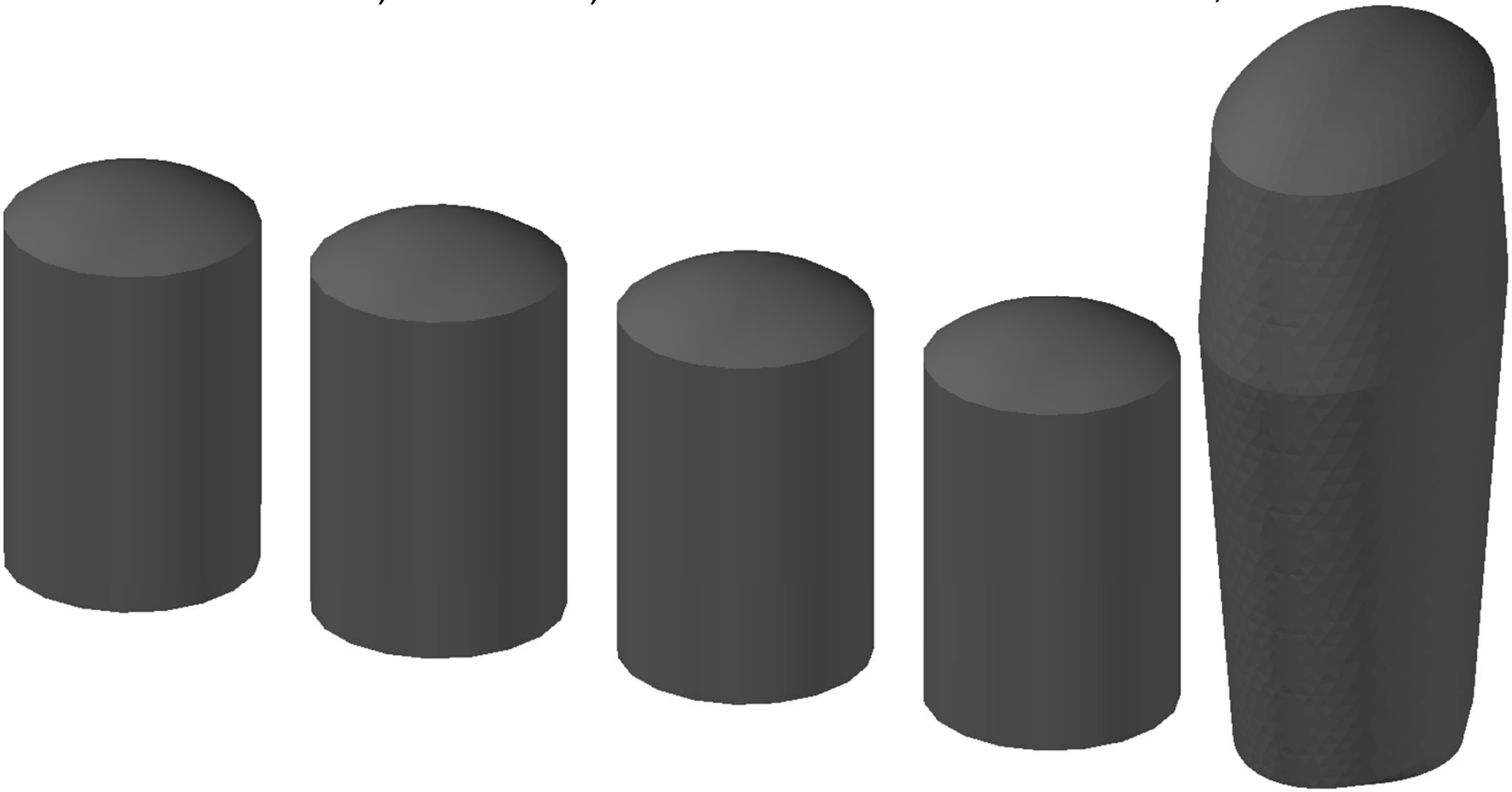
The world biggest (over 40 m) man-made underground caverns are:

Site	*Country*	***span***	*length*	*height*	*depth*	
Gjøvik Olympic Cavern Hall	Norway	**61 m**	91 m	25 m	40 m	
Tytyri Mine, chalk mine museum	Finland	**60 m**			110 m	
LIQUID SCINTILLATOR, LENA	***Finland***	***44 m***	***71 m***	***120 m***	***1450 m***	
Salmisaari coal storage silos	Finland	**42 m**	42 m	65 m	50 m	ROCKPLAN
Leppävirta, cross country ski hall	Finland	**40 m**	100 m	10 m	15 m	ROCKPLAN
Super- Kamiokande, neutrino det.	Japan	**40 m**	40 m	55 m	1000 m	
Vihanti mine	Finland	**40 m**			180 m	

In Finland the size of the cavern is not at the upper limit of the rock mechanical stability.

Comparison of LENA vs. Salmisaari

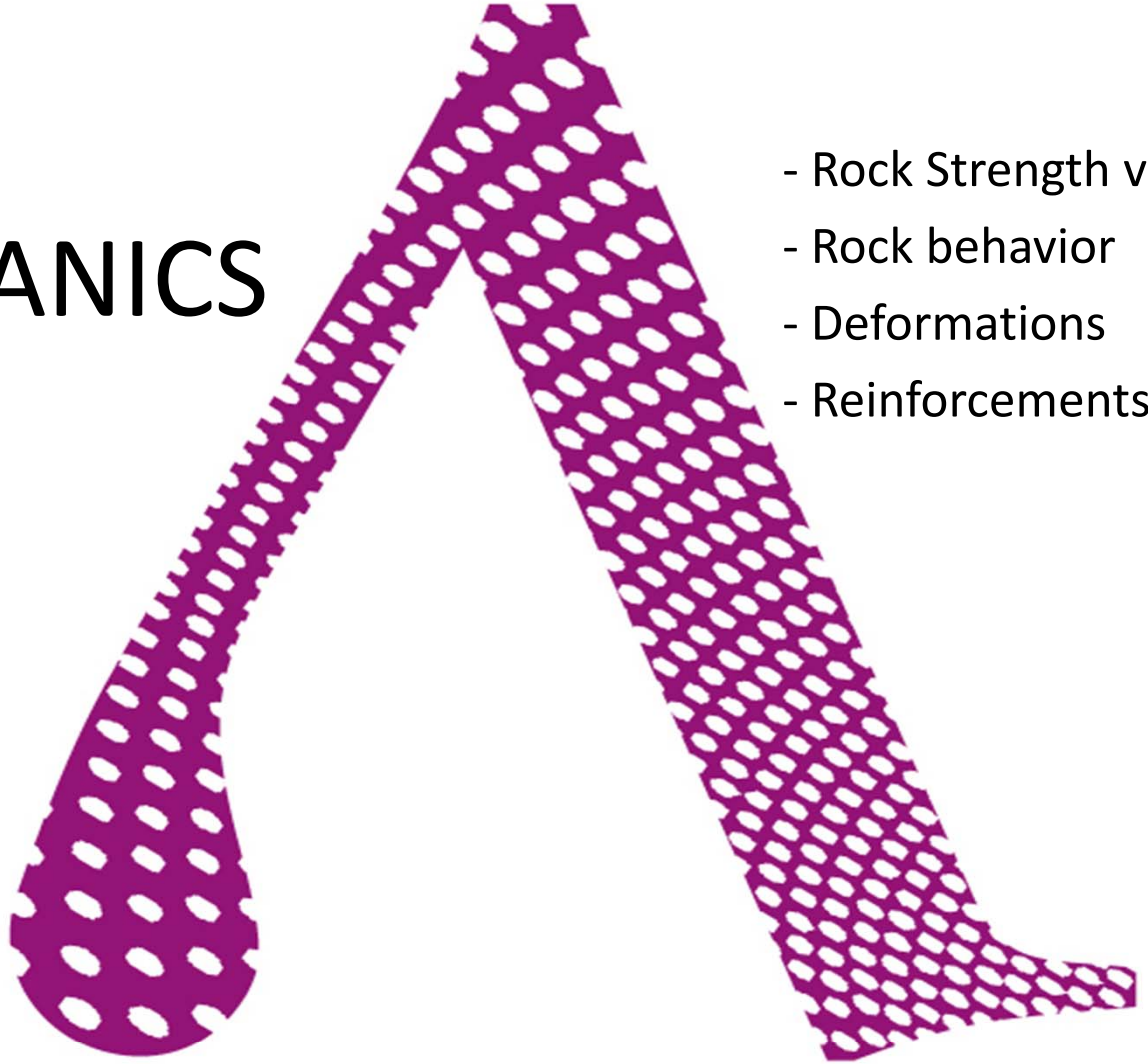
Salmisaari Coal Silos (4 units), Helsinki, Finland, 2004		LENA, Pyhäsalmi	
Dome diameter	42m,	Dome diameter	44 * 71m, elliptical
Dome height	65m	Dome height	120m
Silo volume	4x81,000m3 = 324,000m3	Silo volume	234,000m3



ROCKPLAN

One of the Salmisaari coal storages, Helsinki, in function. Dome diameter 42m

ROCK MECHANICS



- Rock Strength vs. Rock Stress
- Rock behavior
- Deformations
- Reinforcements needs

LAGUNA

ROCKPLAN

Rock strength vs. rock stress (very simplified theory)

Strength =:

- compressive strength from sample testing (i.e. intact rock strength) &
- geological strength conditions (e.g. GSI-value): influence of cracks (like types, density, directions, length, smoothness etc.), stratification, weak zones etc

- combined = rock mass strength

Stress =:

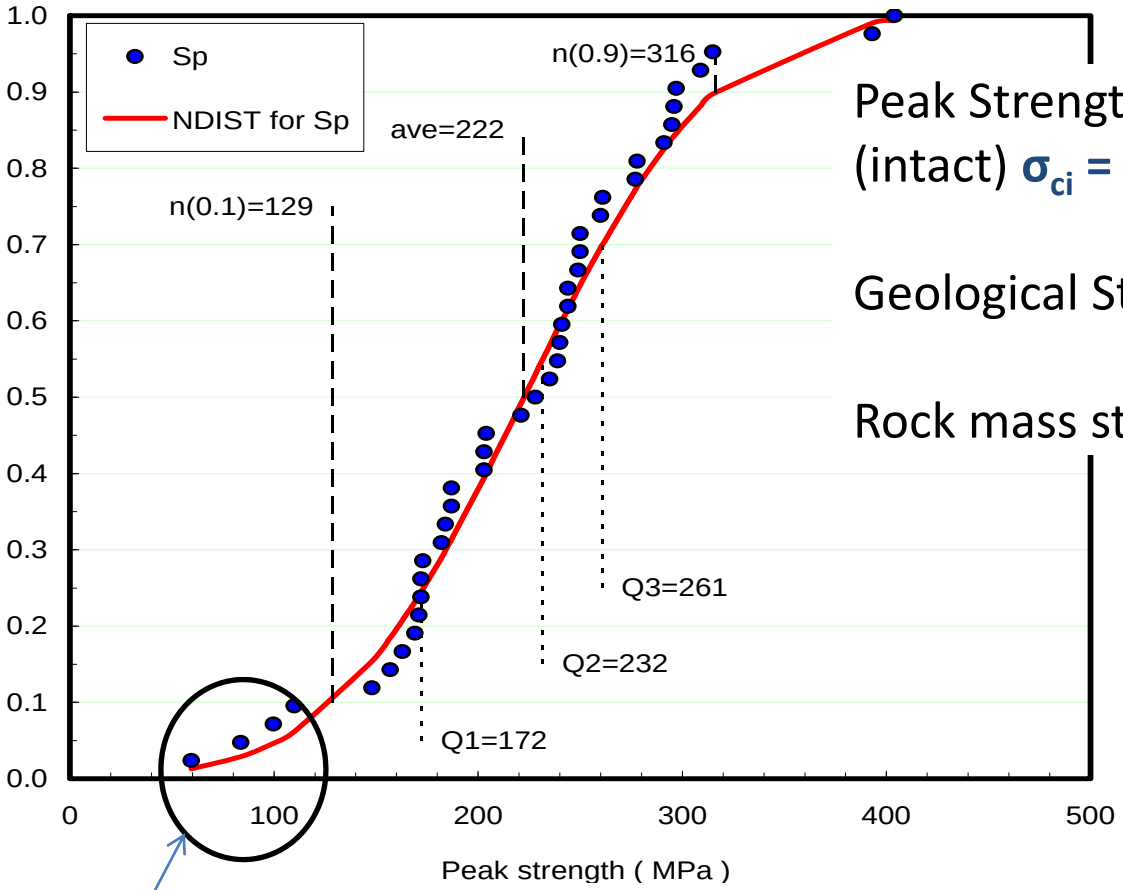
- In situ stress situation (level and direction): condition before excavation
- Excavation induced increasing of stress around cavern (mainly tangential stresses)

- combined = stress around cavern

To be analyzed:

- If rock mass strength > stress around cavern = elastic behavior => OK
- If not => failure (plastic behavior, spalling, creep etc.) => challenges!

Rock strength vs. rock stress (Finland)



Peak Strength of Mafic and Felsic Volcanites (intact) **σ_{ci} = 232 MPa (33,650psi)**

Geological Strength Index = 77

Rock mass strength **σ_{cm} = 132 MPa (19,100psi)**

Note: Pegmatite dykes (intact) σ_{ci} = 110 MPa to be avoided

measurements and stress failure observations confirms Rock mass strength ***σ_{cm} = 132 MPa (19,100psi)***

ROCKPLAN

Rock strength & rock behavior *(comparison with other possible sites)*

Intact Rock Strength		*average (MPa)*	*rock behavior*
Pyhäsalmi	**Finland**	**232 (Mafic and Felsic Volcanites)**	**elastic + risk of spalling**
Frejus	France	**70** (Calc schists)	ductile plastic deformation large deformation + creep
Boulby	United Kingdom	**85** (Upper / Lower anhydrite) **180** (Dolomite, only 35 m thick layer)	elasto-plastic behavior (yield) failures on the boundary
Umbria	Italy	**100** (Limestone, estimated)	ductile plastic deformation
Sc-Polkowice - Poland		**43** (Salt rock) **124** (Anhydrite)	high level of creep brittle elasto-plastic behavior
Canfranc	Spain	**65** (Calcareous slate or limestone)	elasto-plastic deformation
Slanic	Romania	**28** (Massive Salt)	elastic (due to shallowness)
Kamiokande - Japan		**149** (Amphibolite and gneiss)	
Homestake – USA		**111** (Rhyolite) **115** (Amphibolite) http://arxiv.org/ftp/arxiv/papers/1108/1108.0959.pdf	

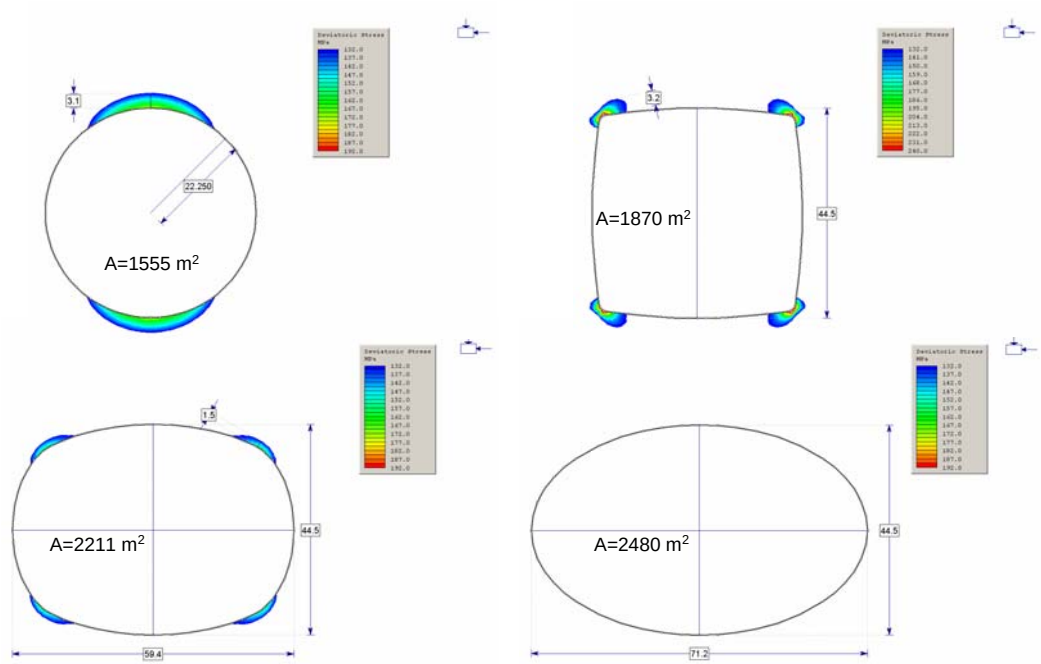
Rock strength vs. rock stress (Finland)

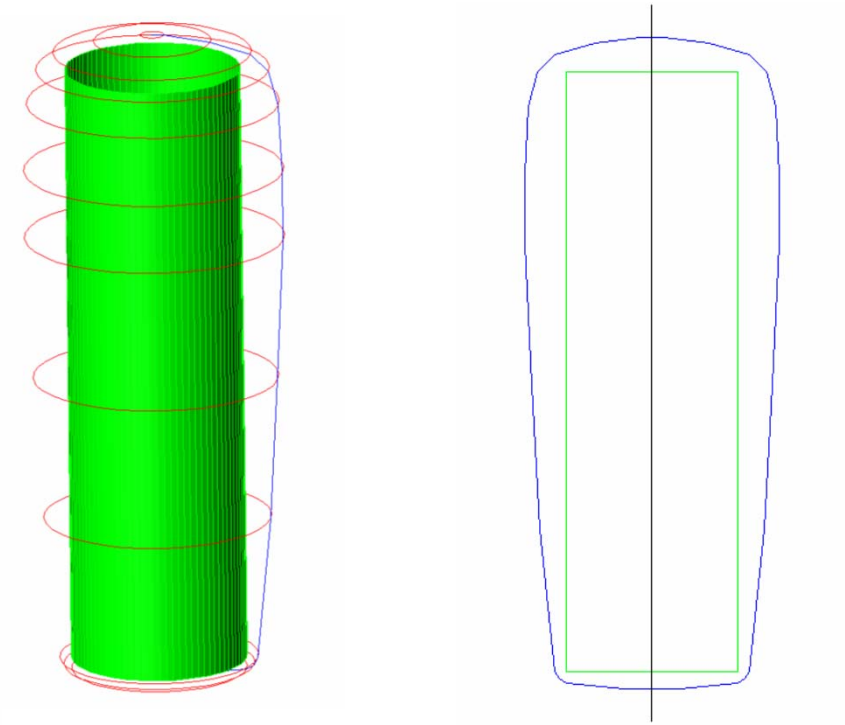
In situ stress (before excavation)

Depth (m)	σ_{H1} *(MPa)*	σ_{h2} *(MPa)*	σ_v *(MPa)*
900	52	33	26
1100	64	40	32
1400	81	51	41
2000	116	73	58

Major principal stress is horizontal and bearing to N-W (310° clockwise from N).

Rock volumes exceeding the spalling strength (colour contours) and max spalling depth for different horizontal cross-section shapes at 1450 level below ground surface.

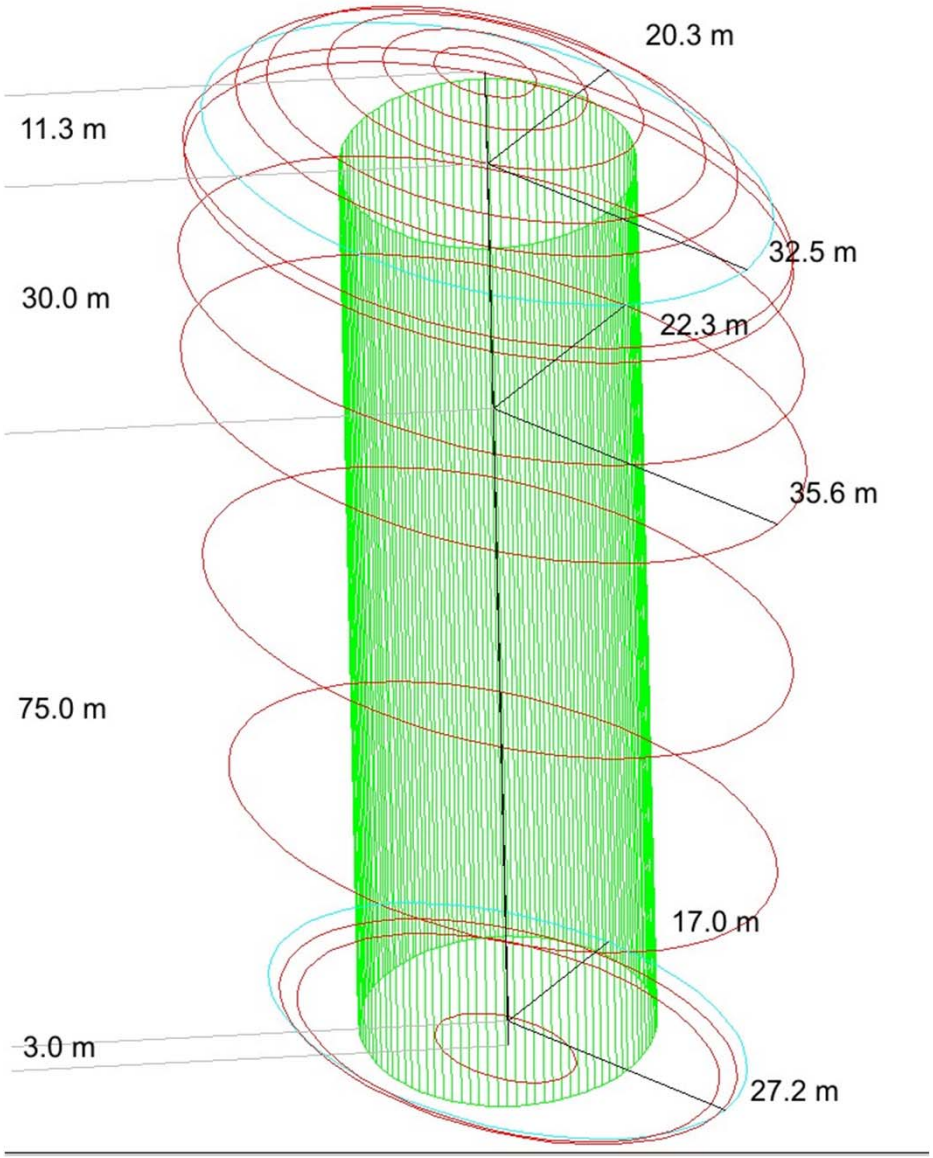




LENA results at -1450m (left)

ROCKPLAN

Rock strength vs. rock stress (Finland)



Rock volumes exceeding the spalling strength (colour contours) and max spalling depth for different horizontal cross-section shapes at 1450 level below ground surface.

Optimum shape to be elliptical (44m * 71m) to deal best with the horizontal stress redistribution around the cavern.

LENA results at -1450m (left)

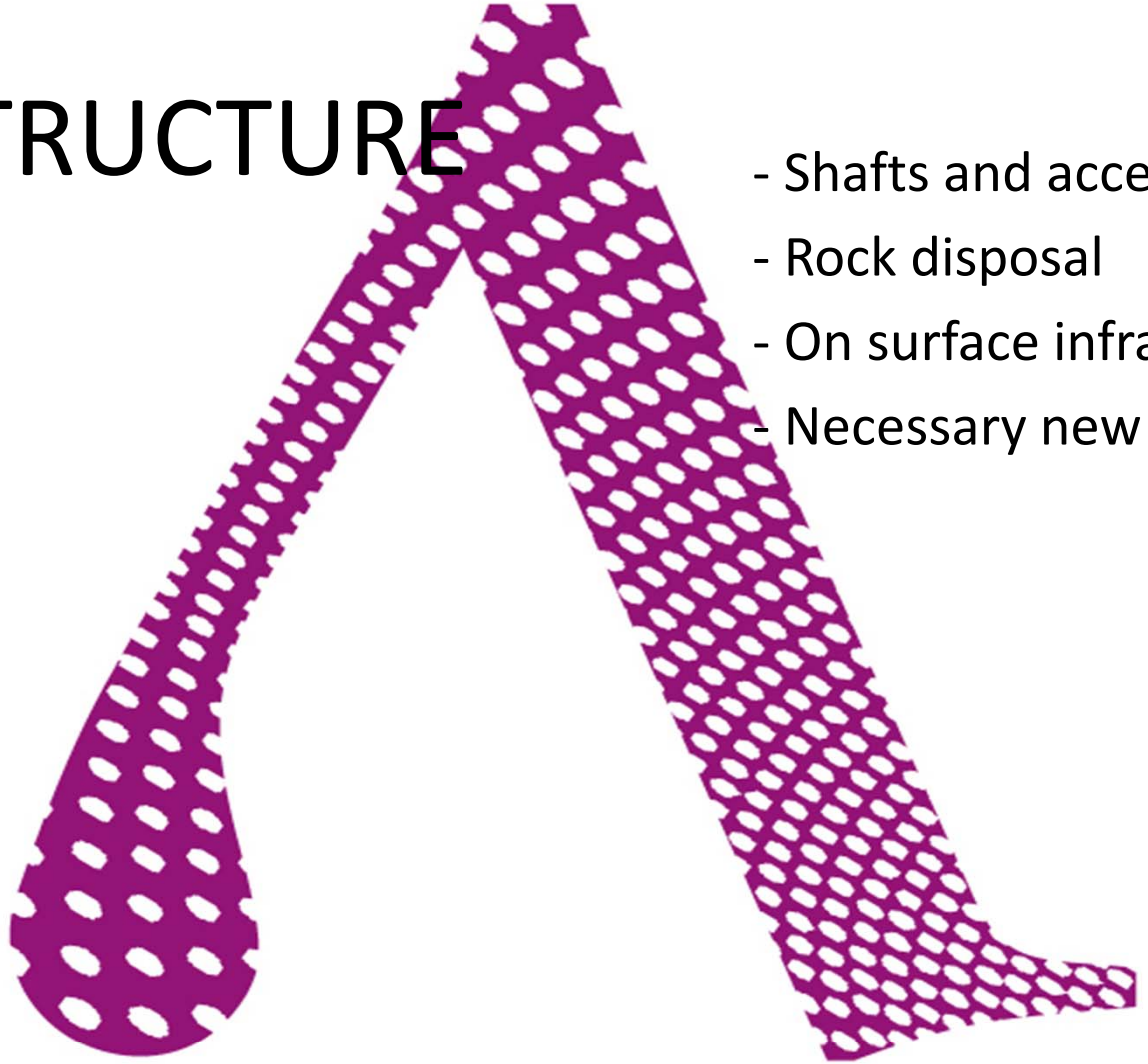
ROCKPLAN

Rock reinforcements

Shotcrete lining at -1430m + (non-visible) bolting in the maintenance hall in Pyhäsalmi

INFRASTRUCTURE AT SITE

- Shafts and access tunnels
- Rock disposal
- On surface infrastructure
- Necessary new infrastructure



LAGUNA

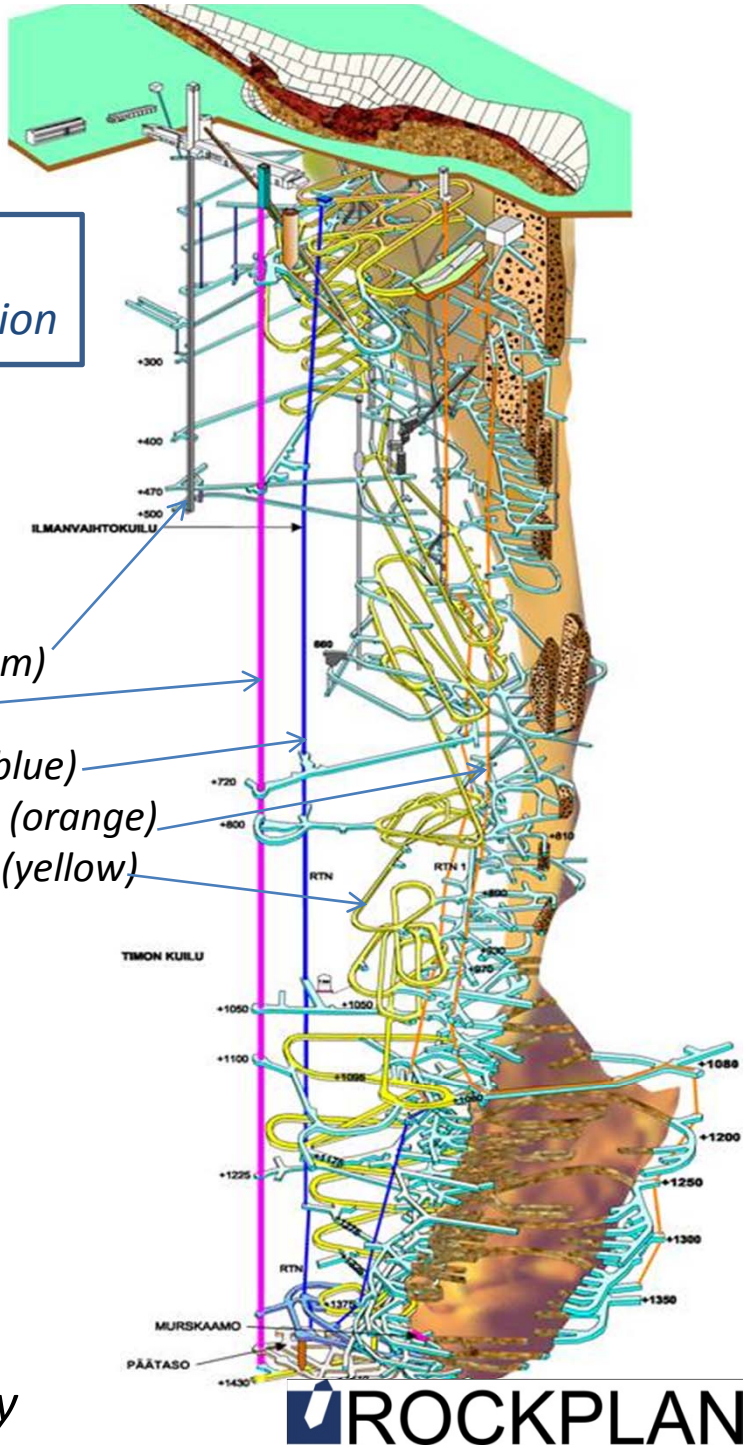
ROCKPLAN

Present Infrastructure at site (mine)

Main challenge:
Not to disturb mine production

Pyhäsalmi Mine

- *Old main shaft (to -500m)*
- *Main shaft (violet)*
- *Inlet ventilation shaft (blue)*
- *Outlet ventilation shaft (orange)*
- *Decline / access tunnel (yellow)*



Pyhäsalmi Mine Oy

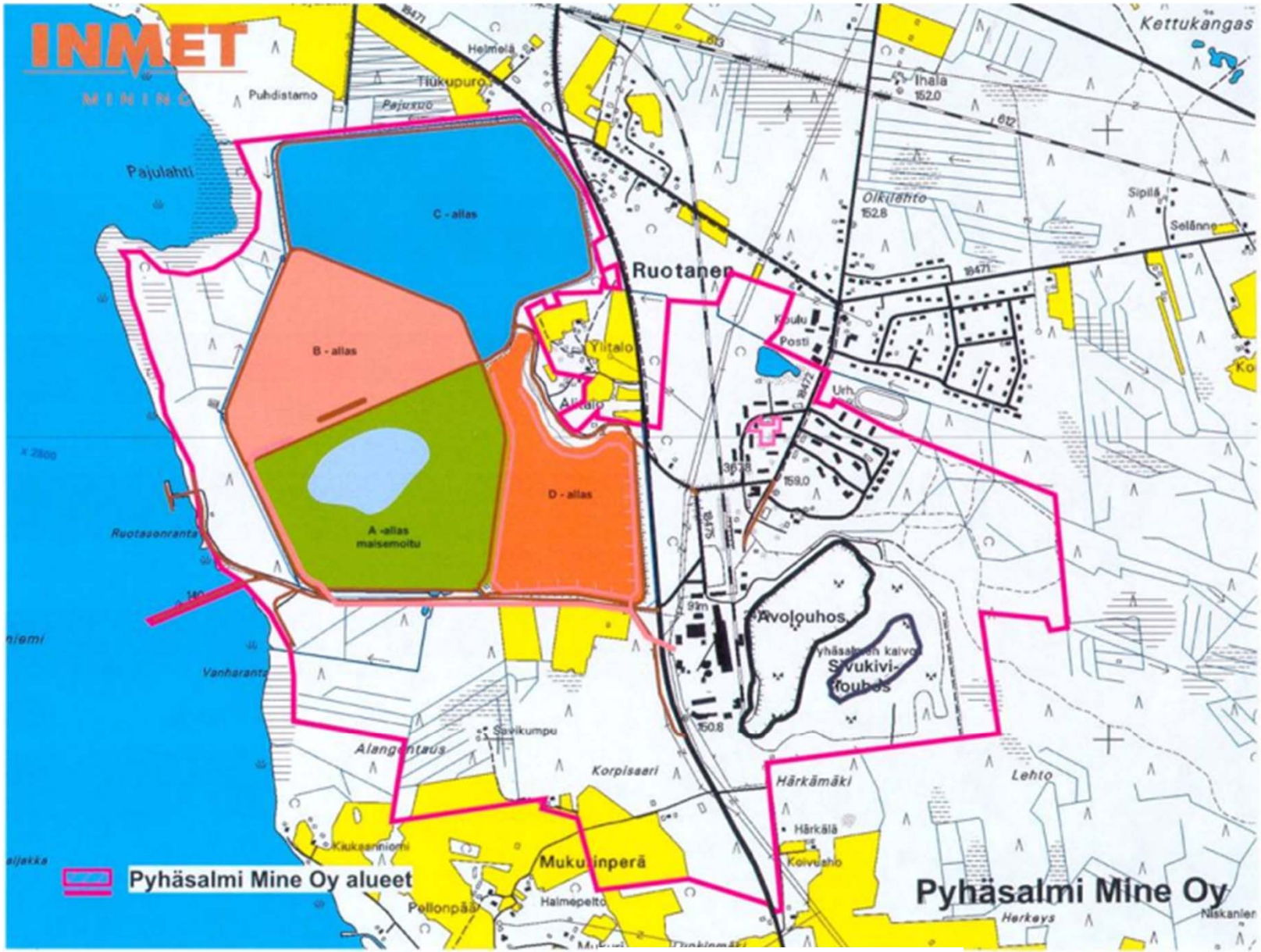
ROCKPLAN

External installation / on surface constructions

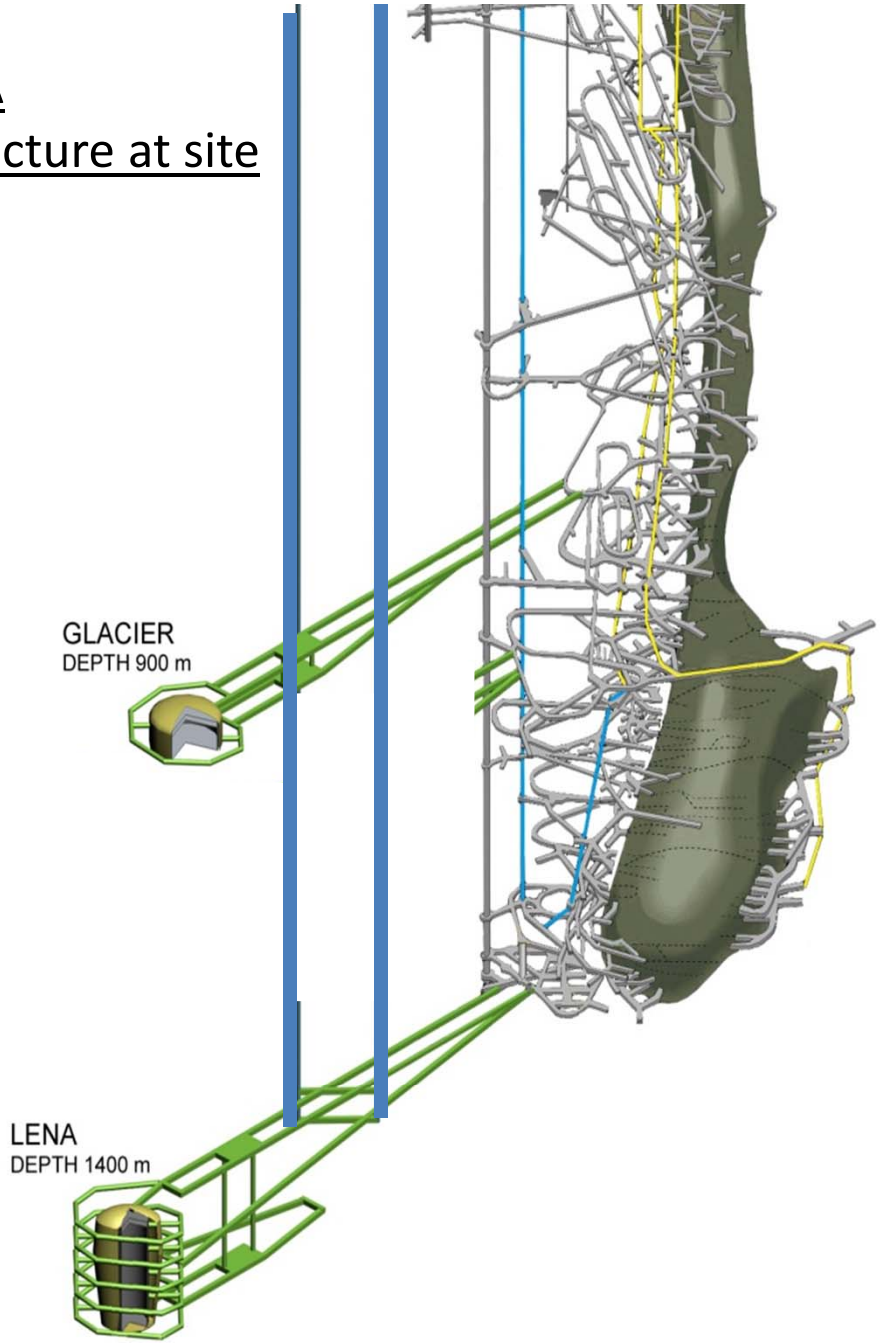
Primary infrastructure (primarily needed and therefore also part of Laguna costs)

railway connection railway yard	is present to the Mine area and is in good condition is present on the Mine area and perfectly suitable for Laguna needs
road infrastructure	is present and in good shape (nearby is the main north south corridor "Road nr. 4" between Oulu and Helsinki)
harbor	situated in Kokkola only 160km away and is connected by rail with the site
electric infrastructure	is present at site (110 kV power supply) and sufficient also for Laguna purposes
water availability	Pyhäjärvi lake nearby with a capacity of 0.83 km^3 and the water quality is generally good
transmission station	the Mine has its own electricity supply, but it is needed to construct the power transmission station for construction and operation on the surface
pipe line	fully operating fuel dry line operative in the Mine between surface and -1400; similar solution of these facilities to be used
airfield / airport	minor airfield is present at 10km distance, main airports located in Oulu and Jyväskylä at 170km distance
parking space	present at the Mine area (large enough also to host trucks and other bigger vehicles)
offices / lunch room	present at site but in use for the Mine; new office to be built, that also has room for seminars and other conventions as Laguna starts operating

Present infrastructure at surface



LAGUNA
infrastructure at site



Main purpose of the infrastructure

- ***Sufficient*** *(to conduct the experiment)*
- ***Efficient*** *(cost & process effectiveness)*
- ***Safe*** *(during all phases)*

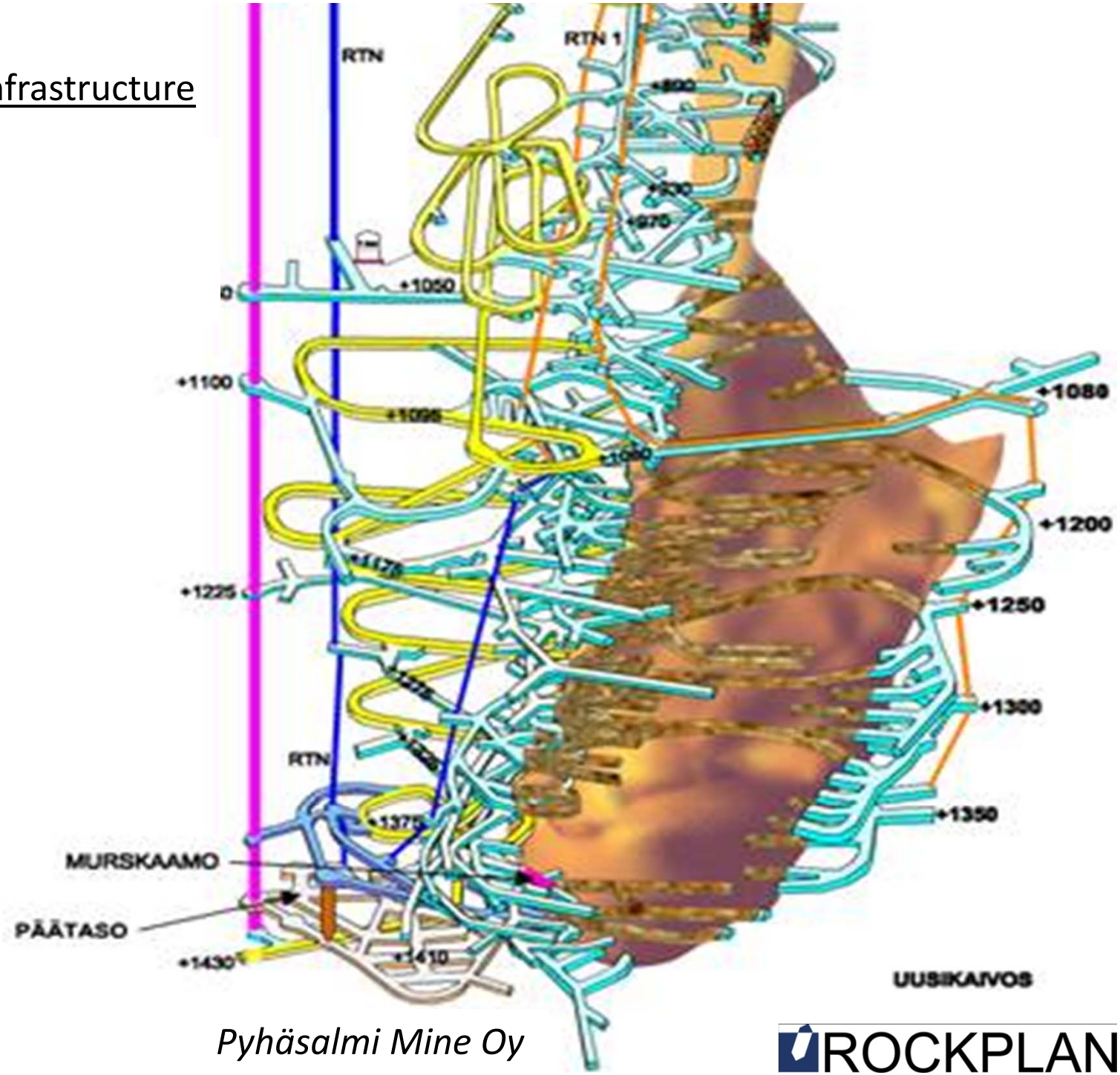
Main aspects of the infrastructure

- *good excavation strategy*
- *efficient rock disposal*
- *no disturbance with hosting site*
- *sufficient fresh air inlet*
- *effective outlet of return air*
- *safety*
- *supply routes for construction*
- *storage of material*
- *quality control of material at the vicinity*
- *supply route (pipe lines) for liquids*

ROCKPLAN

Secret of a good infrastructure

?

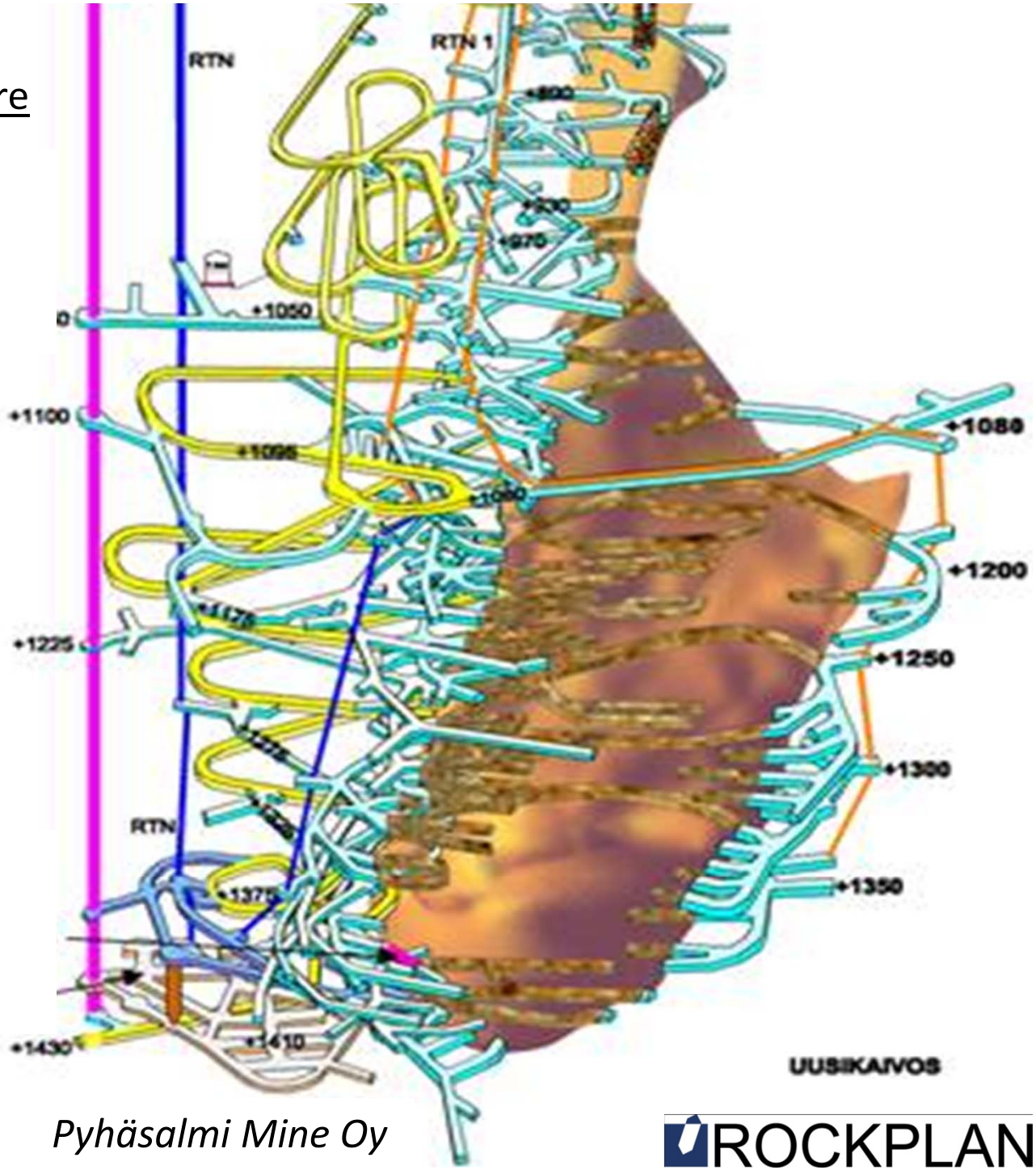


Pyhäsalmi Mine Oy

ROCKPLAN

Secret of a good infrastructure

ALWAYS A LOOP



Pyhäsalmi Mine Oy

ROCKPLAN

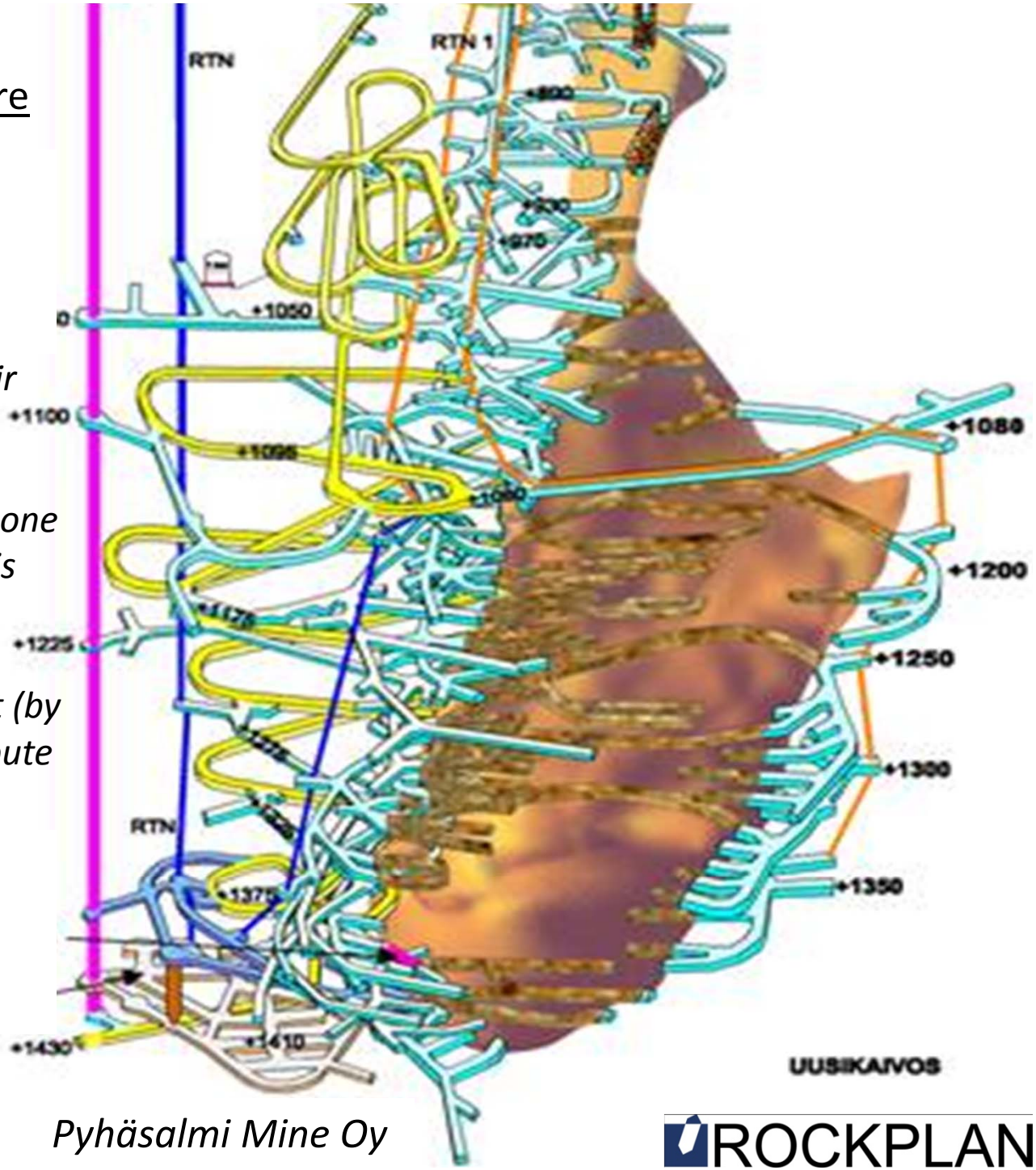
Secret of a good infrastructure

ALWAYS A LOOP

A loop for ventilation (fresh air inlet and regress air outlet)

A loop for emergency (always one exit available in case another is closed due to an accident)

A loop for electricity/transport (by pass, when the main supply route is stuck



Pyhäsalmi Mine Oy

ROCKPLAN

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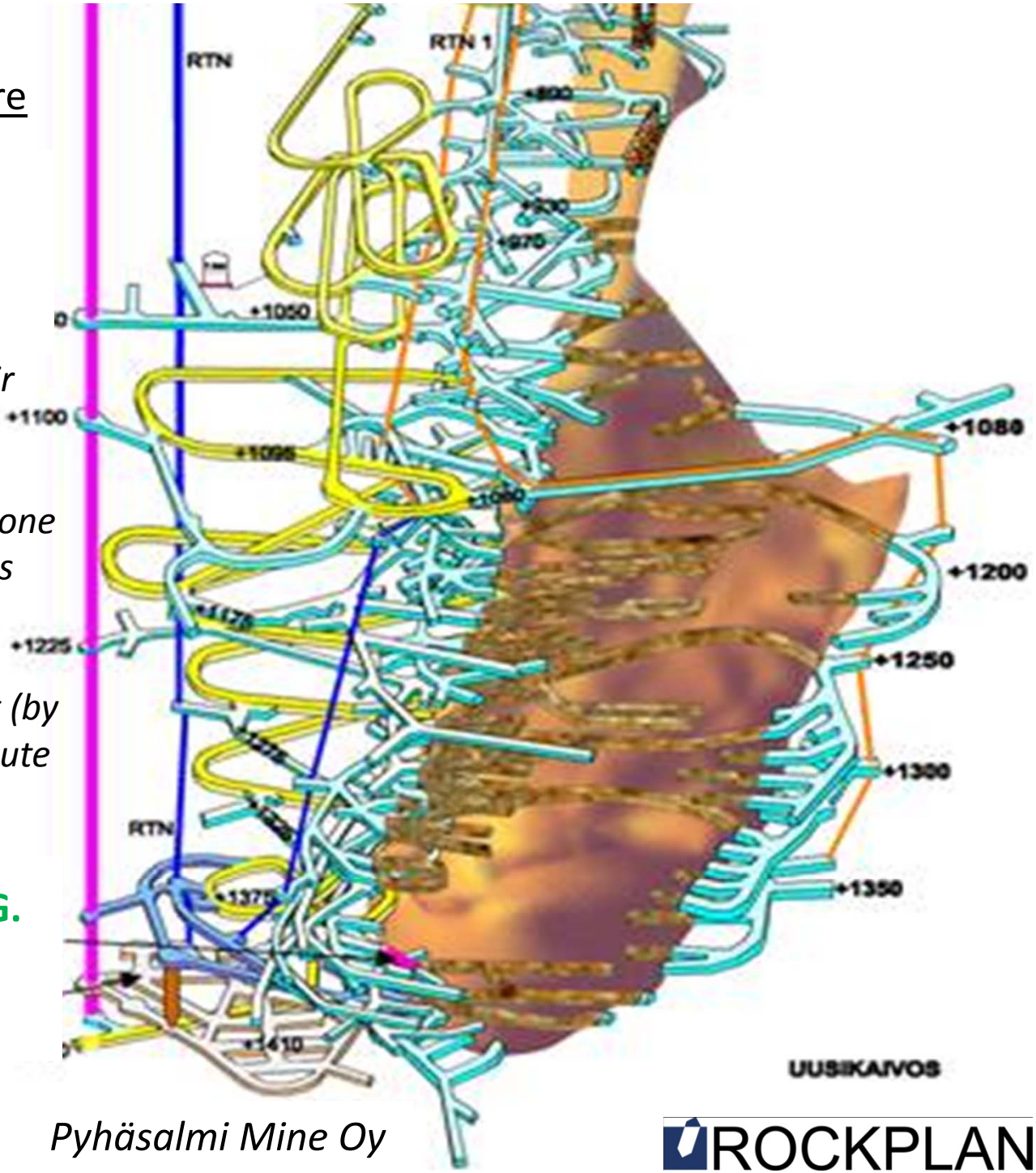
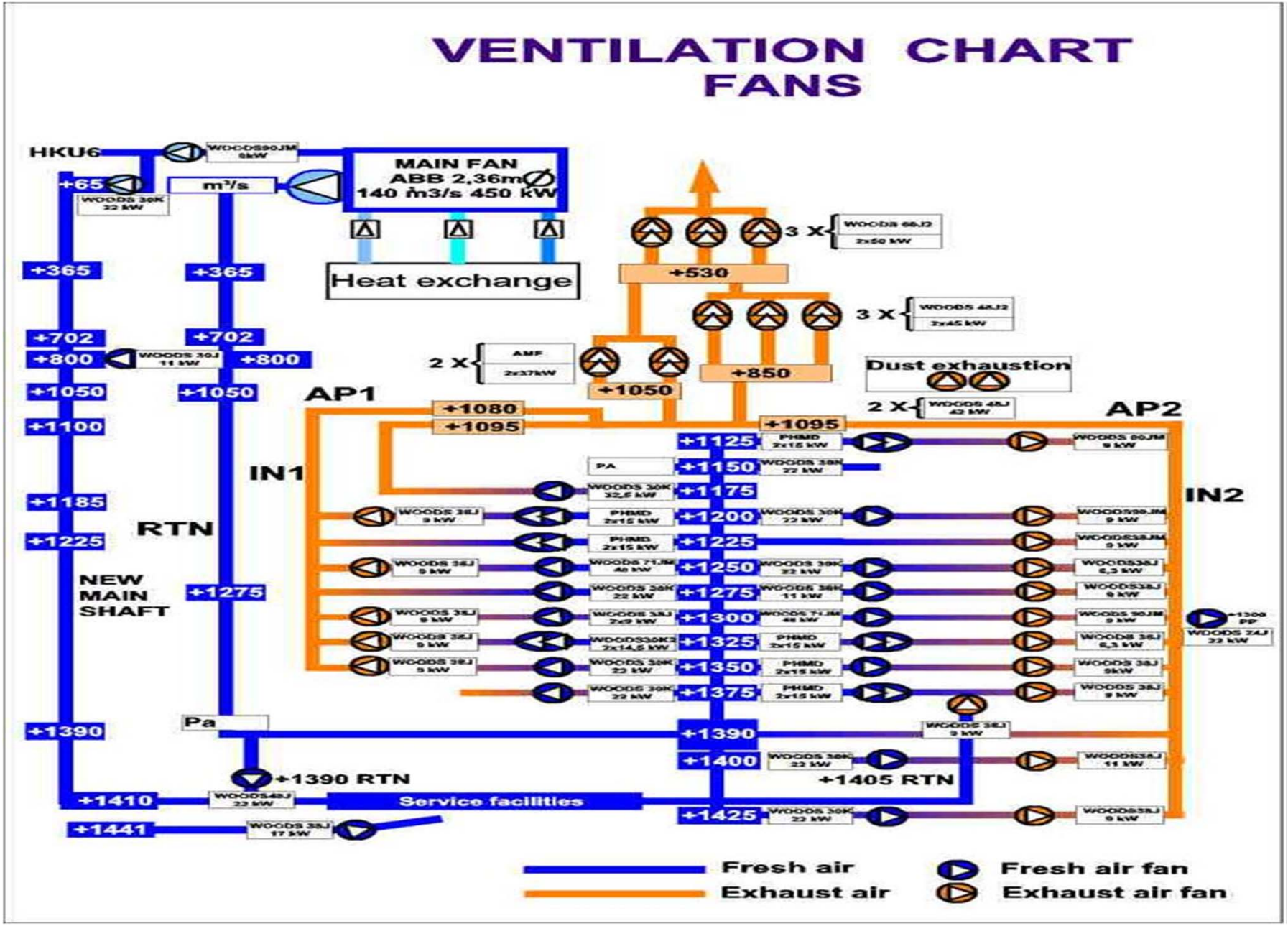
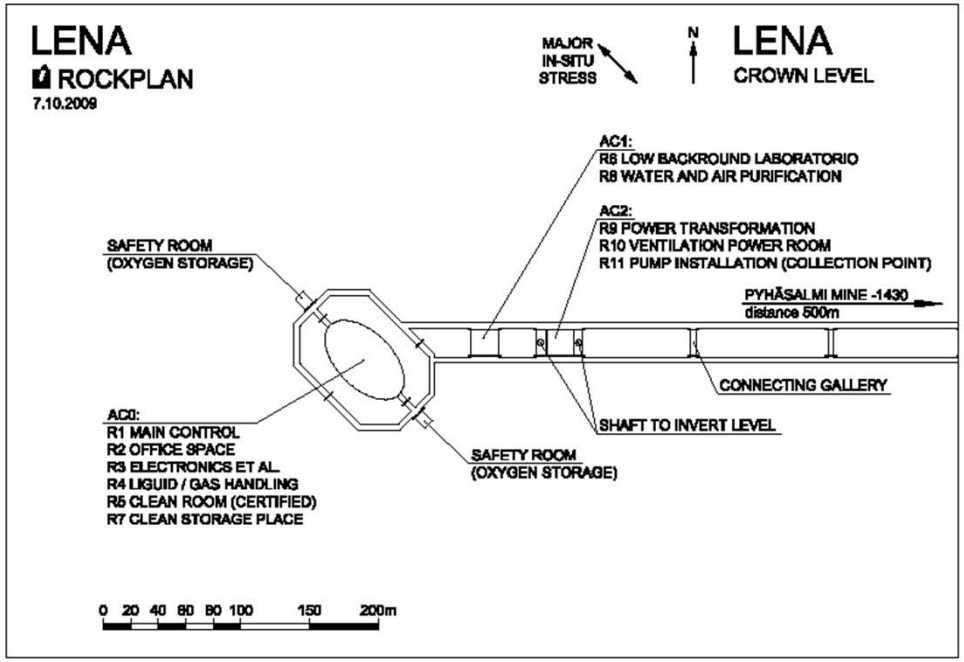
AND GOOD LOGISTICS (E.G. TRANSPORT, MAINTENANCE, STORAGE

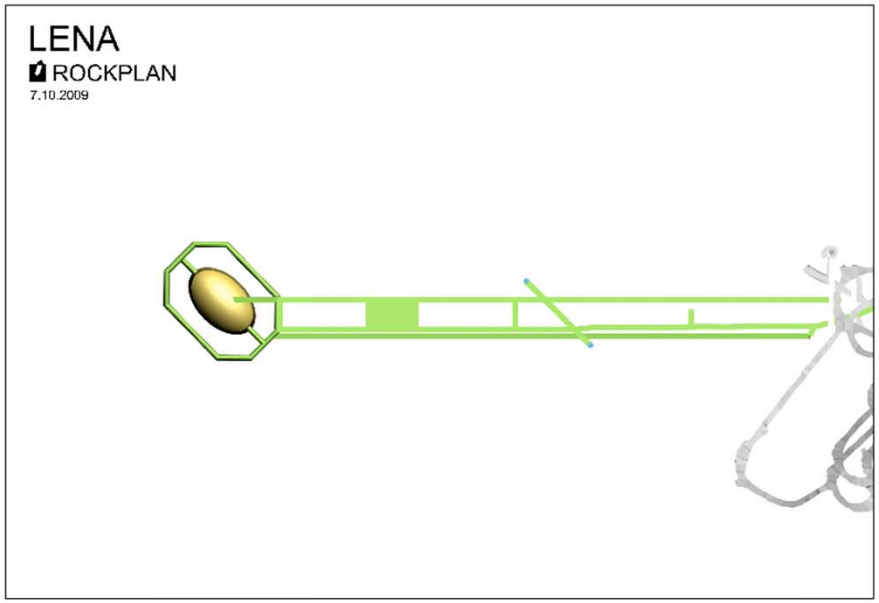


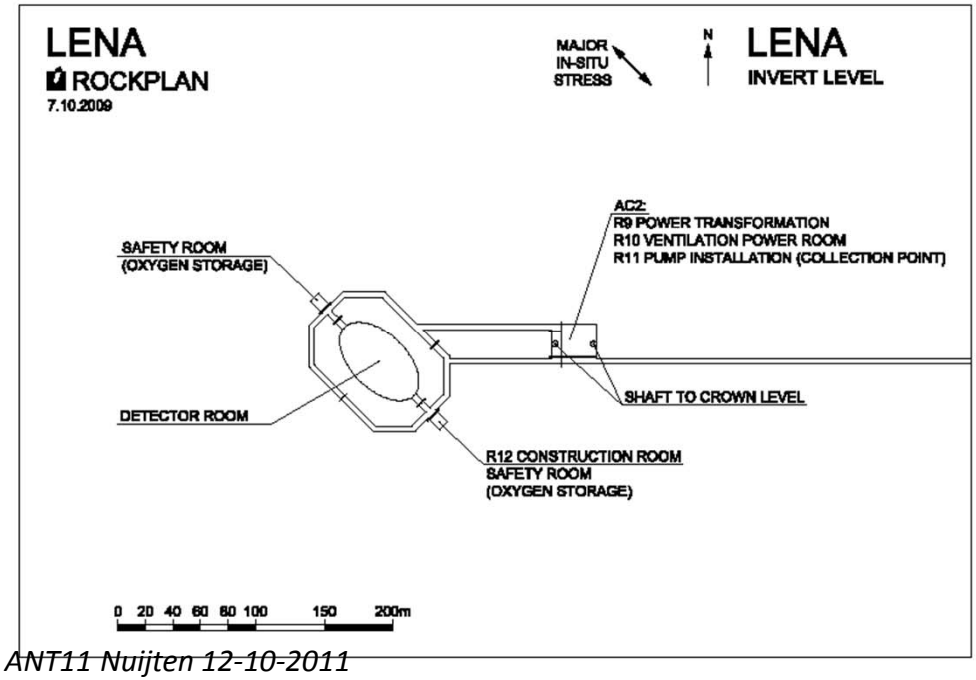
Pyhäsalmi Mine Oy

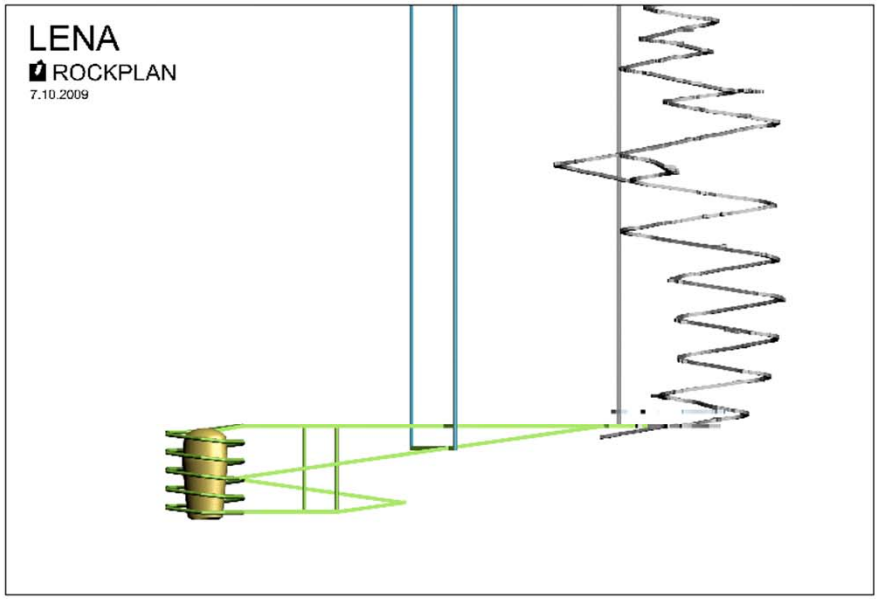
ROCKPLAN


VENTILATION CHART
FANS
HKU6
+65
MAIN FAN
ABB 2,36m∅
140 m3/s 450 kW
m³/s
Heat exchange
+365
+365
+702
+702
+800
+800
+1050
+1050
+1100
+1185
+1225
RTN
NEW
MAIN
SHAFT
+1275
+1390
Pa
+1390 RTN
+1410
Service facilities
+1441
+530
3 X
+850
2 X
+1050
Dust exhaustion
2 X
AP1
AP2
IN1
IN2
+1080
+1095
+1095
+1125
+1150
+1175
+1200
+1225
+1250
+1275
+1300
+1325
+1350
+1375
+1390
+1400
+1405 RTN
+1425
Fresh air
Exhaust air
Fresh air fan
Exhaust air fan


LENA
ROCKPLAN
7.10.2009
MAJOR
IN-SITU
STRESS
N
LENA
CROWN LEVEL
AC1:
R8 LOW BACKROUND LABORATORIO
R8 WATER AND AIR PURIFICATION
AC2:
R9 POWER TRANSFORMATION
R10 VENTILATION POWER ROOM
R11 PUMP INSTALLATION (COLLECTION POINT)
SAFETY ROOM
(OXYGEN STORAGE)
PYHÄSALMI MINE -1430
distance 500m
CONNECTING GALLERY
SHAFT TO INVERT LEVEL
AC0:
R1 MAIN CONTROL
R2 OFFICE SPACE
R3 ELECTRONICS ET AL.
R4 LIQUID / GAS HANDLING
R5 CLEAN ROOM (CERTIFIED)
R7 CLEAN STORAGE PLACE
SAFETY ROOM
(OXYGEN STORAGE)
0 20 40 60 80 100 150 200m

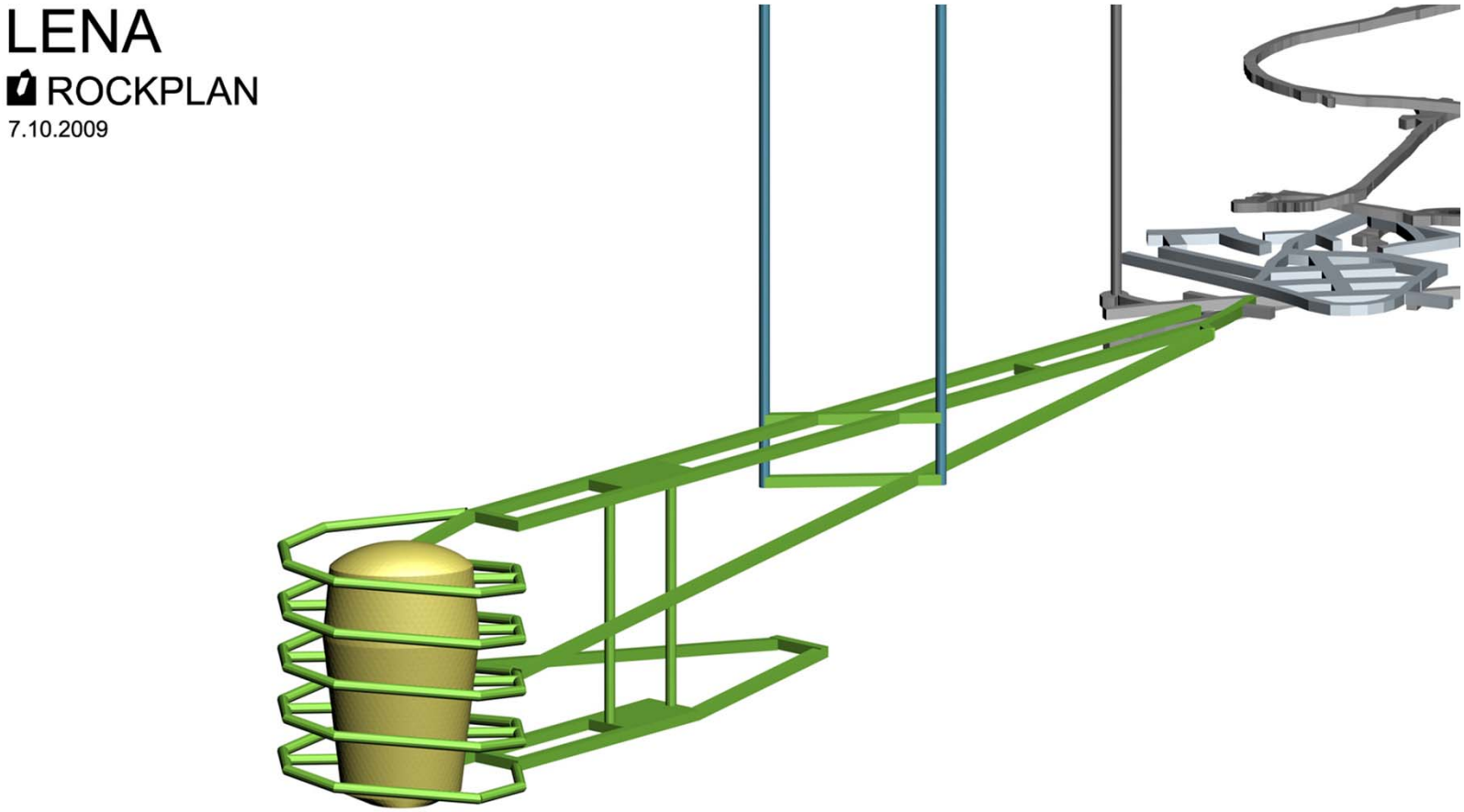

LENA
ROCKPLAN
7.10.2009


LENA
ROCKPLAN
7.10.2009
MAJOR
IN-SITU
STRESS
N
LENA
INVERT LEVEL
AC2:
R9 POWER TRANSFORMATION
R10 VENTILATION POWER ROOM
R11 PUMP INSTALLATION (COLLECTION POINT)
SAFETY ROOM
(OXYGEN STORAGE)
SHAFT TO CROWN LEVEL
DETECTOR ROOM
R12 CONSTRUCTION ROOM
SAFETY ROOM
(OXYGEN STORAGE)
0 20 40 60 80 100 150 200m


LENA
ROCKPLAN
7.10.2009

ROCKPLAN

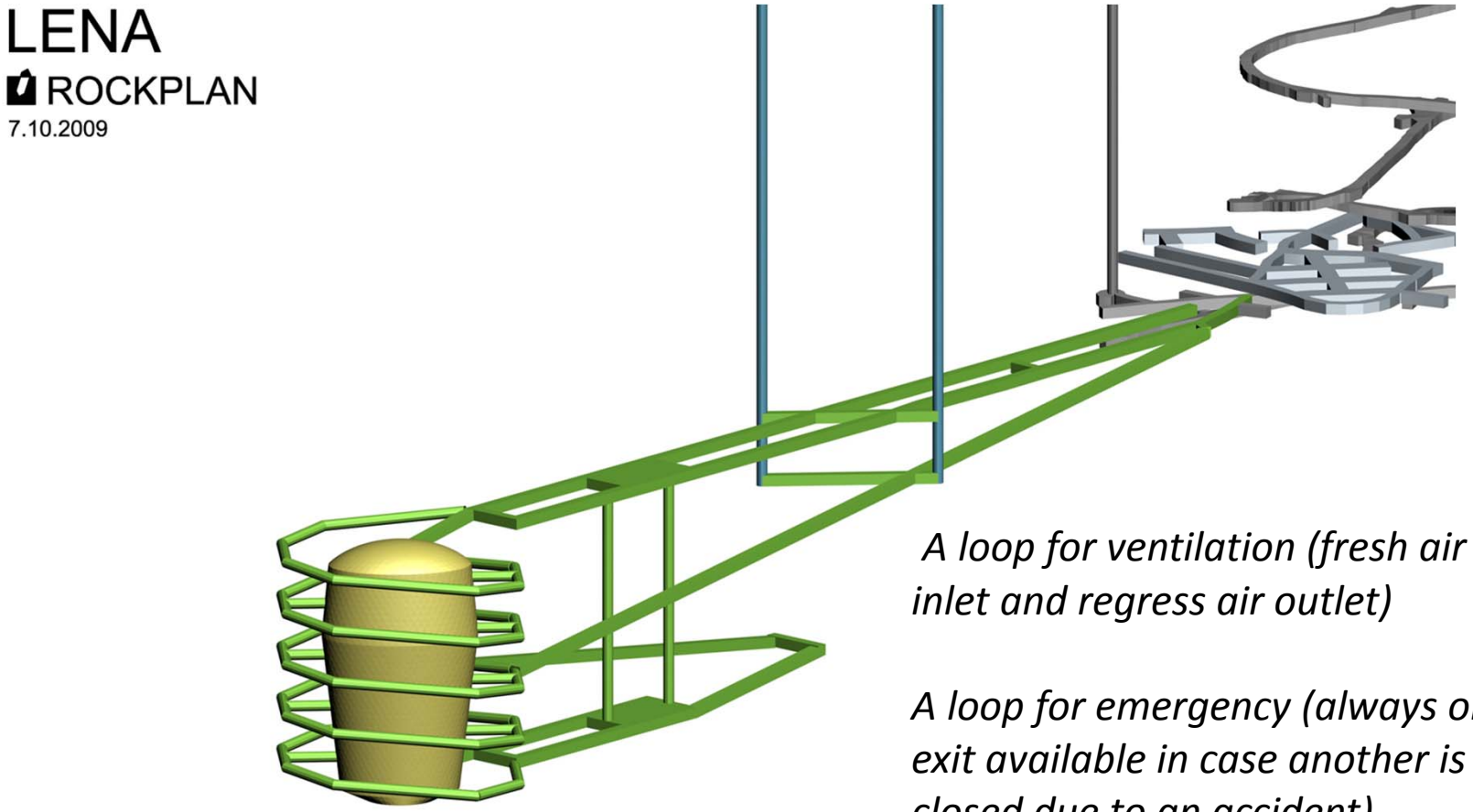
LENA at 4000 m.w.e.



Low Energy Neutrino Astronomy (artistic impression by ROCKPLAN)

- *yellow* *new cavern for tank construction*
- *green* *access tunnels and auxiliary rooms*
- *blue* *new shafts*
- *grey* *existing infrastructure at 1400m*

LENA at 4000 m.w.e.



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- *yellow* *new cavern for tank construction*
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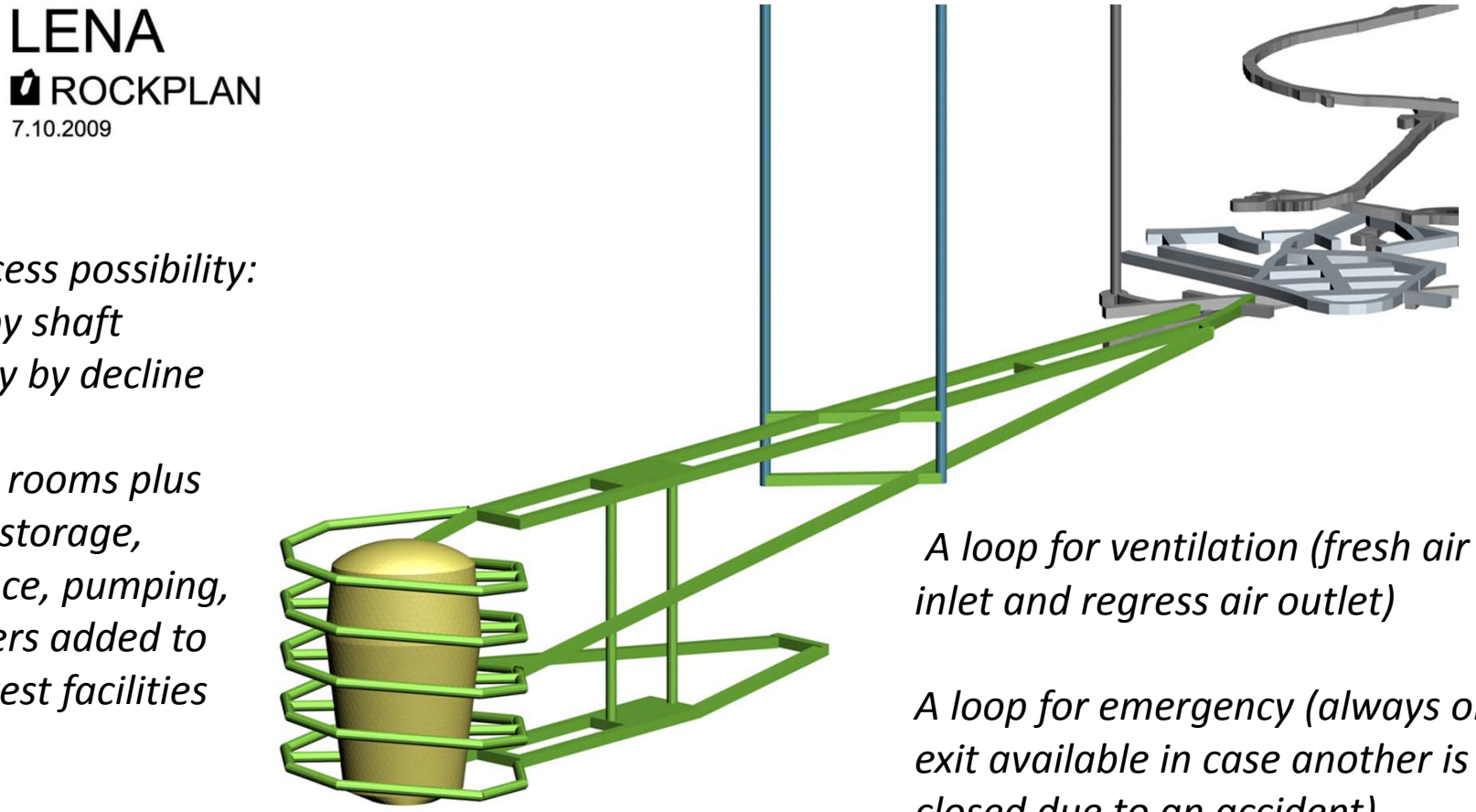
A loop for ventilation (fresh air inlet and regress air outlet)

A loop for emergency (always one exit available in case another is closed due to an accident)

A loop for electricity/transport (by pass, when the main supply route is stuck

ROCKPLAN

LENA at 4000 m.w.e.



Transport:
Double access possibility:
vertically by shaft
horizontally by decline

And safety rooms plus spaces for storage, maintenance, pumping, transformers added to the LENA-test facilities

A loop for ventilation (fresh air inlet and regress air outlet)

A loop for emergency (always one exit available in case another is closed due to an accident)

A loop for electricity/transport (by pass, when the main supply route is stuck

Low Energy Neutrino Astronomy (artistic impression by ROCKPLAN)

- *yellow* *new cavern for tank construction*
- *green* *access tunnels and auxiliary rooms*
- *blue* *new shafts*
- *grey* *existing infrastructure at 1400m*

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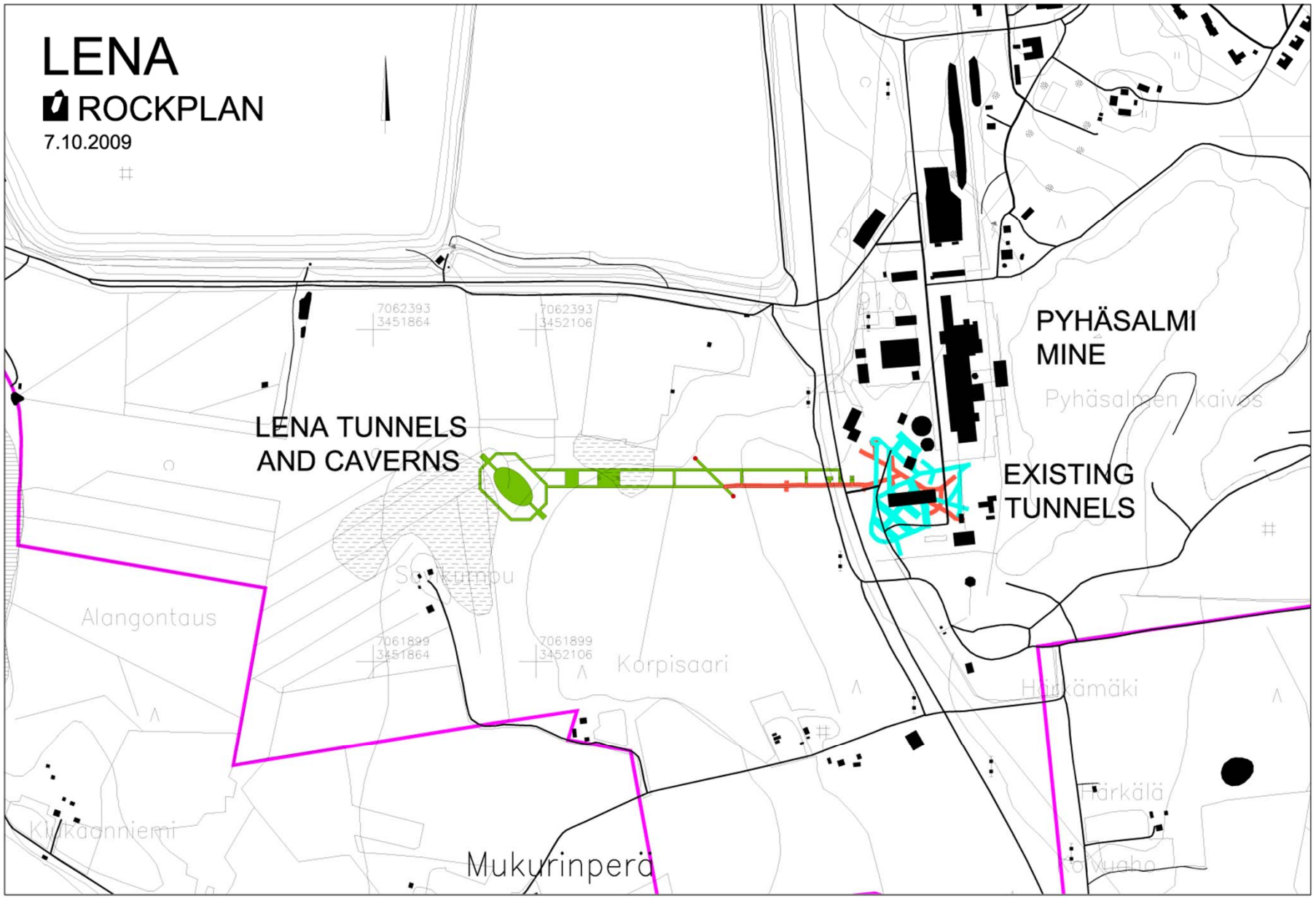
LENA
ROCKPLAN
7.10.2009
LENA TUNNELS
AND CAVERNS
PYHÄSALMI
MINE
EXISTING
TUNNELS
Alangontaus
Korpisaari
Mukurinperä
7062393
3451864
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3452106
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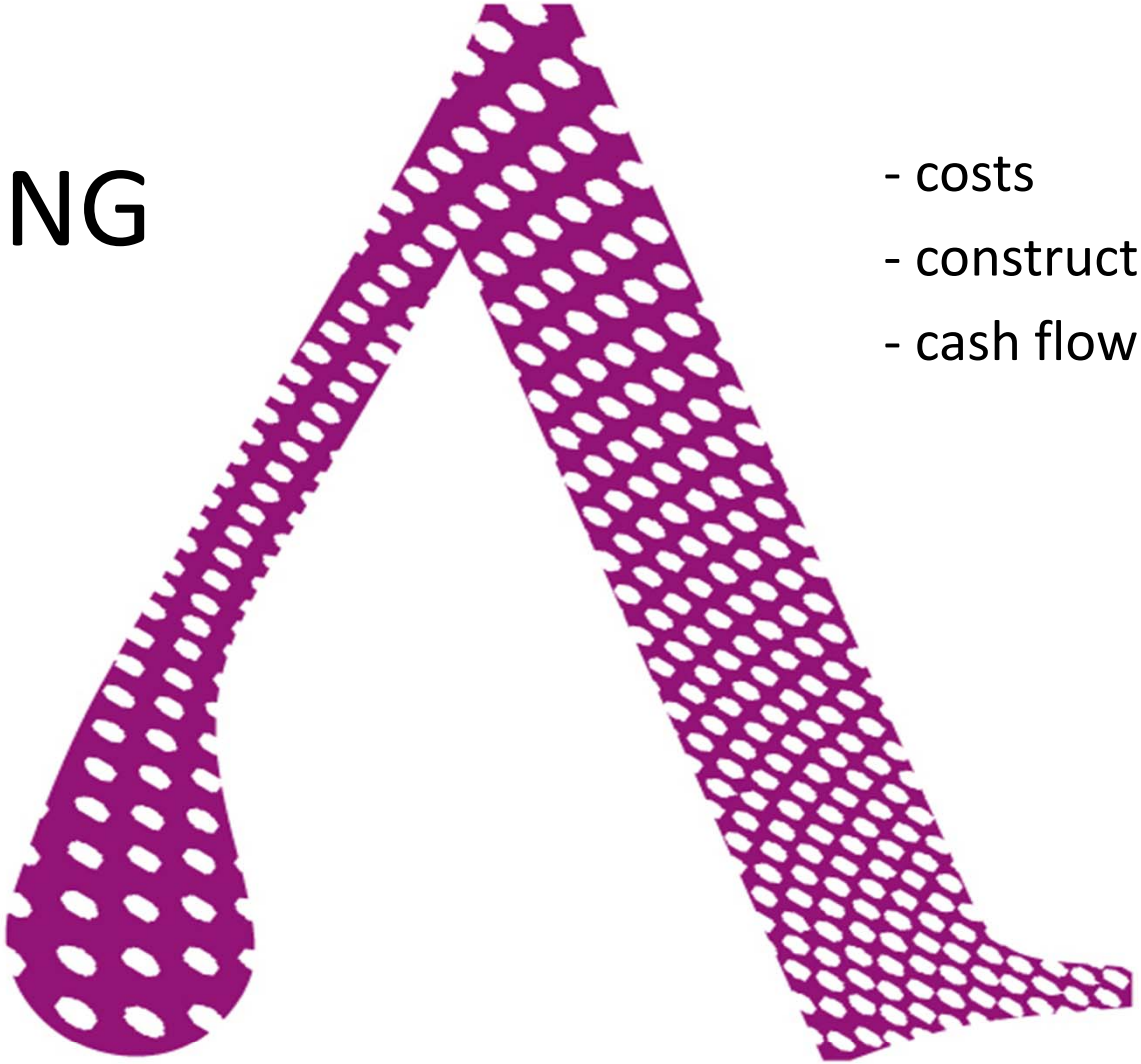
FINANCING

- costs
- construction time
- cash flow



Lagvna

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LENA, cost estimate

Preparation costs

•	General & rock mechanical executive design	3,5 M€	
•	Development, management & consulting service	2,5 M€	
•	Site investigations	3,0 M€	
Total preparation costs:			9,0 M€

Excavation costs

Excavation			
•	Main Detector Cavern	234’000 m^3	8,5 M€
•	New tunnels	155’000 m^3	7,0 M€
•	Shafts	23’000 m^3	10,3 M€
•	Auxiliary Caverns	15’000 m^3	0,7 M€
Excavation additional costs			
•	Ventilation, electricity, drainage during excavation		3,0 M€
•	Bulk transport to the existing Mine		1,0 M€
•	Miscellaneous		2,0 M€
Total excavation		427’000 m^3	32,5 M€

Reinforcement costs

•	Bolting, subtotal:	13,6 M€	
•	Shotcrete & wire mesh, subtotal:	17,8 M€	
•	Other (groundwater & radon ingress prevention measurements)	0,7 M€	
Total reinforcement:			32,1 M€

Total underground infrastructure costs **73,6 M€**

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Overview of costs (FINLAND)

Phase	*LENA*
Site preparation	75 M€
Site investigation	
Design, development & managing	
Excavation	
Reinforcements	
Additional (ventilation, bulk transport)	
Laboratory construction *	275 M€
Tank construction	
Auxiliary constructions	
Liquids + handling / cooling	
Sensors (photomultipliers)	
Data handling, electricity etc.	
Total **	**350 M€**

** to be analyzed more thoroughly*

*** without unforeseen, without operation costs*

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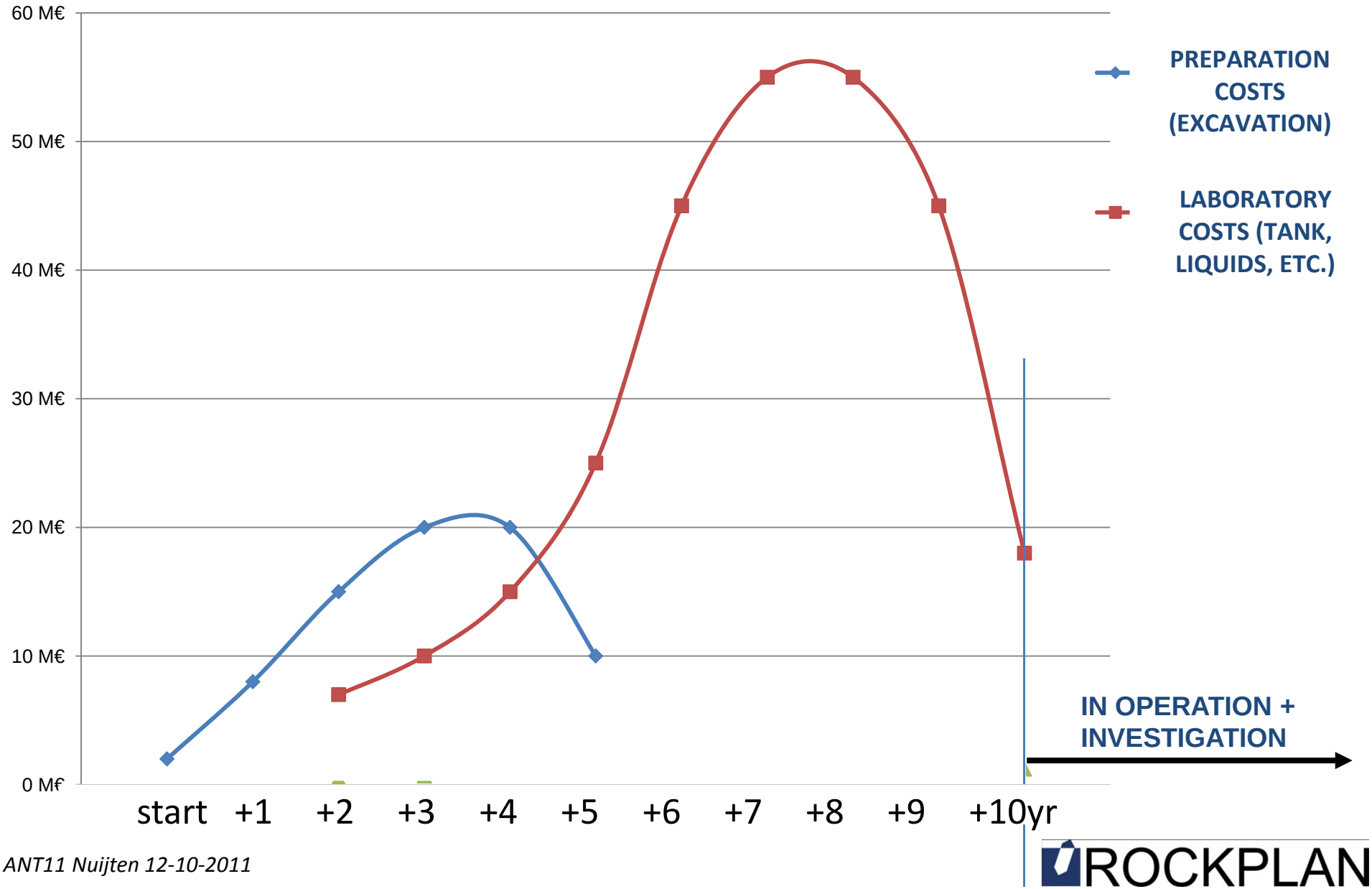
Construction time and cash flow (FINLAND + LENA)



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