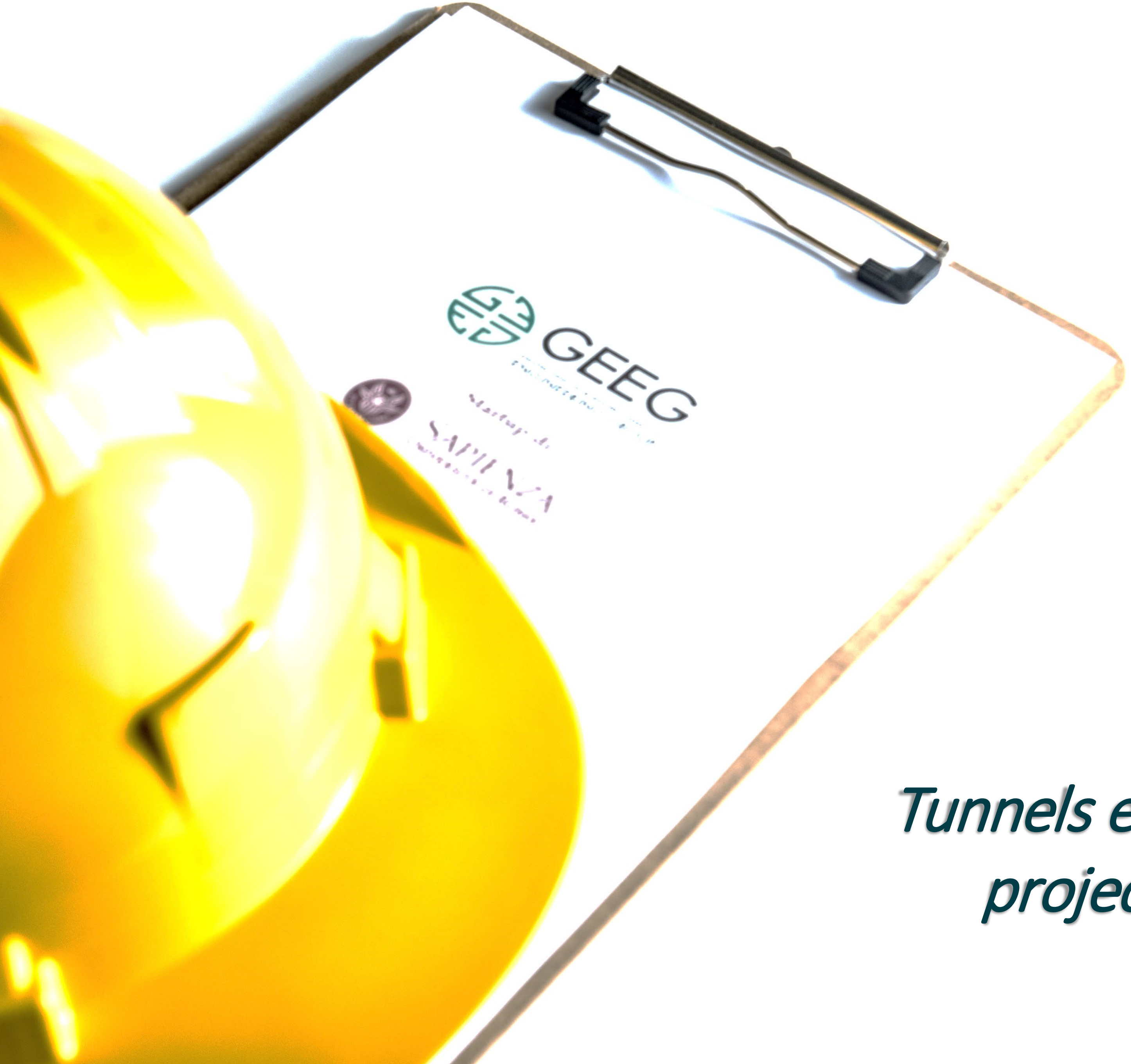


GEEG
GEOTECHNICAL & ENVIRONMENTAL ENGINEERING GROUP

Startup di:

SAPIENZA
UNIVERSITÀ DI ROMA

XIII ET Symposium

Tunnels excavation methods for the ET project and spoil reuse alternatives

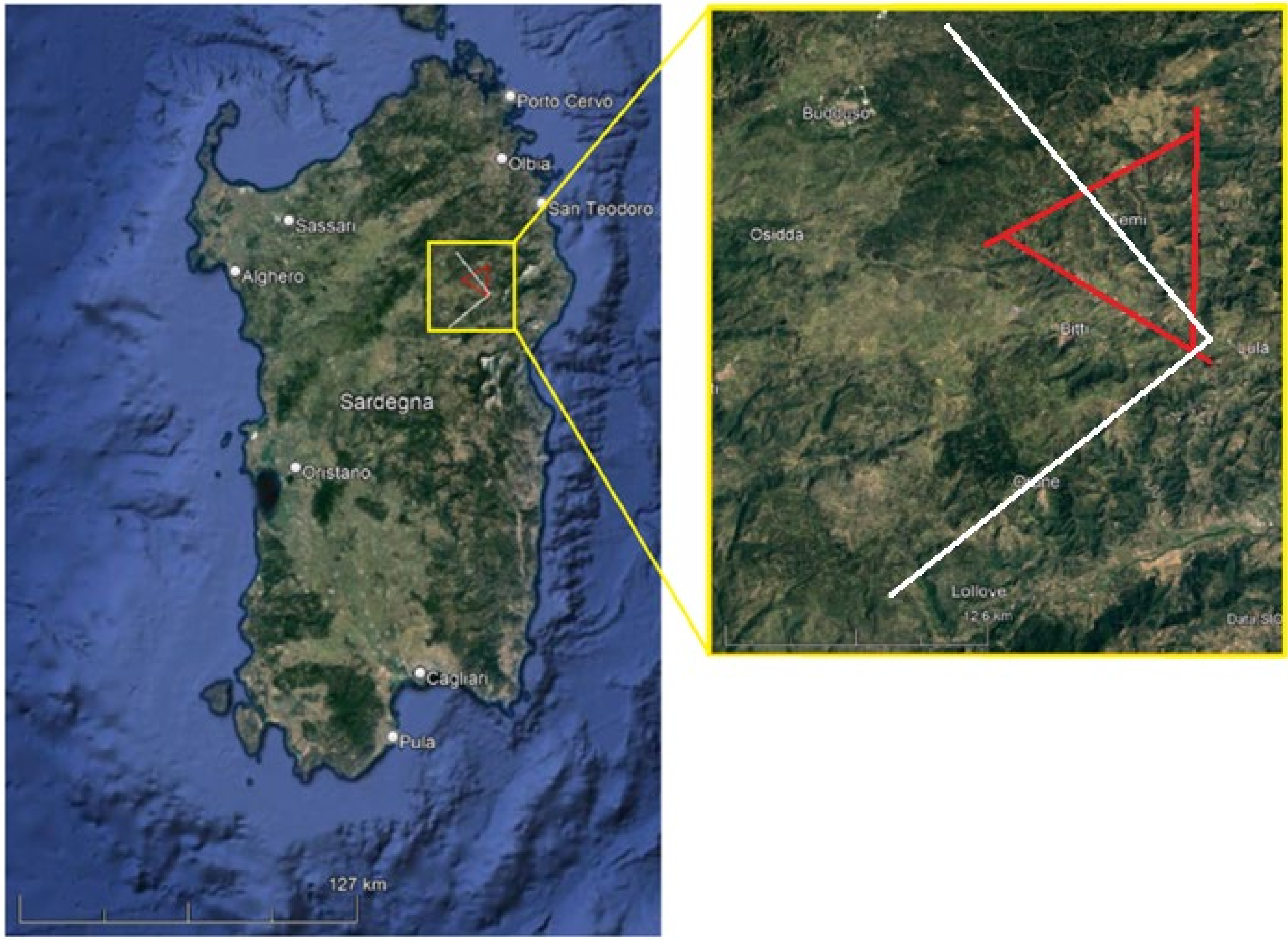
Cagliari, May 8th - 12th 2023

ET Project – Tunnels configurations

- T10 – Triangular shape 10 km:
  3 tunnels of about 10 km each, placed at about 60° from each other and at an average depth of about 250 m.

in alternative:

- L20 – L shape 20 km:
  2 tunnels of about 20 km each, approximately perpendicular to each other and at an average depth of about 250 m.



ET Project – Geological units

- T10 – Triangular shape 10 km:

  granodiorite 40%

  mica schists 32%

  orthogneiss 28%

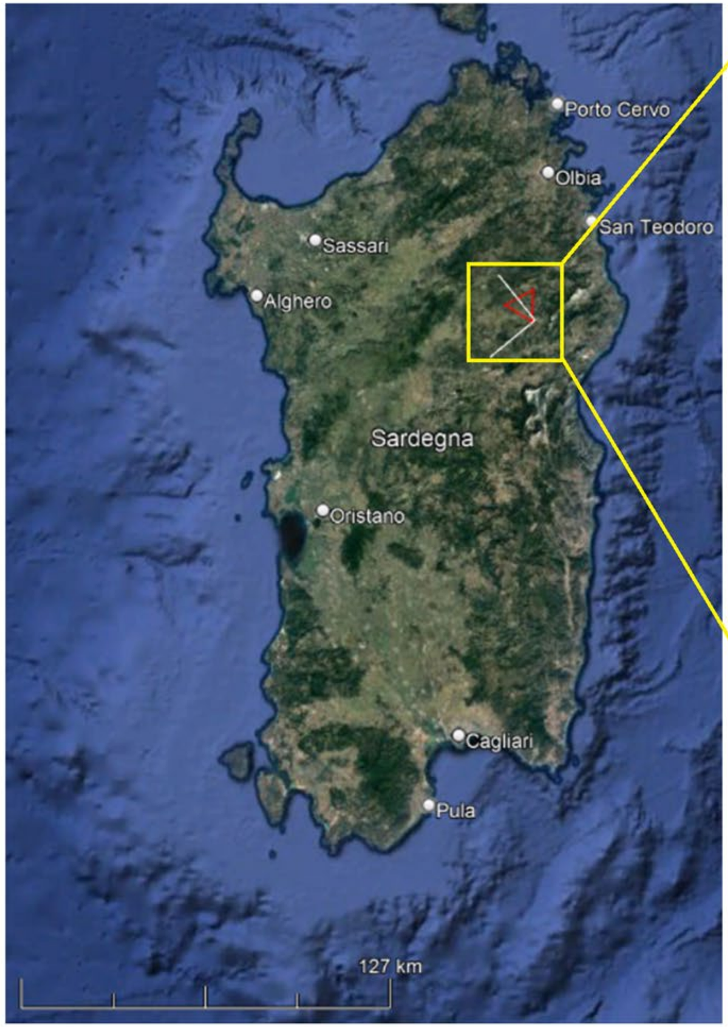
in alternative:

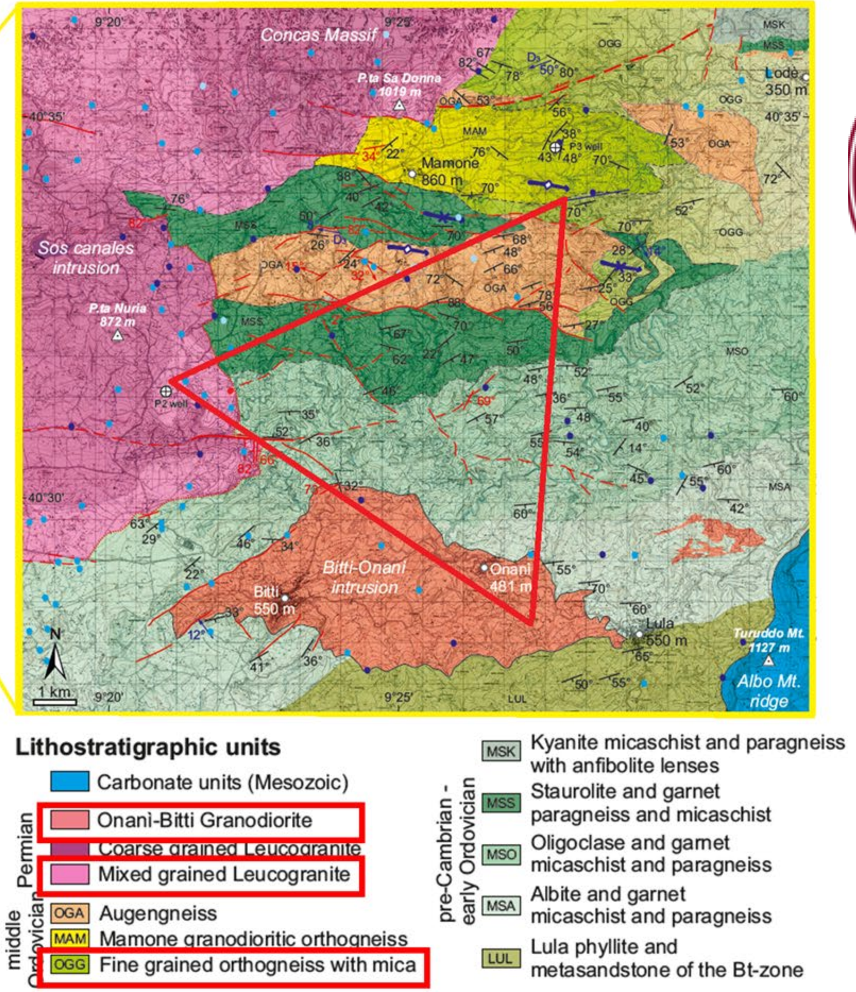
- L20 – L shape 20 km:

  granodiorite 60%

  mica schists 35%

  orthogneiss 5%





G.L. Cardello*, V. Longo, G. Oggiano
University of Sassari, Italy
Nuoro ET meeting, November 2021
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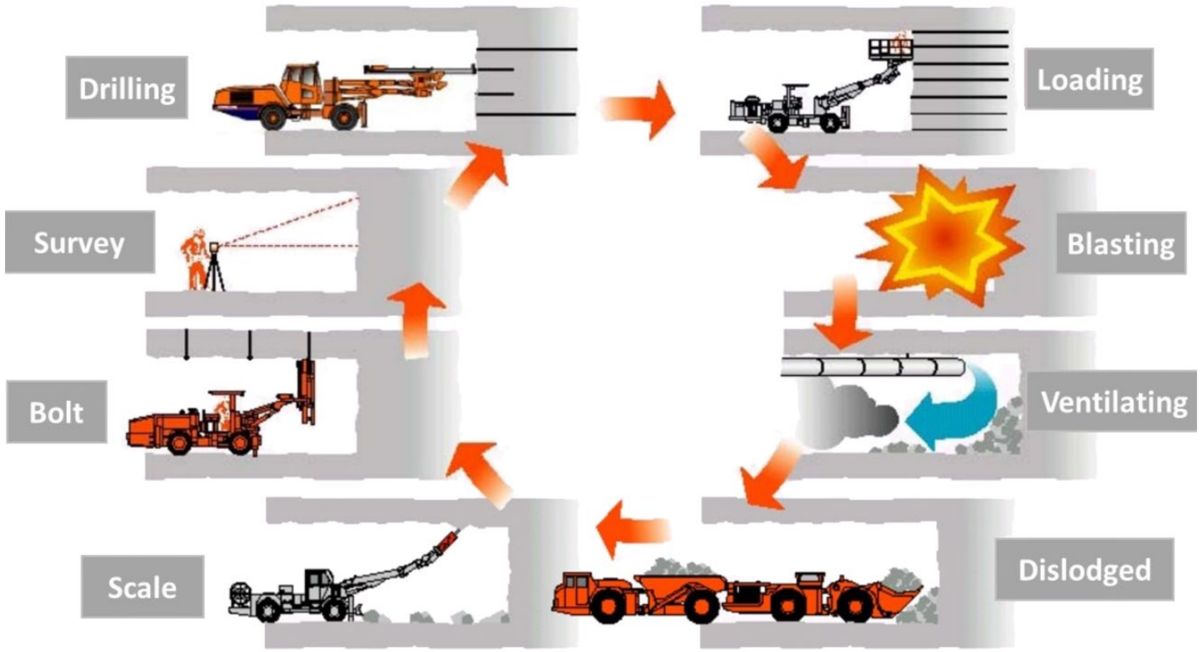
ET Project – Tunnels method choice

factors affecting the choice of tunnel method:

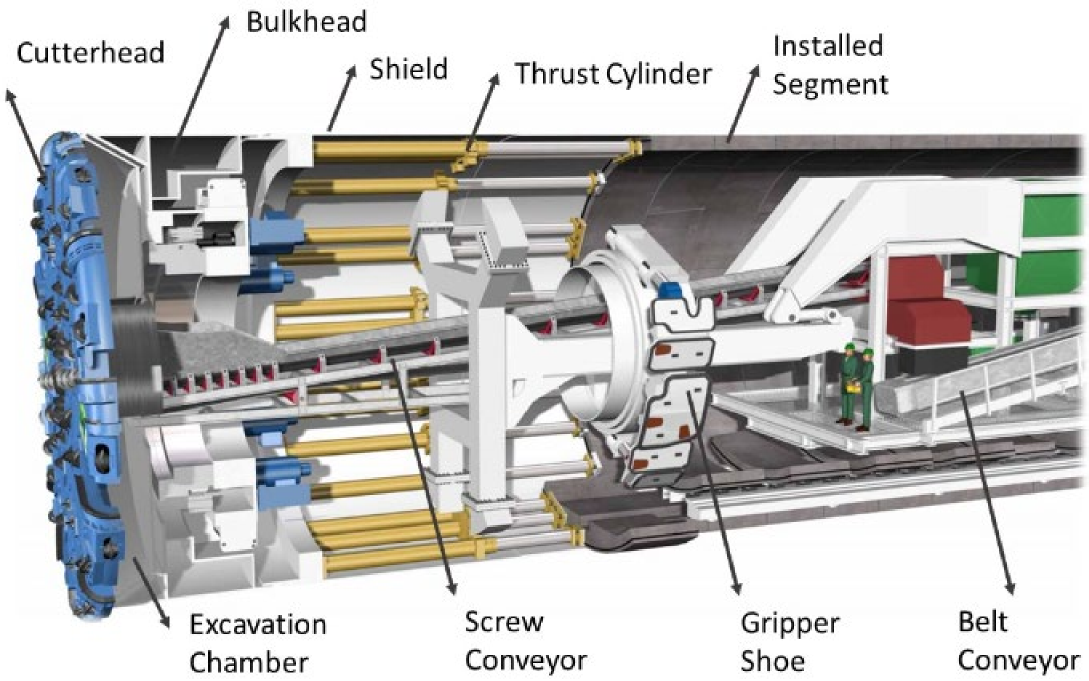
- **tunnel design parameters**: diameter, length, inclination and shape;
- **rock mass characteristics**: strength, geological features, abrasiveness, hydrogeology and rock mass rating;
- **performance factors**: rate of advance, boreability, overbreak, support requirements and skill of the crew;
- **contract related factors**: environmental and safety constraints, cost and quality.

ET Project – Tunnels method choice

drill & blast



TBM



ET Project – Tunnels method choice

Macias J. & Bruland A. *D&B versus TBM: Review of the parameters for a right choice of the excavation method*, 2014

		drill & blast	TBM
project design	geometry	**"any" shape**	circular
	length	shorter (optimal 3 km)	longer (5-25 km)
	start-up time	**5-6 months**	**6-12 months**
	niches and branch tunnels	less problematic	more problematic
health, safety and working environment	safety	lower	higher
	storage and handling explosives	accident risk	avoided
	rock support installation	no protected area	protected area
	working environment	toxic gases	dust
advance rates	advance rate	lower	**higher** (1.5-6 times)
	prediction advance rate	better	uncertain
	rock mass influence	lower	much higher
flexibility	profile	high	not
	layout	**high**	**very low**
	advance in crushed zones	easier	very difficult
	profile variability in construction	high	fairly limited

ET Project – Tunnels method choice

Macias J. & Bruland A. *D&B versus TBM: Review of the parameters for a right choice of the excavation method*, 2014

		drill & blast	TBM
ground stability	ground stability	lower	higher
	water inflow under pressure	more suitable	less suitable
	rock stress conditions	lower delay risk	higher delay risk
	rock support required	increased, less predictable	reduced (30-90%), more predictable
	excavation variations	great variability	no variability
operation and construction crew	operation	cyclical	continuous
	construction crew	all skills required, more difficult training	less skills required, easier training
constructions costs	design cost	lower	higher
	initial investment	lower	**higher**
	construction costs	not vary very much	highly variable
	life time cost	higher	significantly lower
tunnel profile	overbreak	higher (15-25 cm)	much lower (<10 cm)
	tunnel profile quality	**difficult**	nearly total
	filling concrete	high extra cost	limited extra cost
	concrete lining	less predictable	more predictable
environmental disturbance	noise and vibrations	higher	**significantly lower**
	environmental impact	more difficult acceptable	easier acceptable
	blasting fumes	continuously	not
	contamination	not possible to avoid	potential reduction

ET Project – Estimated time

hypothesis:

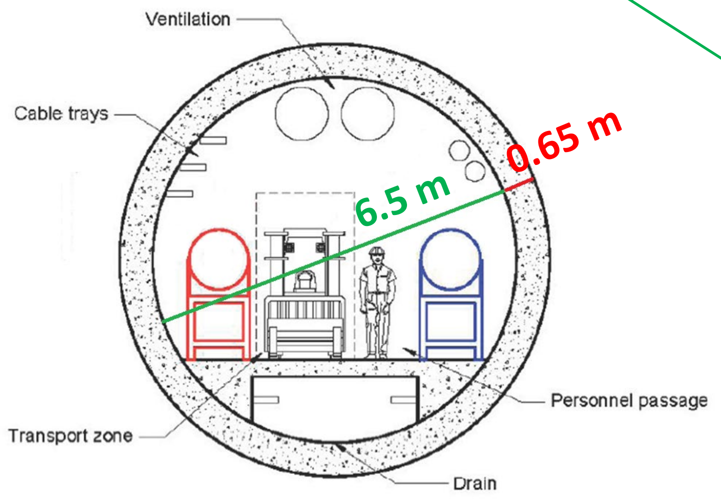
- **TBM** technology (Single Shield or Double Shield);
- average advance rate equal to **12-14 m/day**;
- **granodiorite**, **mica schists** and **orthogneiss** as the main geological units;
- excluding the access tunnels

	2 TBM SS	3 TBM SS	2 TBM DS	3 TBM DS
configuration	years	years	years	years
T10	5.3	2.4	4.5	2
T15	7.7	3.6	6.5	3
L15	3.6	-	3	-
L20	4.8	-	4	-

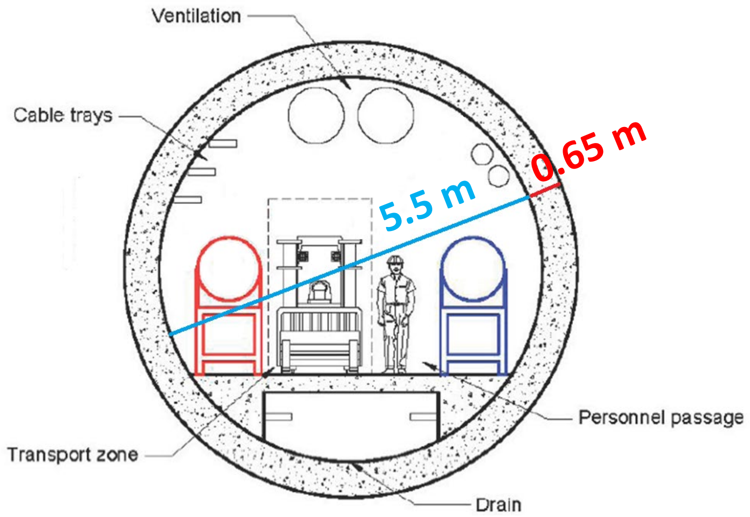
ET Project – Estimated volume

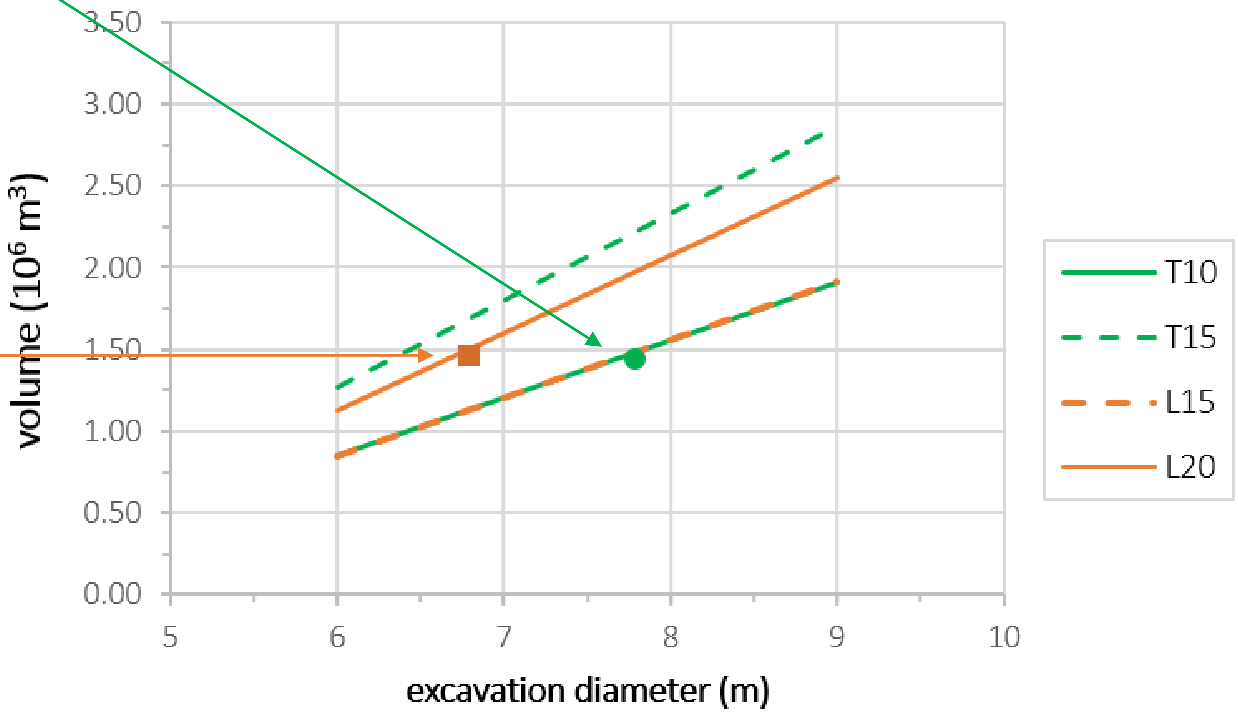
by varying the **excavation diameter** and the **total length** of the main tunnels for different configurations:

configuration T10



configuration L20





ET Project – Estimated volume

	configuration T10		configuration L20	
	excavated volume (10^6 m^3)	muck volume* (10^6 m^3)	excavated volume (10^6 m^3)	muck volume* (10^6 m^3)
surface excavations	-	-	-	-
caverns (drill&blast)	1.1	1.3	0.5	0.6
portals/connections/service tunnels	0.7	0.9	0.3	0.4
shafts	0.03	0.04	0.07	0.1
access tunnels**	1.1	1.3	1.1	1.3
main tunnels	1.4	1.7	1.5	1.7
TOTAL	**4.4**	**5.3**	**3.5**	**4.2**

*muck volume is determined as 1.2 times the excavated volume

**since the estimated volume obtained from the excavation of the access tunnels is a high percentage of the total volume, it’s important to carefully choose their excavation methodology

ET Project – Spoil reuse

for the promotion of sustainable development (as envisaged by the 2030 Agenda of the UN General Assembly and promoted by the UE Circular Economy Action Plan) the **reuse of excavated soils and rocks plays an increasingly important role** in the evaluation of a project

ET Project – Spoil reuse

the main steps of the spoil reuse process are:

- ✓ chemical analyses and verifications according to the Italian legislation (D.P.R. 120/2017)

- ✓ definition of suitable reuse options based on the characteristics of the excavated material (grain size, volumes, …)

in-situ reuse
effective exclusion from the field of application of the waste legislation (art. 185 del D.Lgs.152/2006)

ex-situ reuse
management as a "by-product" (art. 184-bis del D.Lgs.152/2006)

waste disposal site

ET Project – Alternative spoil reuse for rocks

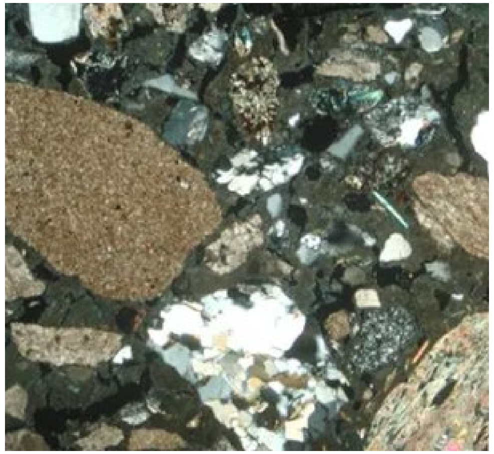
already adopted and studied solutions, high feasibility, **no innovation** and low added value

backfill	acceptable grain size with specific precautions but less effective can be used without particular processing if necessary, other elements must be included (i.e. cement, lime, fibers, …)
road embankments	optimal grain size can be used without particular processing if necessary, other elements must be included (i.e. cement, lime, fibers, …)
morphological reprofiling	acceptable grain size with specific precautions but less effective can be used without particular processing if necessary, other elements must be included (i.e. cement, lime, fibers, …)
slope stability	optimal grain size can be used without particular processing if necessary, other elements must be included (i.e. cement, lime, fibers, …)
rock-fall barrier	optimal grain size can be used without particular processing if necessary, other elements must be included (i.e. cement, lime, fibers, …)

ET Project – Alternative spoil reuse for rocks

partially tested and studied solutions, good feasibility, **innovation** and added value, possibility of optimization

filler for backfilling mortars	optimal grain size can be used without particular processing if necessary, other elements must be included (i.e. cement, lime, fibers, …)
pea gravel	optimal grain size can be used without particular processing if necessary, other elements must be included (i.e. cement, lime, fibers, …)
aggregate CLS	optimal grain size can be used without particular processing if necessary, other elements must be included (i.e. cement, lime, fibers, …)
road paving aggregates	optimal grain size can be used without particular processing if necessary, other elements must be included (i.e. cement, lime, fibers, …)



ET Project – Alternative spoil reuse for rocks

promising solutions, high feasibility, **high innovation** and high added value

cement raw materials	optimal grain size other elements must be included (i.e. cement, lime, fibers, …) other processes other than mixing are required (i.e. cooking or micronization)
geopolymers	acceptable grain size with specific precautions or but less effective other processes other than mixing are required (i.e. cooking or micronization)

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study carried out by

GEEG (Anita Di Giulio, Sara Mangifesta and Diego Sebastiani)

within the activity coordinated by

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in collaboration with

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