Could the landscape preserve traces of a deep underground nuclear waste repository over very long time?

"What we can learn from the archaeology of old mines"

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The analysis takes into account future natural evolution of the site

→ 2 scenarii / possible future climate and geomorphological evolutions
The 2 scenarii taken into account for future climate change (Bioclim)

**Natural evolution**

- Beginning of the next glaciation in 50 kyrs

**Current time climate**

**Cold climates**

**Modified evolution of the climate due to large impact of human activities**

5000 GT of fossil carbon injected into atmosphere during the next 325 years

- Hot climates will prevail during the next 500 Kyrs

**Hot and wet climates**
Usually, abandoned underground mines exhibit at surface a lot of traces over millenniums.

Do traces of ancient mines represent valid analogs for Cigeo project?
Slag heaps:
Big traces; but possible short life, due to human activities

Examples in the Longwy iron mining basin:
This big slag heap does not exist any more today...
Today the surface of the plateau is flat!
At 1,000 years time scale, traces could be well preserved in a woody landscape.

Exemple of a copper mine forgotten since the XVII\textsuperscript{th} century, discovered at the end of the XX\textsuperscript{th} century (ph. J.-P. Fizaine)
Traces of ancient mines 1,000 to 10,000 years old still exist

Examples of antic mines:

The 3,500 years old mine of Laurion, in Greece

Excavation in a coarse slag heap of the silver mine of Laurion

Head of one of the antic shafts

(photos J.-P. Fizaine)
Traces of ancien mines 1,000 to 10,000 years old still exist

Archeological studies in an antic copper mine slag heap 3,000 years old
in the Jordanian desert

Khirbat en-Nahas

Photograph ©2008 Thomas Levy, UC San Diego.
Example of the Neolithic flint mine of Casa Montero (SE of Madrid)
An open-area excavation of 4,2 ha has been documented over 3,500 vertical shafts.

Aerial view showing open neolithic shafts (excavated during the archeological survey of the site), and traces of still filled shafts.
Traces of ancient mines exist also in temperate countries

A 4,000 years old copper mine in UK:
*Great Orme, Llandudno, Wales*

robert-thewanderer.blogspot.co.il
The remains of mineshafts, pits, and heaps

The Neolithic flint mining complex of Brandon, East of England
5,000 to 4,000 years old

Ron Strutt - From geograph.org.uk


http://neoagebc.blogspot.fr/
Geological evolution will gradually remove the traces of Cigéo ...

- Colluvial deposits
- Removing of the mounts of limestone material on the scarp
- Retreating of the cuesta
- Removing of limestone material of the colluvial deposits in the flood plain
Conclusion: in a very distant future, traces of the heads of shafts and of inclined tunnels will still exist

→ Natural examples
The traces of Cigeo will be mixed with other human traces of all ages

Exemple : LIDAR image (« light detection and ranging ») → Detection of ancient mines on the Barrois plateau
The main question:
How could these traces be well interpreted by archeologists and geomorphologists in a far future?

How to avoid traces to be misinterpreted as some natural geomorphological features?

A very large karstic « shafts » network, 120 million years old, exists on the Bure plateau...

Quaternary karstic wells will exist on the Bure plateau, close to the Cigeo project site...
A possible solution:
Marking the site and the long lived traces (heads of the shafts and inclined tunnels) **over very long time** with **long lived small** anthropological elements (ceramic pieces for example)

1) The material which could be used to mark the Cigeo site
   - Small engraved pieces
   - Included in some geologically exotic material (for example: siliceous sand / limestone plateau)

2) The marks design
   The material could be included in some few meters long drill holes,
   This concept allows pieces distribution at surface over a long time period despite natural erosion of the site

3) Spatial distribution of the marks in the landscape
   Markers could be distributed around the main Cigeo surface facilities
Thank you for your attention