GSEU
GEOLOGICAL SERVICE FOR EUROPE

The good, the bad and the ugly (maps&blanks&fakenews)

Exploring, Quantifying and Communicating Uncertainties in Geological Models |
Session 4: Communication & Applications
Teams Session 03/03/2026

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Funded by the European Union

EuroGeoSurveys
The Geological Surveys of Europe

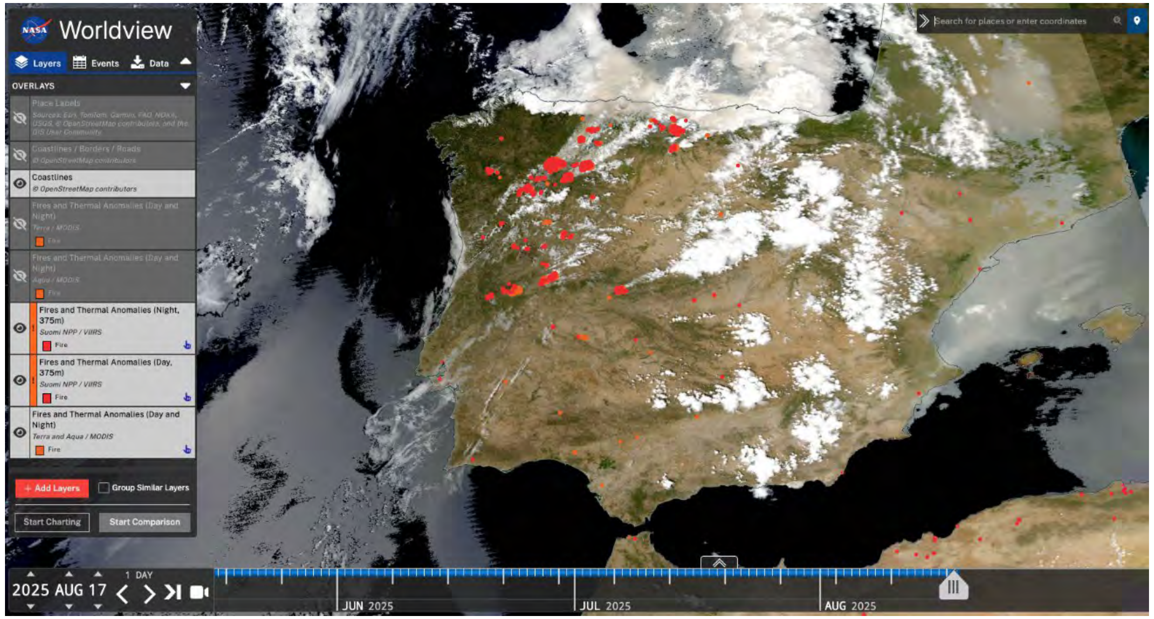
Intro

Presentation script

- **The good**: Maps: GSEU CRM Europe Map & Spanish Fires
- **The bad**: Map uncertainities & misunderstandings
- **The ugly**: Fake news
- **Final duel** or how to deal with social media**.**

Forest fires in Spain (Summer 2025)

2025 was the worst forest fire season in Spain in more than 30 years, with nearly **400,000 hectares** burned and 8 fatalities.



The fires have been exacerbated by extreme weather conditions, including a heatwave that has raised temperatures and reduced humidity. The combination of temperatures above 30 °C, strong winds and low humidity has created an environment conducive to the rapid spread of fires.

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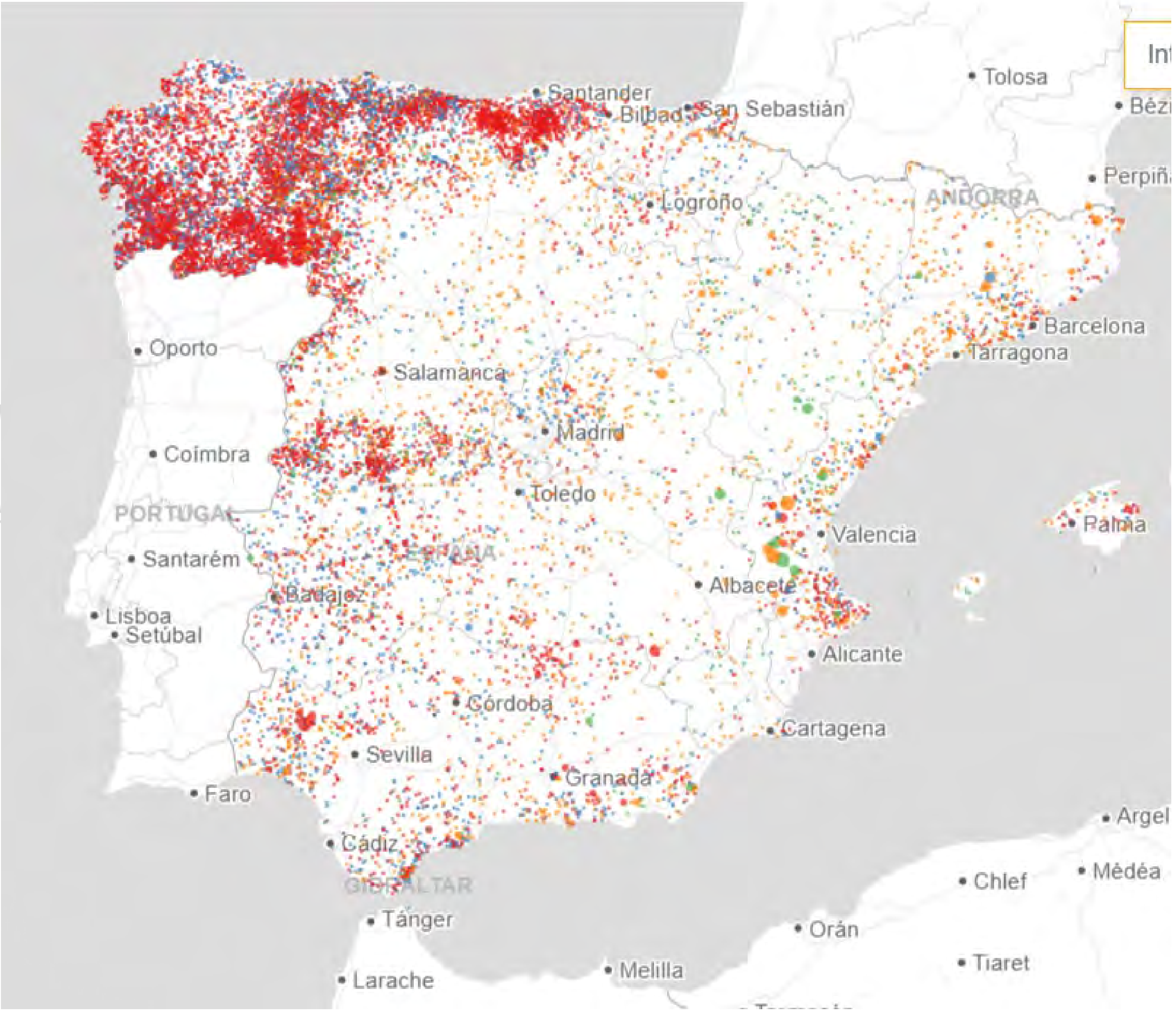
The good:
Maps: GSEU CRM Europe Map & Spanish Fires

Fires between 1983 and 2012

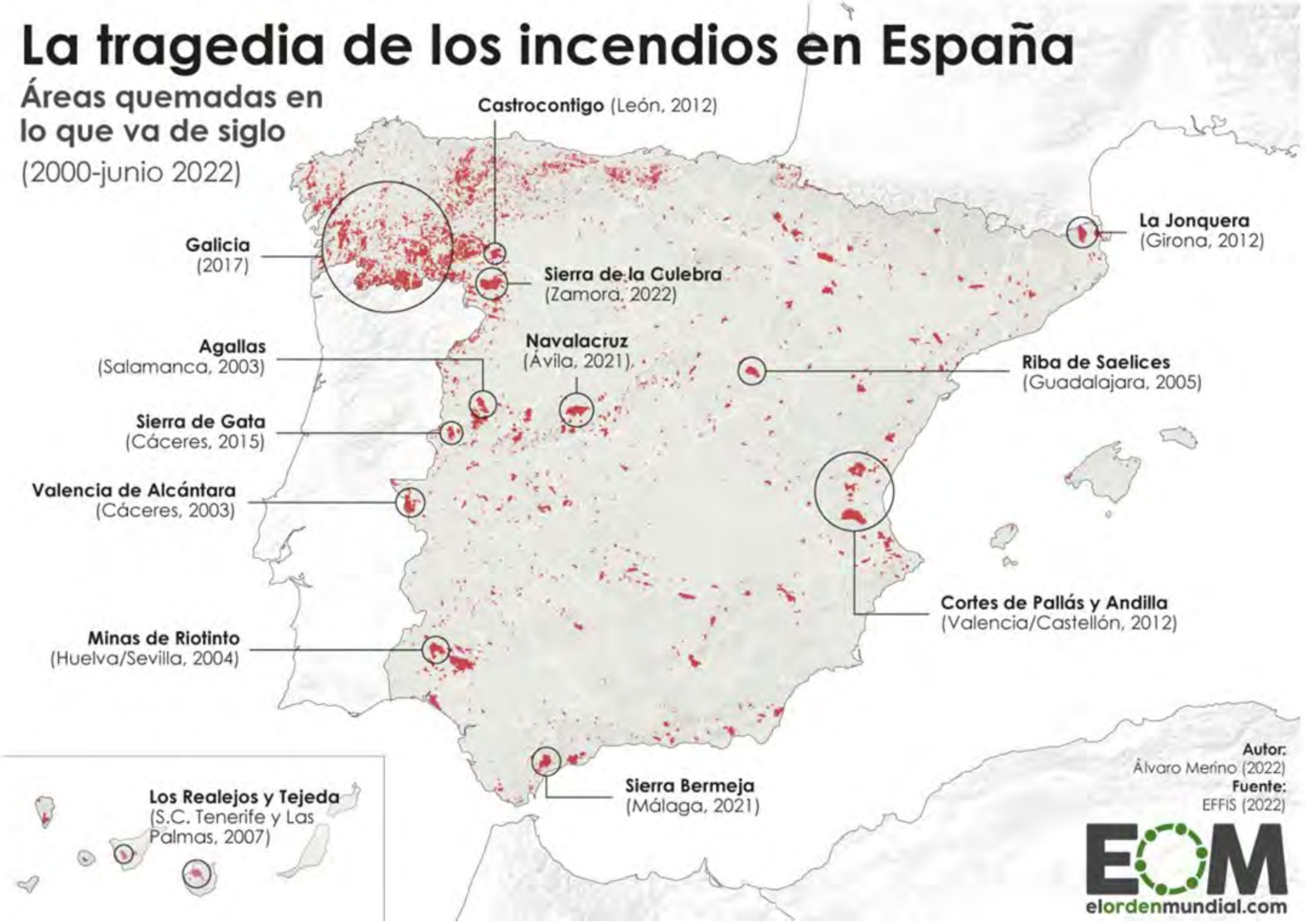
228,486 fires
5,321,172 burned hectares
171 fatalities
1,605 wounded

Intended Fire
By Accident
By lightning
Unknown



Source (Civio meteorología)
https://civio.es/medio-ambiente/mapa-de-incendios-forestales/#explora

Burned áreas 2000-2017



Source: El mapa de los incendios en España - Mapas de El Orden Mundial - EOM

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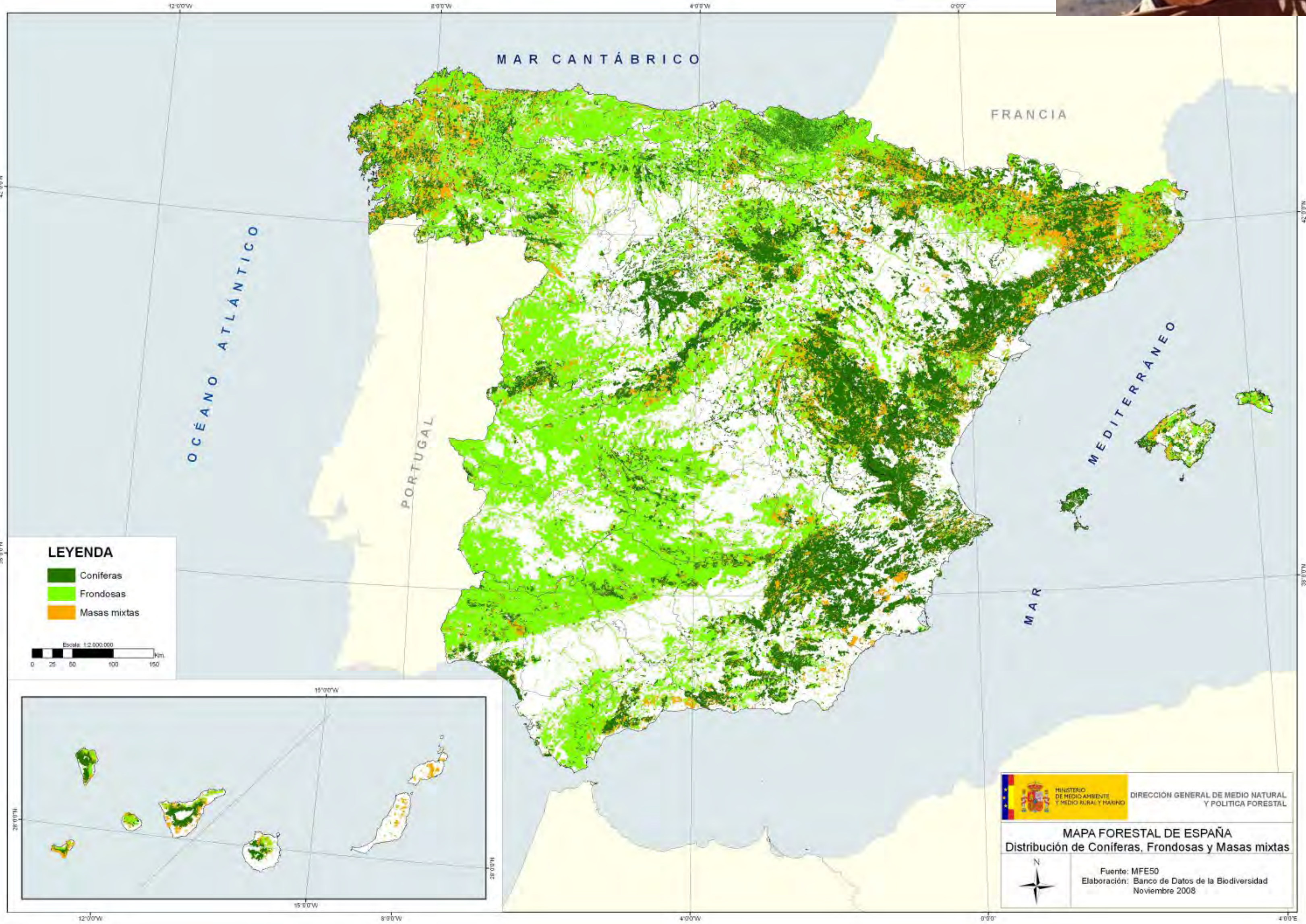
Spanish foresty Map

Conifers

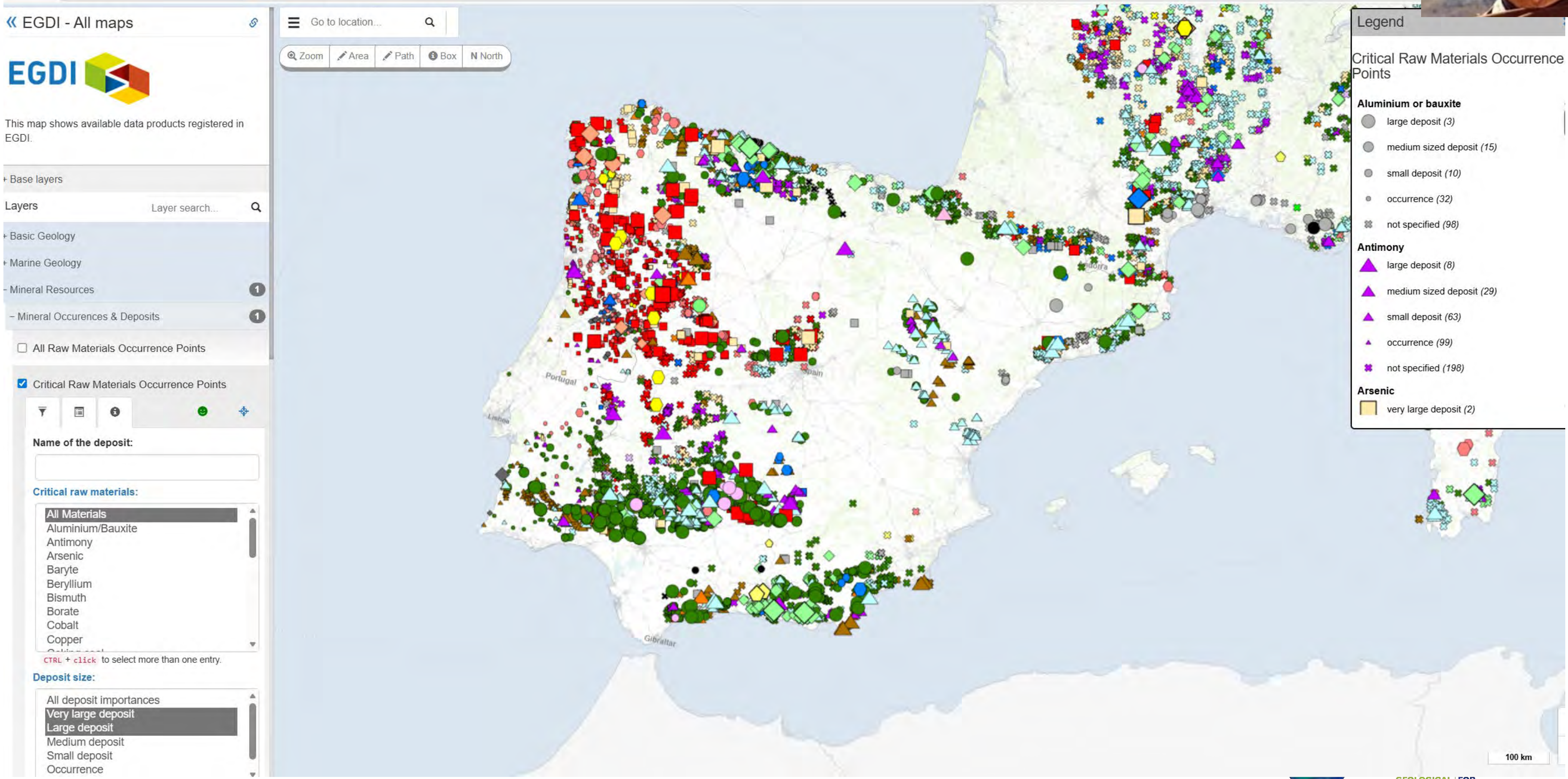
Decidious trees

Mixed stands

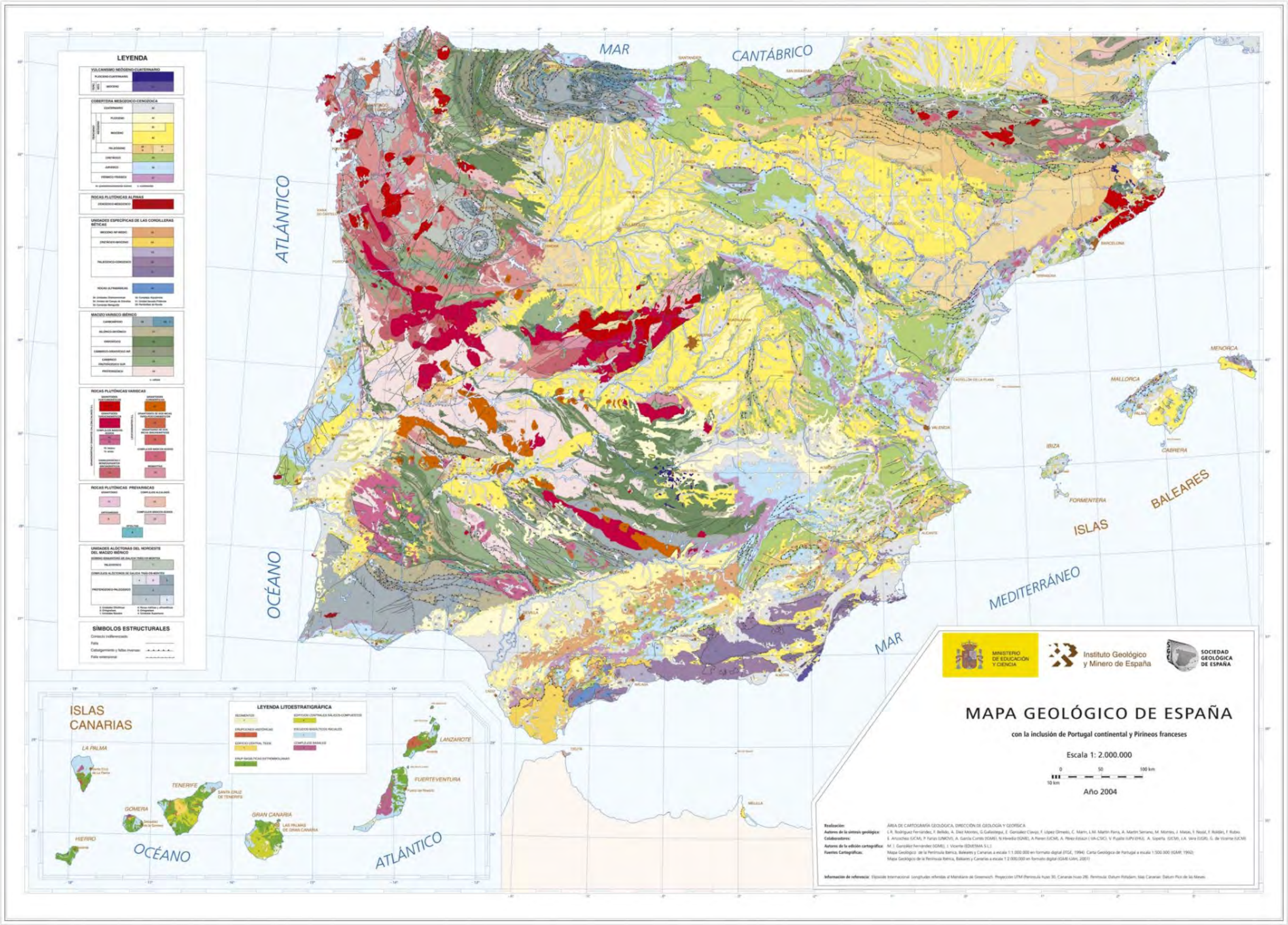


Source Ministry of Envriomental, rural and Marine affairs (2008)

CRM Map (Date: 02/03/2026)

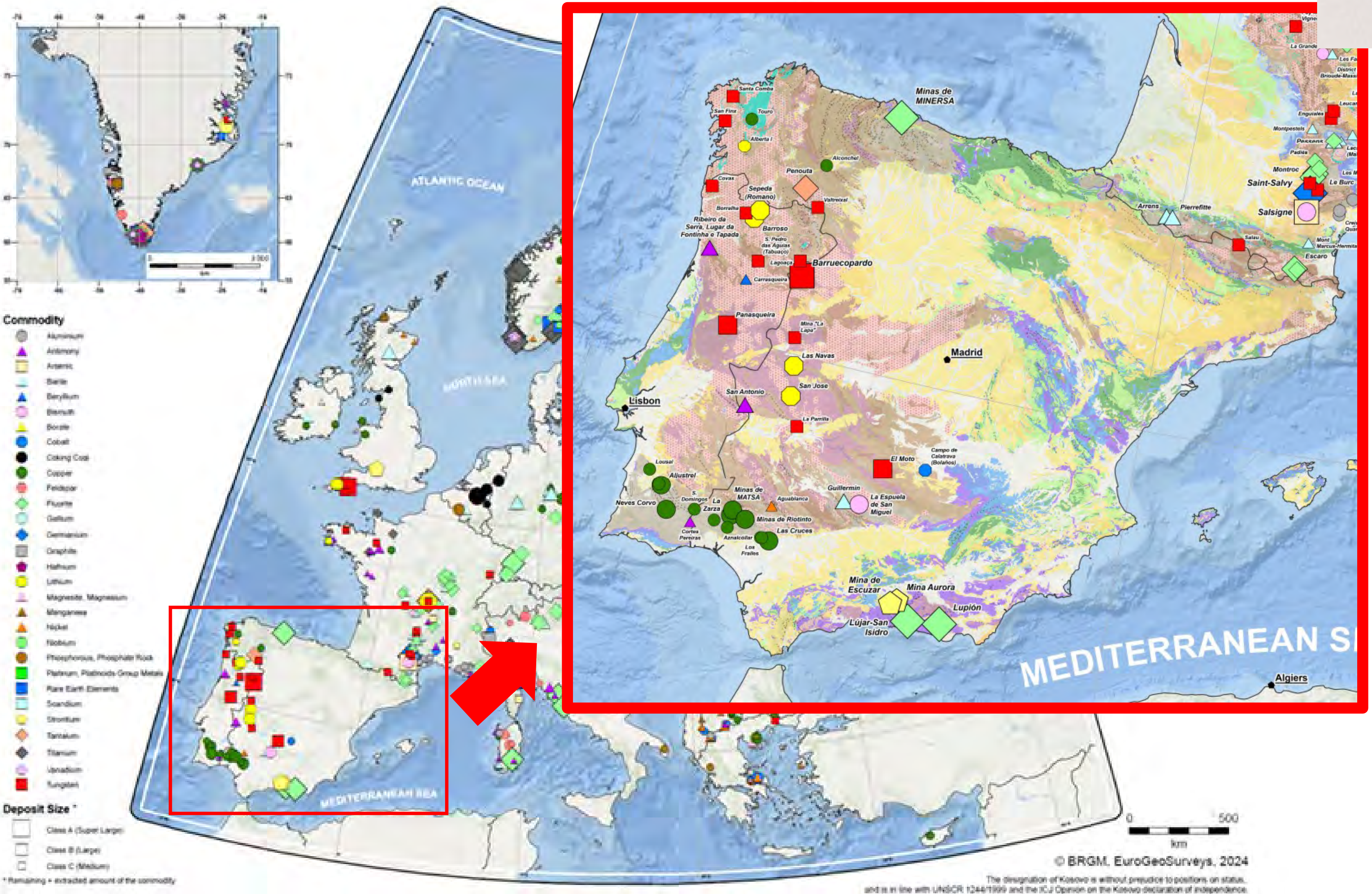


Iberian Peninsula Geologic map



The bad: Map uncertainities & misunderstandings

CRM hard Rock deposits of Europe (2024)



Here comes the press Expansión Newspaper (12/03/2025)

Spain has rare earth elements: here is a map showing where they are located

Es noticia | Ibex 35 | Última hora | Ibex 35 hoy | Criptomon... | Crónica Bolsa

Expansión | Merca... | Inicie sesión

Empresas | Industria | Banca | Energía | Más +

INDUSTRIA

España tiene tierras raras: así es el mapa de dónde están

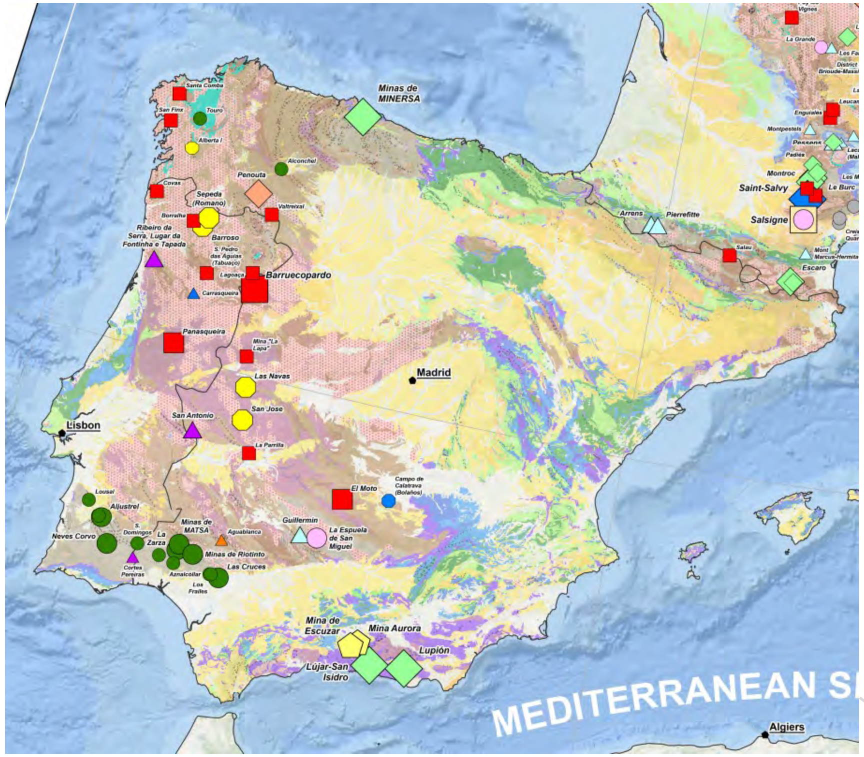
MIGUEL Á. PATIÑO @mpatinogomez 12 MAR. 2025 - 01:20

Comentar

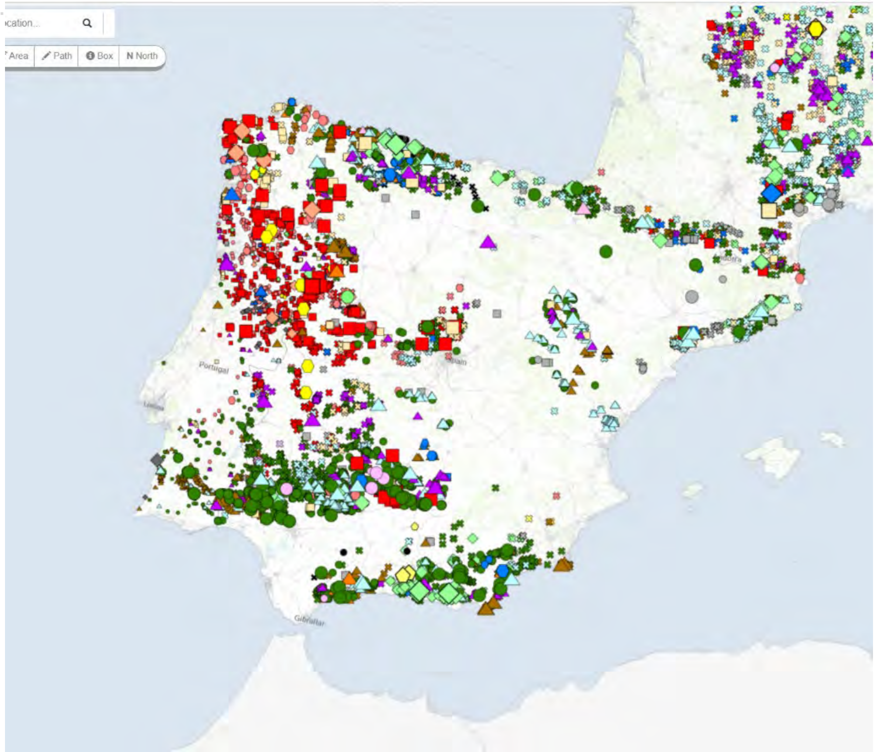
La minería en España en la actualidad tiene alta tecnología de prospección, con grupos muy especializados muchos de ellos foráneos: Berkley, Atalaya (Riotinto), First Quantum o Denarios Metals o Technology Metals, entre otros.. DREAMSTIME EXPANSION

- Por qué las tierras raras son importantes para Donald Trump y para Occidente
- Las tierras raras, cada vez más decisivas en la geoestrategia

CRM Maps comparison



2024



2026

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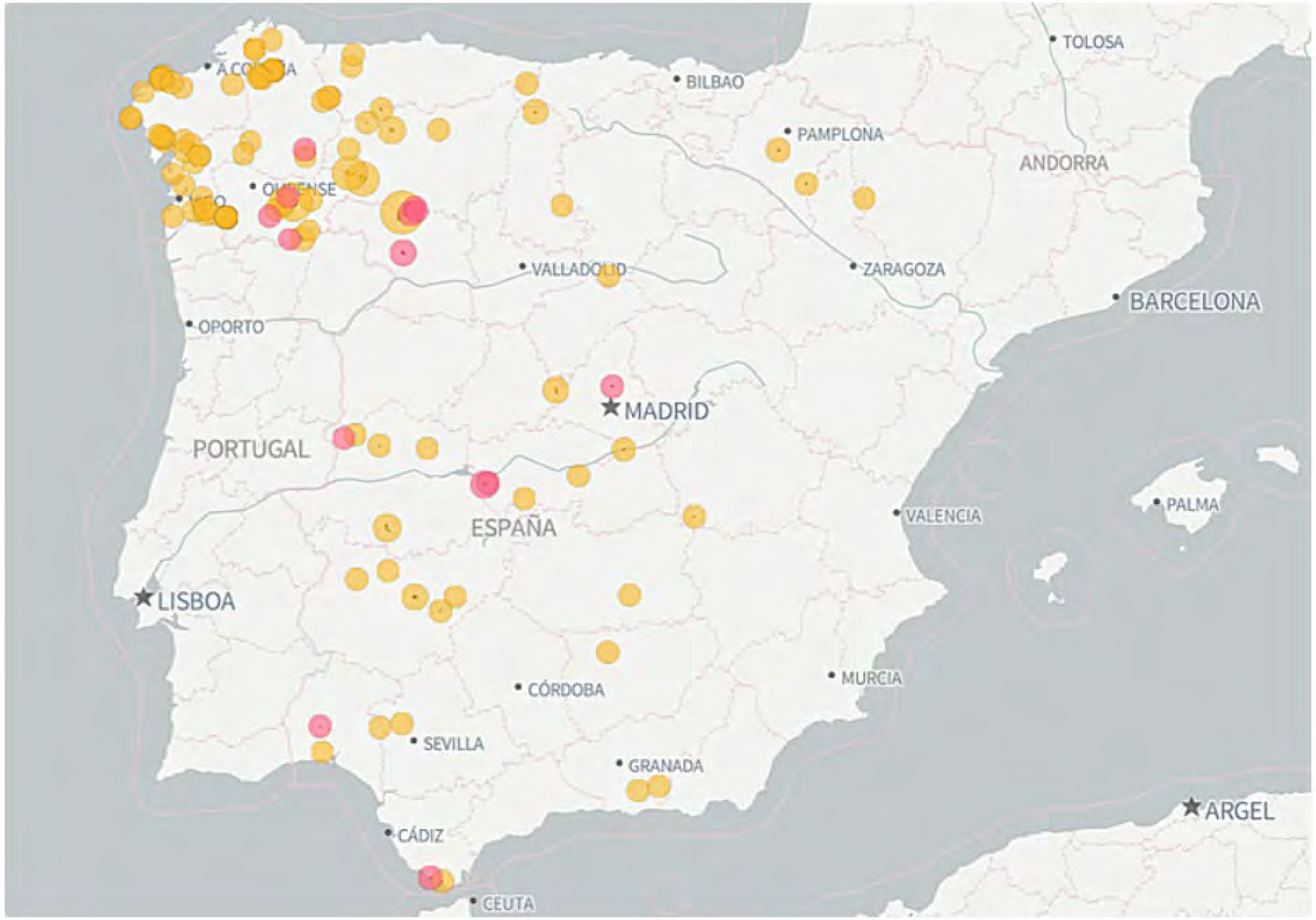
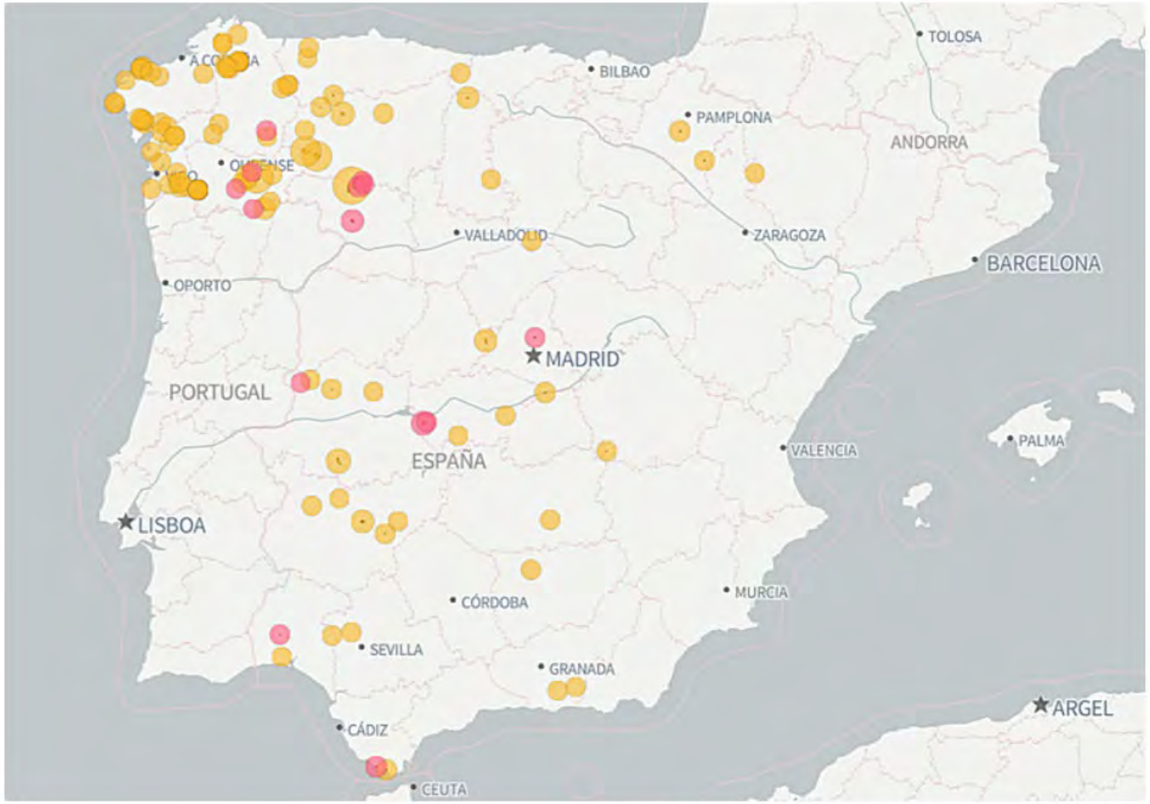
Fires Map (August 2025)



Mapa de incendios forestales en España en agosto de 2025. (ABC)

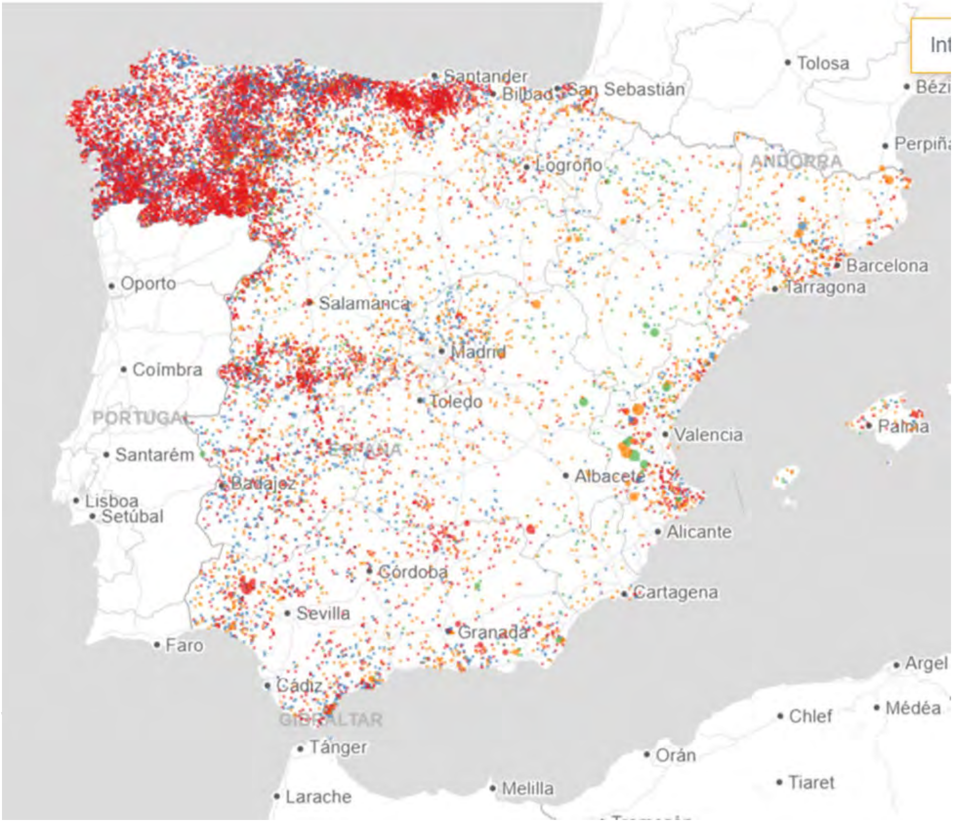
Source: ABC newspaper (August 2025)

Fires Map (August 2025)



Mapa de incendios forestales en España en agosto de 2025. (ABC)

2025



1983-2012

The ugly: fake news

aka « Maps don’t lie, but humans do » (Renata Barros)

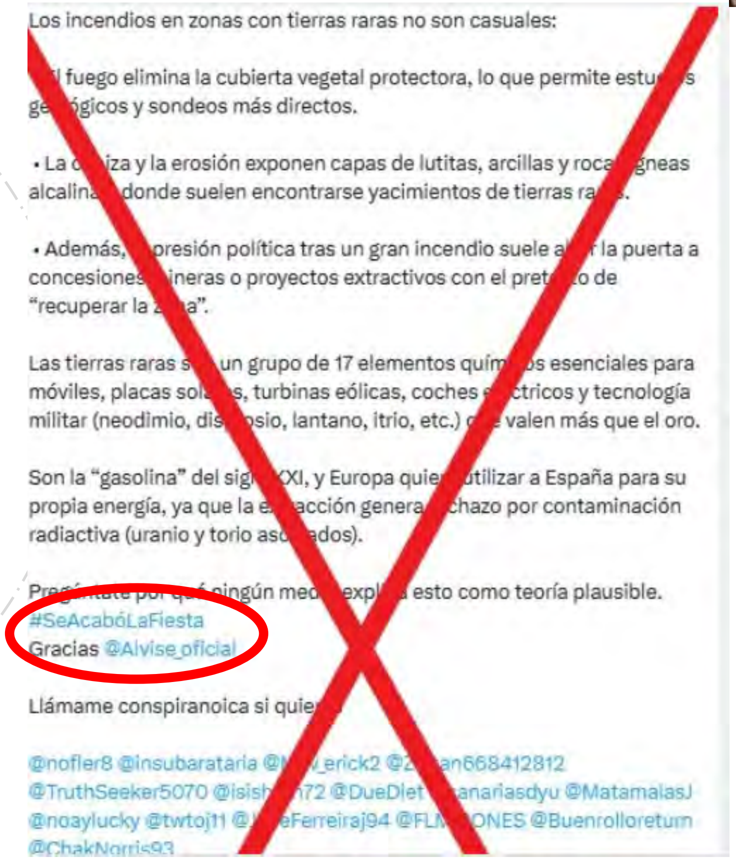
Fake new: Publication (20/08/2025)

Everything is better understood together.

Don't you think that's strange?

Fake new: Argumentation

Fire removes the protective vegetation cover, allowing for more direct geological studies and surveys.Ash and erosion expose layers of shale, clay and alkaline igneous rocks where rare earth deposits are often found.
In addition, political pressure following a major fire often opens the door to mining concessions or extraction projects under the pretext of 'recovering the area'.
Rare earths are a group of 17 chemical elements essential for mobile phones, solar panels, wind turbines, electric cars and military technology (neodymium, dysprosium, lanthanum, yttrium, etc.) **that are worth more than gold**.
They are the 'petrol' of the 21st century, and Europe wants to use Spain for its own energy, as extraction generates rejection due to radioactive contamination (associated uranium and thorium).
Ask yourself why no media outlet explains this as a plausible theory.


Los incendios en zonas con tierras raras no son casuales:

[illegible]l fuego elimina la cubierta vegetal protectora, lo que permite estu[illegible]s ge[illegible]ógicos y sondeos más directos.

• La [illegible]iza y la erosión exponen capas de lutitas, arcillas y roca[illegible]gneas alcalina[illegible] donde suelen encontrarse yacimientos de tierras ra[illegible].

• Además, [illegible]presión política tras un gran incendio suele a[illegible] la puerta a concesione[illegible]ineras o proyectos extractivos con el pret[illegible]o de "recuperar la [illegible]a".

Las tierras raras s[illegible] un grupo de 17 elementos quím[illegible]s esenciales para móviles, placas sol[illegible]s, turbinas eólicas, coches e[illegible]ctricos y tecnología militar (neodimio, dis[illegible]osio, lantano, itrio, etc.) q[illegible] valen más que el oro.

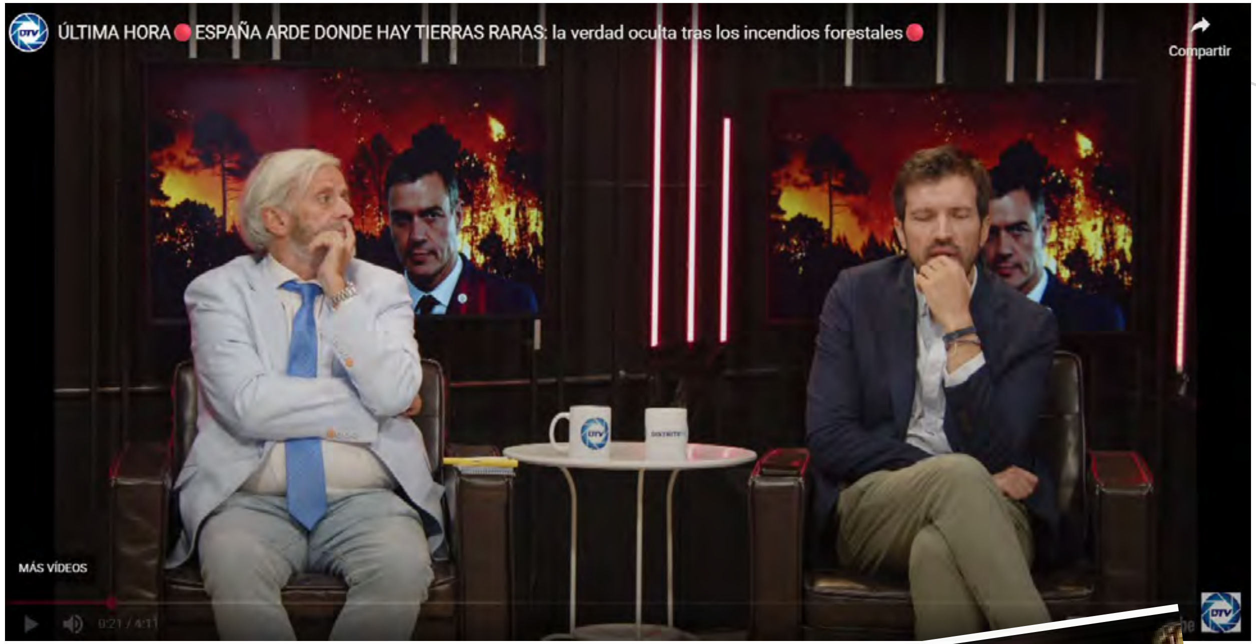
Son la "gasolina" del sig[illegible]XXI, y Europa quie[illegible]utilizar a España para su propia energía, ya que la e[illegible]acción genera[illegible]chazo por contaminación radiactiva (uranio y torio as[illegible]dos).

Preg[illegible] por qu[illegible] ningún med[illegible] expl[illegible] esto como teoría plausible.
#SeAcabóLaFiesta
Gracias @Alvise_oficial

Llámame conspiranoica si quie[illegible]

@nofler8 @insubarataria @[illegible]_erick2 @[illegible]an668412812 @TruthSeeker5070 @isish[illegible]72 @DueDiet[illegible]anariasdyu @MatamalasJ @noaylucky @twtoj11 @[illegible]eFerreiraj94 @FL[illegible]ONES @Buenrolloretum @ChakNorris93

Fake new: Dissemination & Political affairs



Source DTV Channel
"BREAKING NEWS: SPAIN BURNS WHERE THERE ARE RARE EARTHS: The hidden truth behind the forest fires" (YOUTUBE)

Source **Informe López | Geopolítica & Política Española (YOUTUBE)**

España

Sánchez se reunió en China con los 'capos' del litio que ansían los yacimientos españoles

Fue su primer acto en la agenda china: reunirse con los magnates cuyo negocio gira en torno al litio y su minería

Pedro Sánchez reunido con los empresarios chinos del litio durante su viaje oficial. | Moncloa

Pelayo Barro

PUBLICIDAD

Publicado: 11/05/2025 • 04:30

Síguenos en Google News

Favorito | 23 comentarios

El primer acto oficial del presidente del Gobierno, **Pedro Sánchez,** en su reciente viaje oficial a **China** fue un **«encuentro empresarial»** en Pekín, antes incluso de reunirse con el presidente chino **Xi Jinping**. En aquella mesa se sentaron

Source: Digital Newspaper THEOBJECTIVE (11/05/2025) "

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Final duel or How to deal with social media.

How should we react?

Typical Geological Survey reaction: **a serious press note**. Problem: poor imapct

Maldita.es Portada La Buloteca Secciones INICIAR SESIÓN

ALERTA MALDITO BULO MALDITO CLIMA

Cuidado con el mapa que relaciona sin pruebas los incendios de agosto de 2025 con supuestos yacimientos de litio y tierras raras

Publicado el 27 ago 2025, 17:54:00 Actualizado el 4 sept 2025, 15:09:00 Tiempo de lectura: 15 minutos

COMPARTIR:

En corto:

- Se difunden contenidos que relacionan las zonas con más incendios este año (sur de Galicia, noroeste de Castilla y León y zona central de Extremadura) y zonas donde habría yacimientos de litio y otros elementos en España
- En uno de los mapas más compartidos se muestran 31 yacimientos en España. De estos, 17 ya estaban operativos o en desarrollo en 2024
- Las leyes urbanísticas de Galicia, Castilla y León y Extremadura permiten la explotación de minas en suelo rústico, sin que sea necesario recalificar el suelo, y dos expertos nos indican que quemar un posible yacimiento no facilita su exploración o explotación

desinformación y la mentira

Metodología de Maldita.es

Beware of the map that links the fires of August 2025 to alleged lithium and rare earth deposits without evidence.

Source: maldita.es 27/08/2025

Better solution: Contact anti-fake journalists

Anti-fake arguments (I).

- Beware of the map that links the fires of August 2025 to alleged lithium and rare earth deposits without evidence is being shared that links the areas with the most fires this year (southern Galicia, north-western Castile and León, and central Extremadura) to areas where there are alleged deposits of lithium and other elements in Spain.
- One of the most shared maps shows 31 sites in Spain. Of these**, 17 were already operational** or under development in 2024.
- The urban planning laws of Galicia, Castile and León, and Extremadura allow mining on rural land without the need to rezone the land, and **two experts tell us that burning a potential deposit does not facilitate its exploration or exploitation**.
- The content does not provide any evidence as to why these fires would facilitate the extraction of minerals.
- The fires of 2025 coincide with the areas that **have historically been burned** the most in Spain

MOTTO: Correlation does not imply causation.

Source: maldita.es 27/08/2025

Anti-fake arguments (II)

- Rare earths are a group of 17 chemical elements, ranging from atomic numbers 57 to 71 (lanthanides), along with yttrium and scandium, explains the Geological Society of London in a document.
- The map shared 'does not contain rare earth elements,' **Paula Canteli, PhD in mining engineering and head of Institutional and International Relations at the Geological and Mining Institute of Spain (IGME),** explains to Maldita.es. This can also be read in the legend of the original map.Spain
- On the other hand, at Maldita.es we have researched which companies are responsible for these operational and developing deposits. There are different companies from different countries (such as Canada, Australia, Mexico, Germany, among others) and some have different projects in Spain. **According to the public information available on these companies, none of them are Chinese**. That does not mean that none of these companies have activities or interests in China or that there are Chinese individuals or companies with minority stakes that, due to their size, are not reflected in the available information.

Source: maldita.es 27/08/2025

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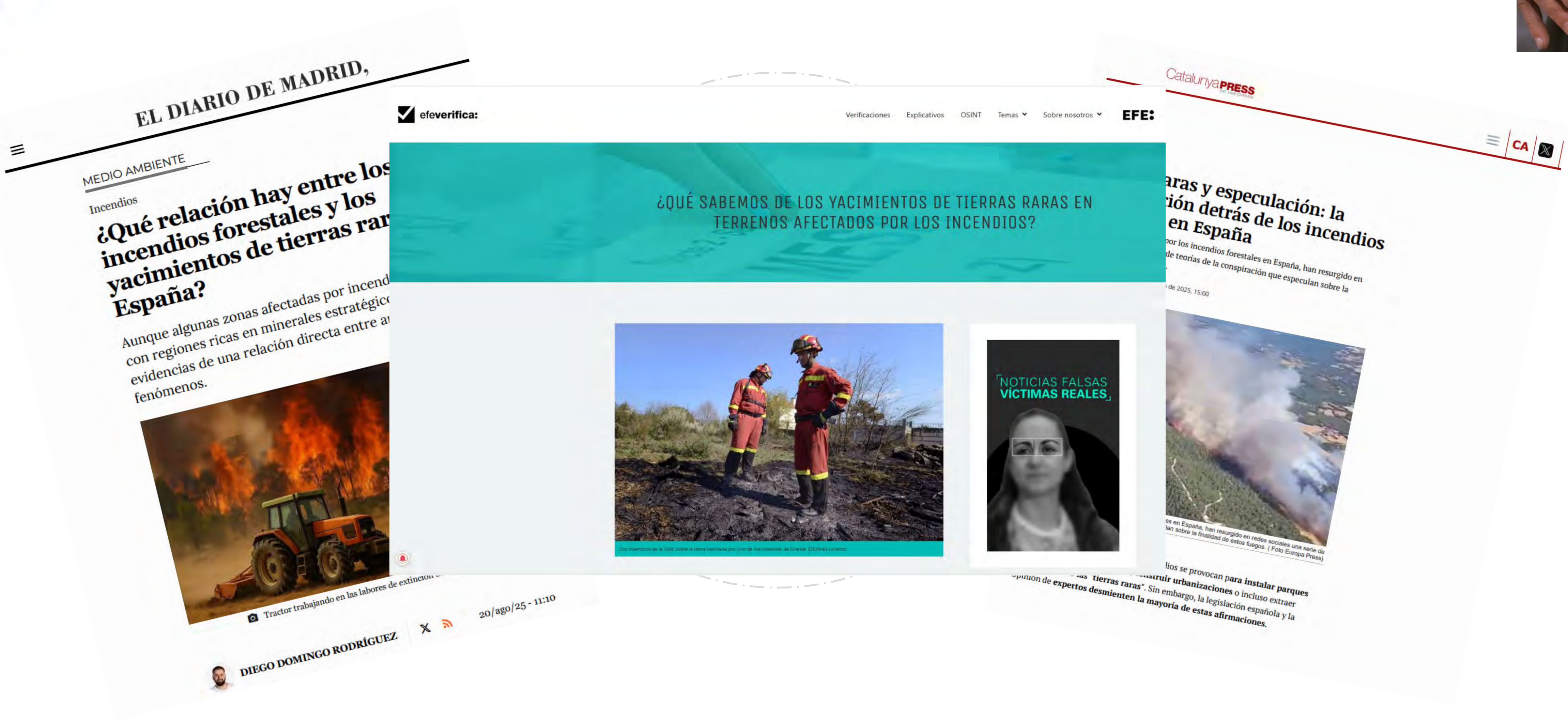
Anti-fake dissemination.



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Thank you for your attention !

Geo Workshop:

Exploring, Quantifying and Communicating Uncertainties in Geological Models

Handling of uncertainties in geological and geotechnical layer modelling in infrastructure projects

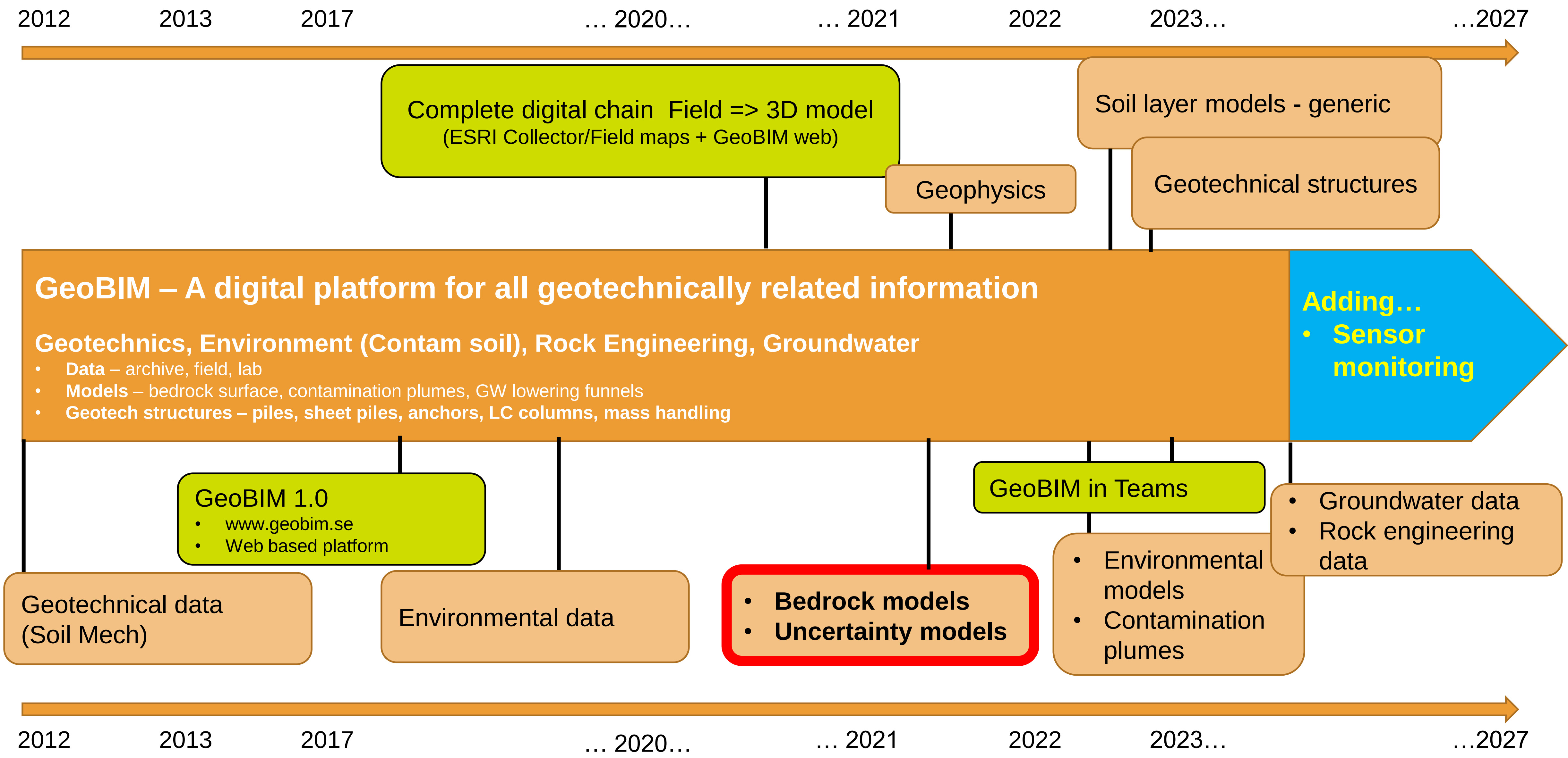
Mats Svensson, PhD

Tyréns Sweden

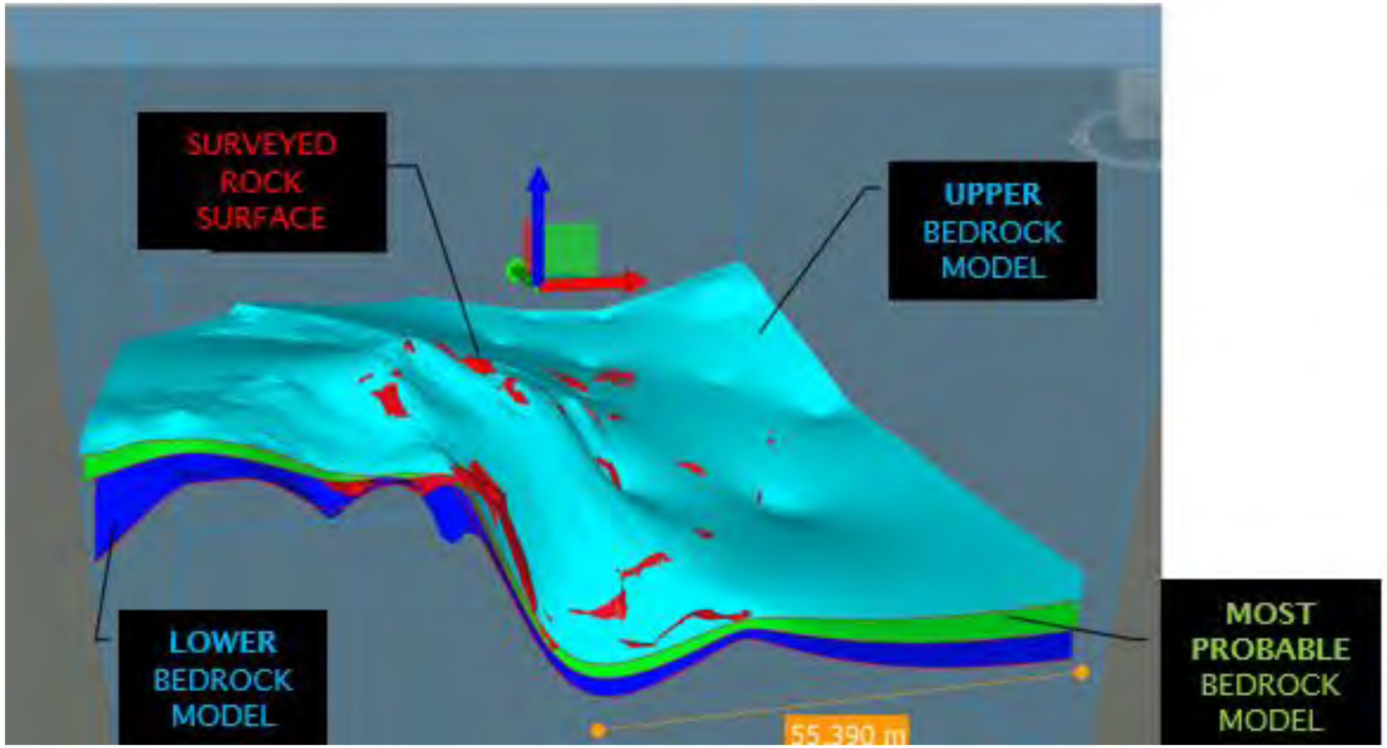
March 2-3, 2026

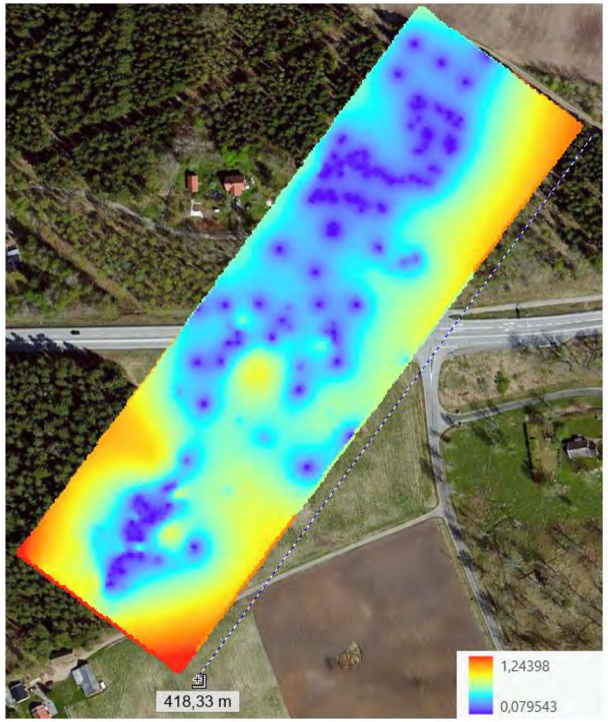
GEOBIM DATA MANAGEMENT

TYRÉNS



3 models and an uncertainty map



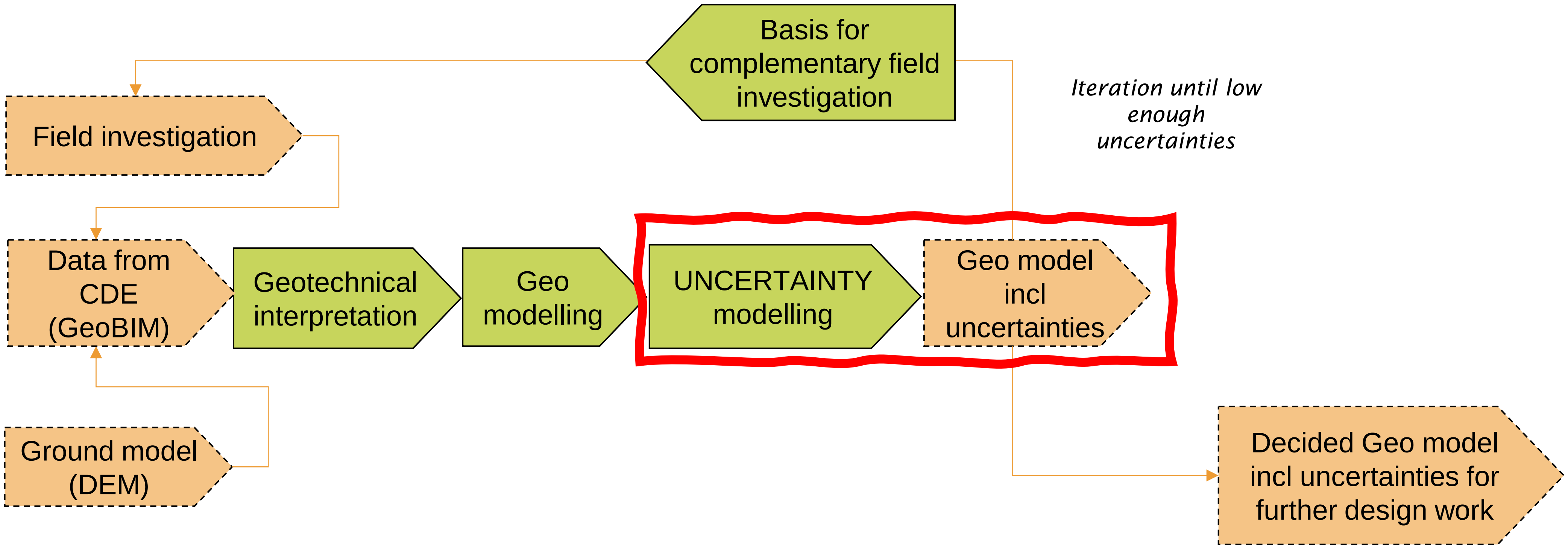


Why uncertainty models?

- Geotechnical models are ALWAYS a discussion
- Differing geological/geotechnical conditions often a reason for claims
- Possible to optimize planning of investigation program at all times

- Clearer risk sharing in contracts (less claims)
- Sustainability by optimized mass handling

The process



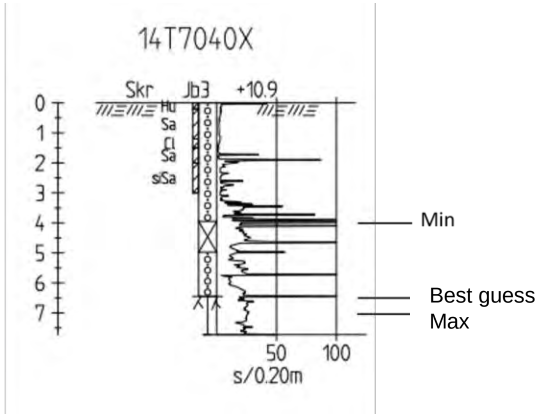
Basis for complementary field investigation
Field investigation
Iteration until low enough uncertainties
Data from CDE (GeoBIM)
Geotechnical interpretation
Geo modelling
UNCERTAINTY modelling
Geo model incl uncertainties
Ground model (DEM)
Decided Geo model incl uncertainties for further design work

How the uncertainties are calculated

2 types of indata

- Individual uncertainties on each investigation
- Distance to nearest investigation

- Kriging, Monte Carlo-simulations – 100+ (-1 000) models



Osäkerhetsbedömningar Berg

Sök efter verktyg, hjälp med mera (Alt + C)

Arkiv Start Infoga Dela Sidlayout Formler Data Granska Visa Automatisera Hjälp Rita

Kommentarer Genomgång Redigering Dela Stäng

H38

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**Instruktioner**															
2	Mall för osäkerhetsbedömning av Geoarkiv, godkända typer = **Tolkning,** övriga metoder som man vill få med läggs i Övrigt material Annat (se kommentar)															
3	Notera att endast djup (oranga fält) behöver bedömas (exkludera post från import genom att lämna Min-djup/Max-djup/Avvikelse uppåt/Avvikelse nedåt tomma)															
4	Fält i **fetstil** är obligatoriska, datum anges med ÅÅÅÅ-MM-DD, Riktning/lutning sätts till verktikalt om inget annat anges															
5																
6	**PunktID**	**Typ**	**Northing**	**Easting**	**Z-mark (m)**	Riktning	Lutning	Etappnamn	**Tolkat djup (m)**	**Min-djup (m)**	**Max-djup (m)**	Tolkningskommen	Tolkningsdatum	Signatur	Källa (fritext)	Dokumentlänk
7	25TY03	Tolkning	6397549,319	148766,475	16,011	0	-90	Etapp 0_0	1,15	1,05	1,25				Importerad från G	25TY03.pdf
8	25TY04	Tolkning	6397568,265	148792,658	15,784	0	-90	Etapp 0_0	8,82	8,72	8,92				Importerad från G	25TY04.pdf
9	25TY05	Tolkning	6397537,999	148774,874	16,319	0	-90	Etapp 0_0	1,15	1,05	1,25				Importerad från G	25TY05.pdf
10	25TY06	Tolkning	6397555,118	148802,852	16,221	0	-90	Etapp 0_0	4,2	4,1	4,3				Importerad från G	25TY06.pdf
11	25TY09	Tolkning	6397520,01	148794,446	17,142	0	-90	Etapp 0_0	1,58	1,48	1,68				Importerad från G	25TY09.pdf
12	25TY10	Tolkning	6397528,22	148807,054	17,157	0	-90	Etapp 0_0	2,7	2,6	2,8				Importerad från G	25TY10.pdf
13	25TY11	Tolkning	6397536,2	148816,154	17,136	0	-90	Etapp 0_0	1,23	1,13	1,33				Importerad från G	25TY11.pdf
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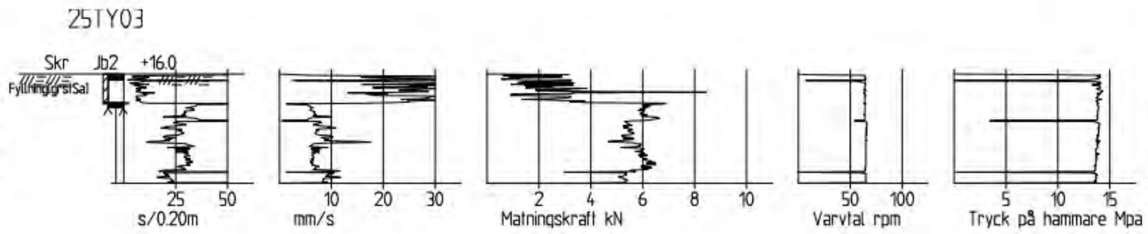
17	PH4	Tolkning	6397563,248	148899,021	17,247	0	-90	Et								s 2025-12-
18	PH9	Tolkning	6397552,167	148906,908	17,347	0	-90	Et								s 2025-12-
19	PH10	Tolkning	6397546,239	148899,847	17,647	0	-90	Et								s 2025-12-
20	SK5	Tolkning	6397523,922	148930,619	18,447	0	-90	Et								s 2025-12-
21	SK6	Tolkning	6397516,851	148937,547	18,547	0	-90	Et								s 2025-12-
22	SK7	Tolkning	6397508,78	148944,464	18,547	0	-90	Et								s 2025-12-
23	SK10	Tolkning	6397513,036	148919,507	18,347	0	-90	Et								s 2025-12-
24	SK11	Tolkning	6397505,965	148926,434	18,347	0	-90	Et								s 2025-12-
25	SK12	Tolkning	6397498,893	148933,362	18,447	0	-90	Et								s 2025-12-
26	SK101	Tolkning	6397538,199	148903,765	18,147	0	-90	Et								s 2025-12-
27	SK102	Tolkning	6397546,116	148911,846	17,847	0	-90	Et								s 2025-12-
28	SK103	Tolkning	6397490,017	148921,271	18,647	0	-90	Et								s 2025-12-
29	SK105	Tolkning	6397503,078	148915,405	18,547	0	-90	Et								s 2025-12-
30	SK106	Tolkning	6397518,066	148916,558	18,347	0	-90	Et								s 2025-12-
31	SK107	Tolkning	6397528,066	148916,661	18,547	0	-90	Et								s 2025-12-
32	SK108	Tolkning	6397531,024	148920,691	18,547	0	-90	Et								s 2025-12-

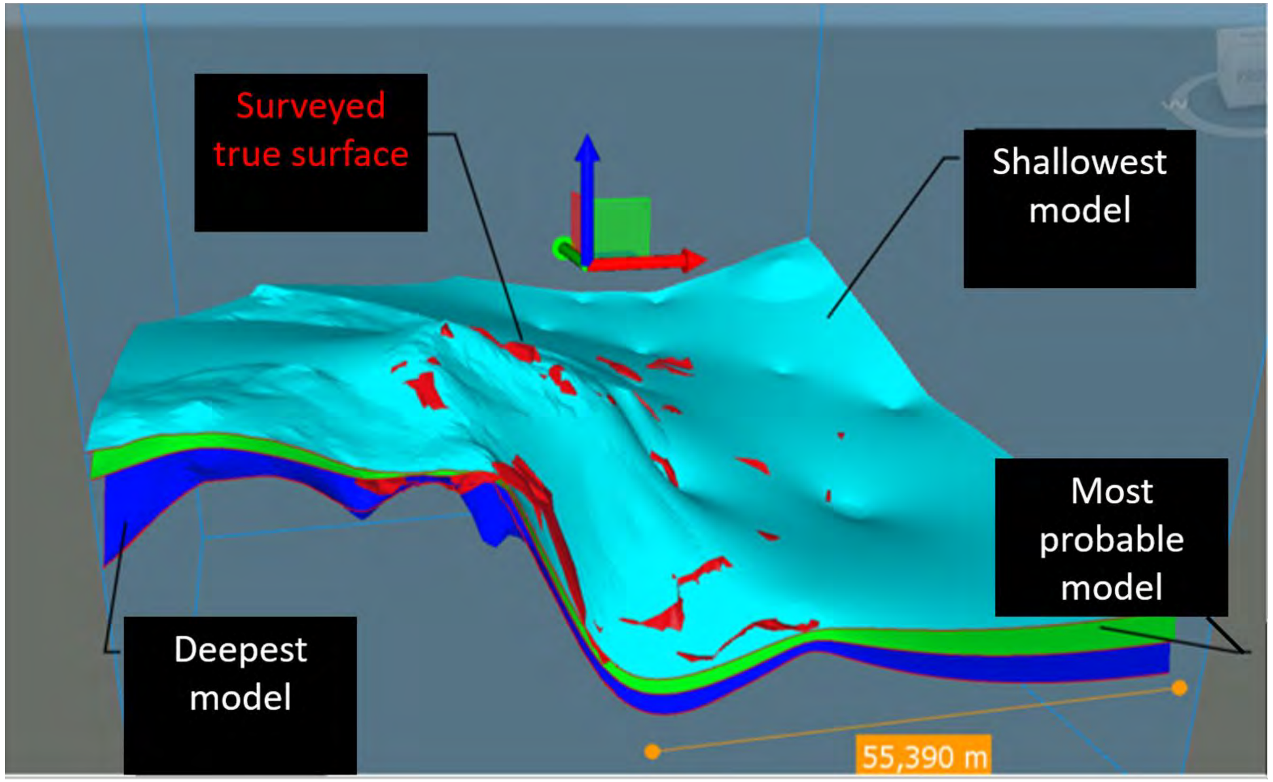
25TY03.pdf

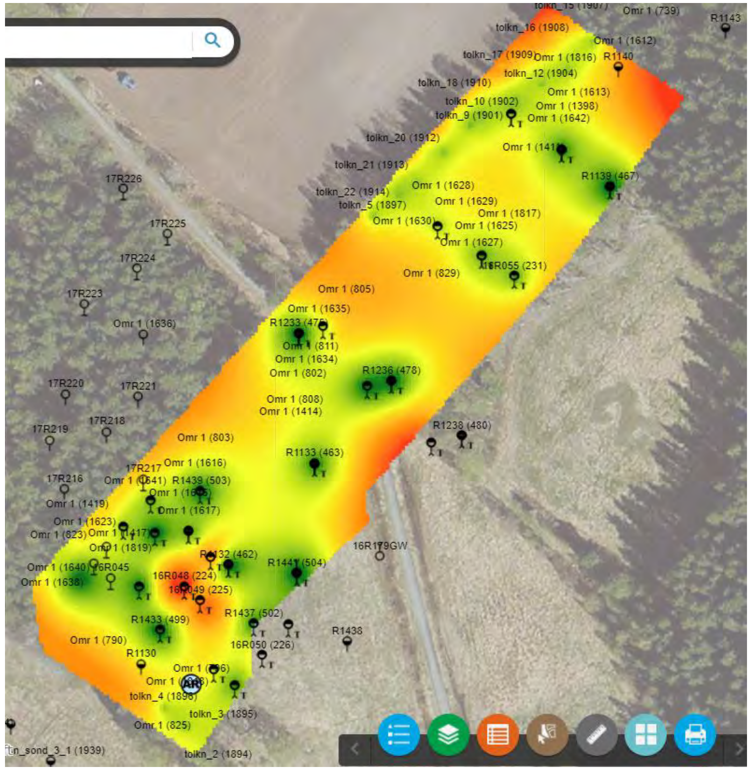
https://tyrens.sharepoint.com/sites/333856-SE-TYR/Shared%20Documents/Geo...

1 of 1



Result


Surveyed true surface
Shallowest model
Most probable model
Deepest model
55,390 m



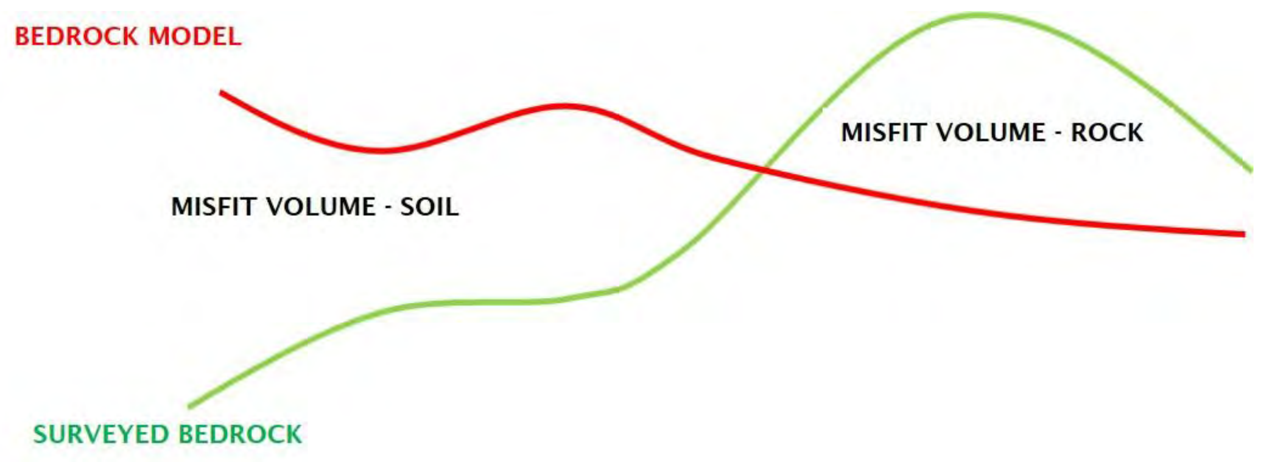
The reality

How good is the model?

5 uncovered bedrock surfaces – the truth

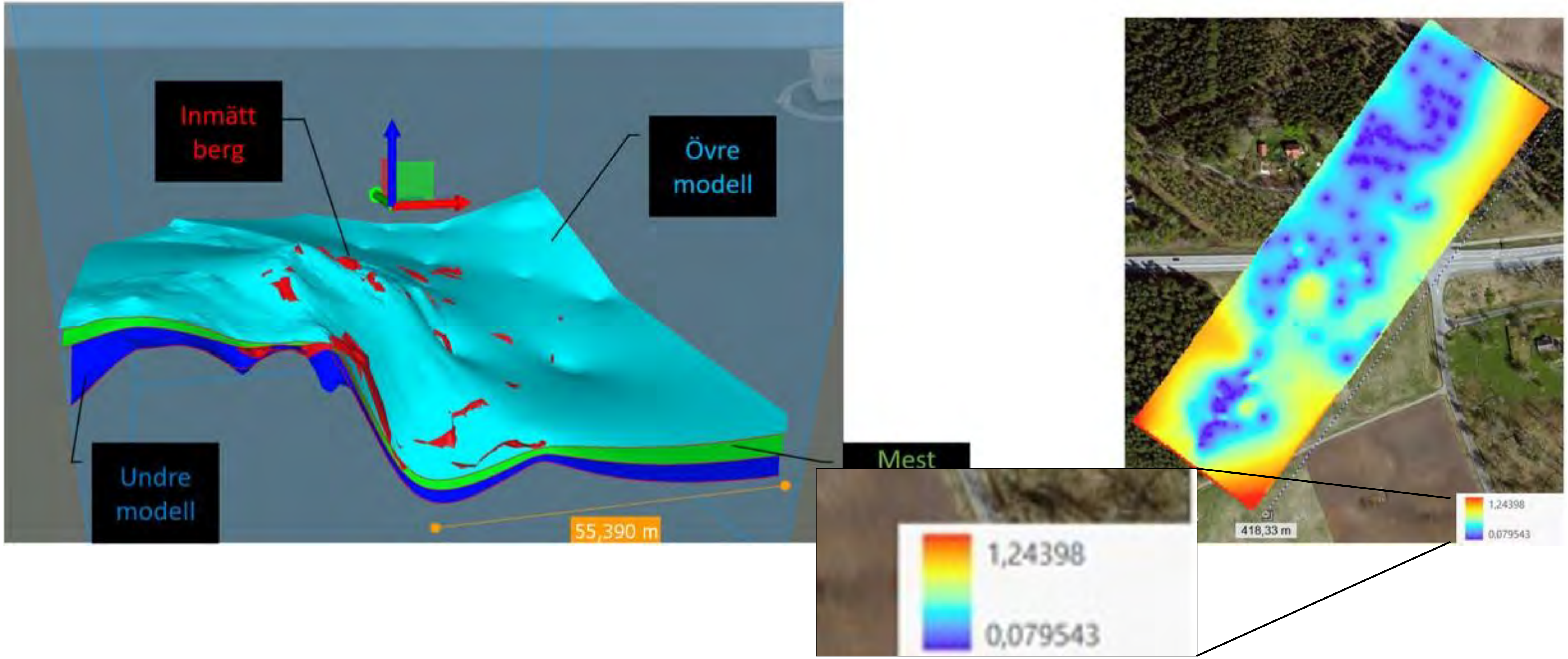
- CASE 1: E20 Bälinge – Vårgårda, Northern area
- CASE 2: E20 Bälinge – Vårgårda, Middle area
- CASE 3: E20 Bälinge – Vårgårda, Southern area
- CASE 4: Varberg railway tunnel, S
- CASE 5: HSE Skellefteå

Misfit - model vs true bedrock

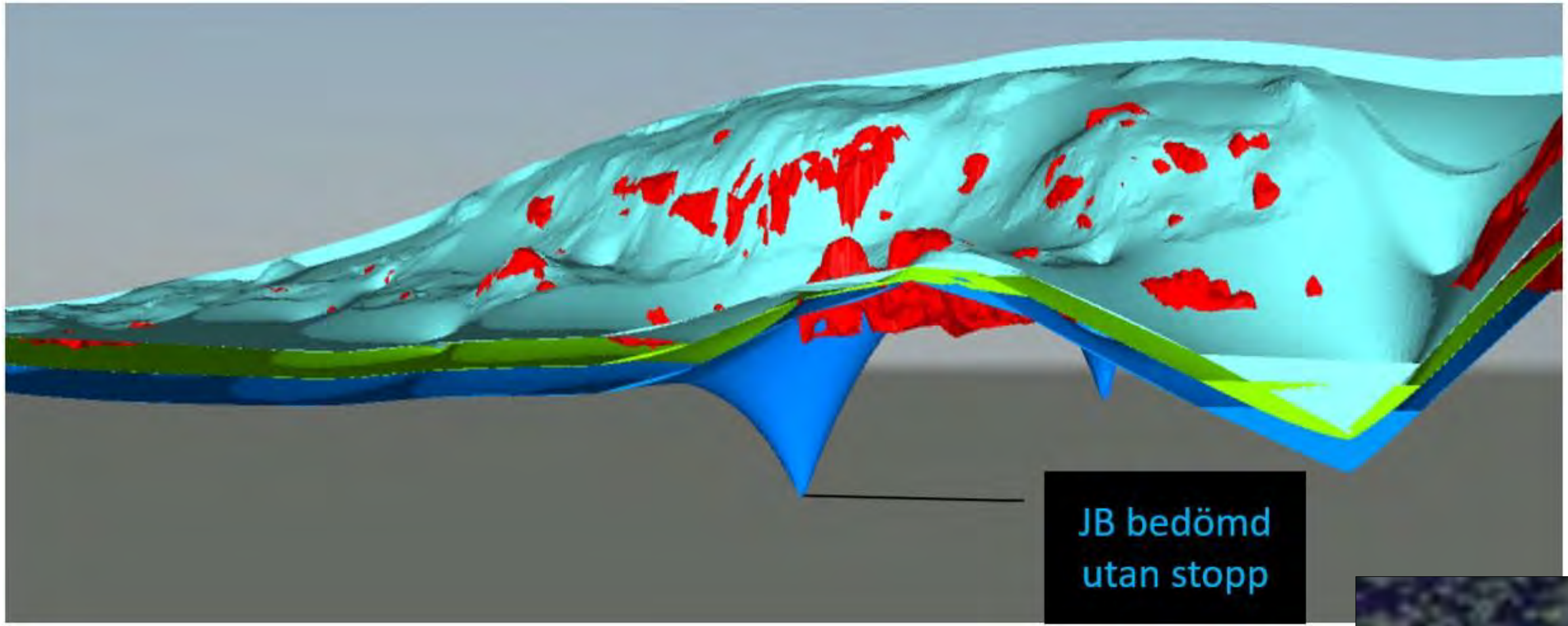


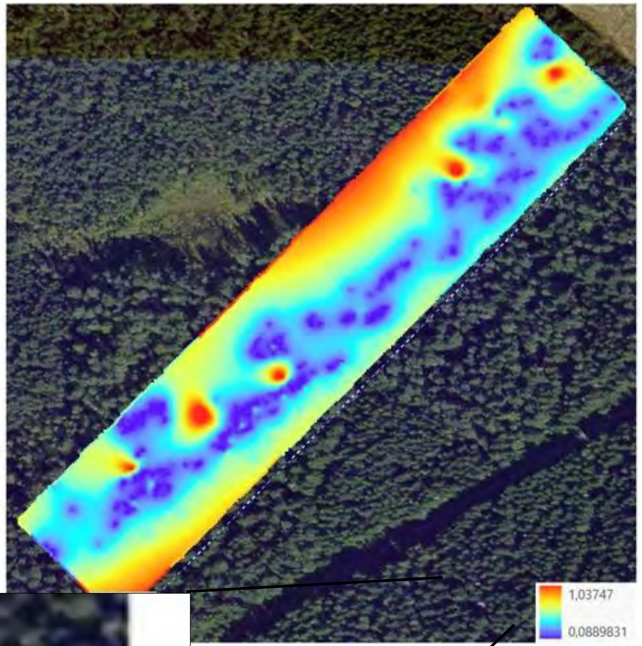
	CASE 1	CASE 2	CASE 3	CASE 4	CASE 5
TOTAL MISFIT (m)	**0.4**	**0.5**	**0.8**	**0.5**	**0.9**
MISFIT – MORE SOIL (m)	0.1	0.1	0.7	0.4	0.5
MISFIT – MORE ROCK (m)	0.3	0.4	0.1	0.1	0.4

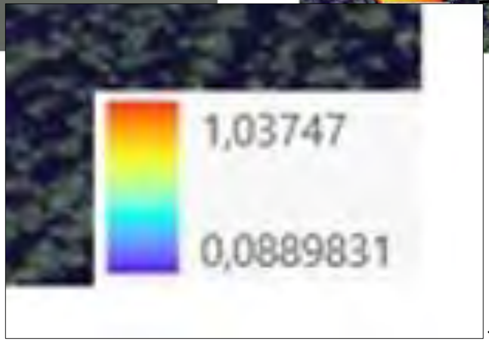
Case 1


Inmätt
berg
Övre
modell
Undre
modell
55,390 m
Mest
1,24398
0,079543
418,33 m
1,24398
0,079543

Case 2





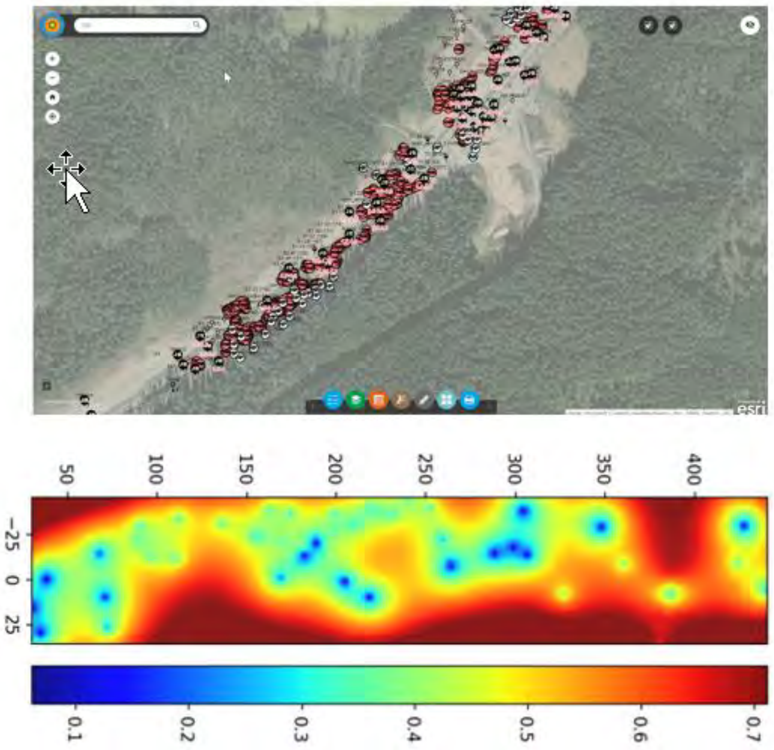


TYRÉNS

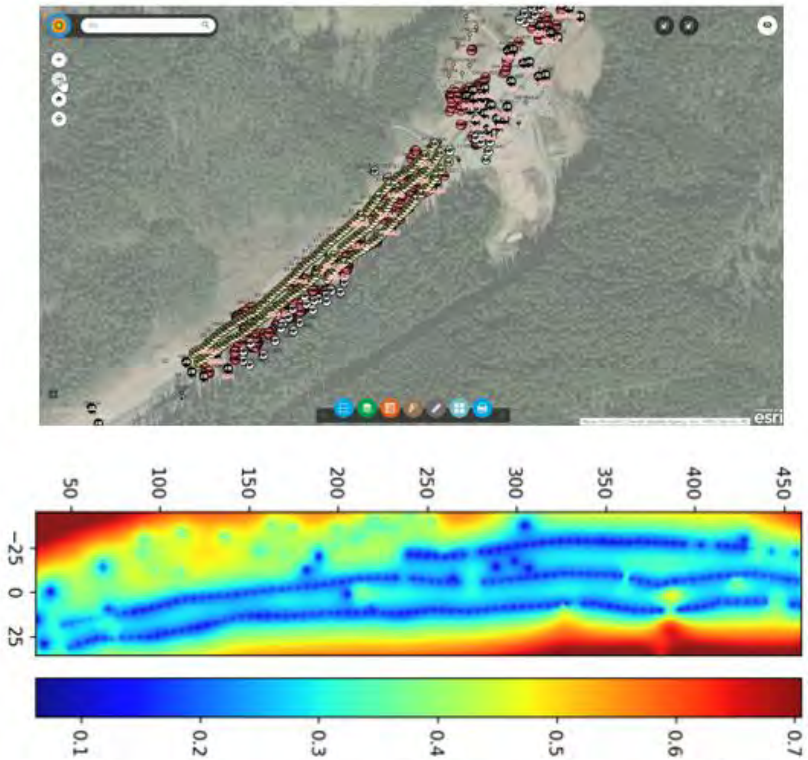
Many boreholes not always a guarantee for a precise model

- Large individual uncertainties overrule large number of boreholes
- Basis for decision of changing method
  - Core drilling

Geophysics adding value



Uncertainty of bedrock level, Standard dev (m).
Based only on **borehole sounding data.**



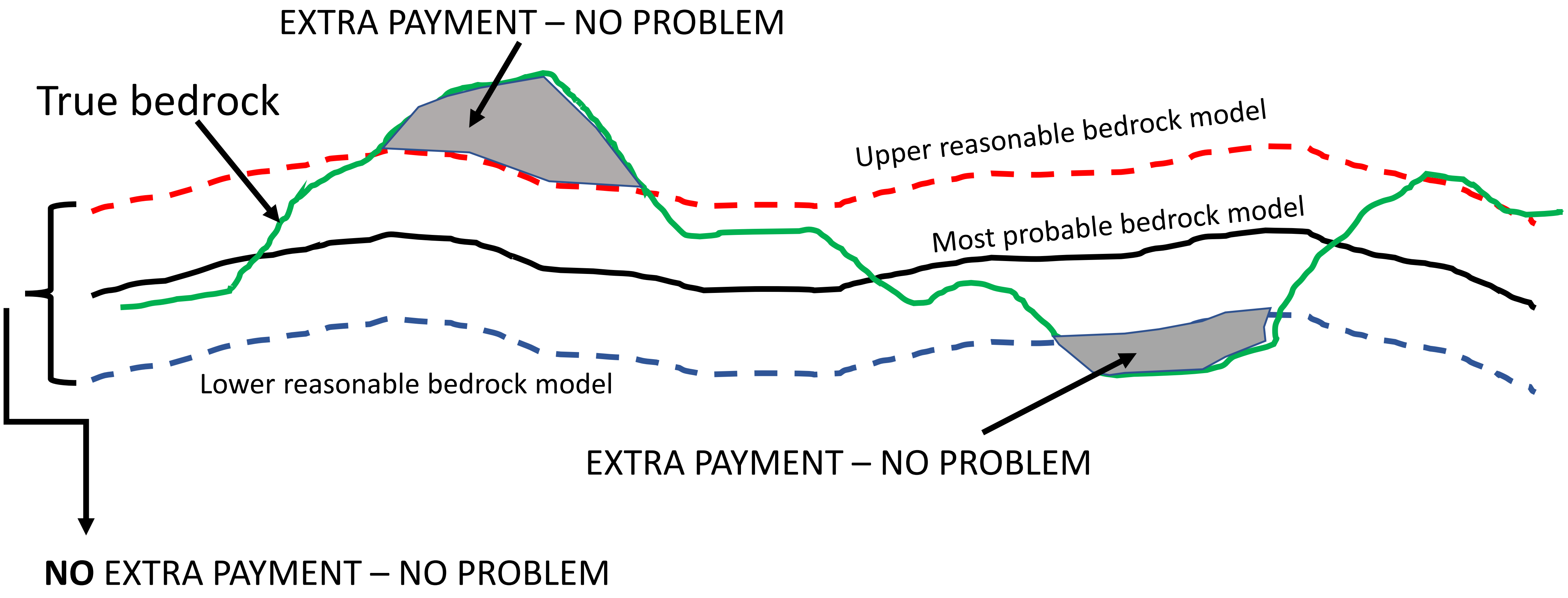
Uncertainty of bedrock level, Standard dev (m).
Based on **borehole sounding data and seismics**.

The value of being certain on the uncertainties

- Optimization of investigation program
  - Always most value for money
- Confidence in team during project
  - You always have control

- Clearer risk sharing in contract between client and contractor
- Less claims

Why less claims?



ITA-AITES World Tunnel Congress, WTC2022 and 47th General Assembly Bella Center, Copenhagen 22-28 April 2022

GeoBIM for handling geological and geotechnical uncertainties in tunnelling

M. Svensson[1] and O. Friberg[2]
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ABSTRACT: In tunnelling, still unforeseen conditions concerning the geological environment is the main reason for claims. Excluding water, the uncertainties are basically of two kinds – geometrical and design values – e.g., rock coverage or rock quality. A new method has been developed for handling the geometrical uncertainties in tunnelling projects. The method is based on the GeoBIM concept for efficient information handling. The total uncertainties of a certain geometrical feature, i.e., a bedrock model, is based on 1) individual uncertainties which are assigned to each data point when it is imported to the database, and 2) the distance to the nearest investigation point. The algorithm is successfully validated with five uncovered and surveyed bedrock surfaces in three infrastructure projects in Sweden.

KEYWORDS: Uncertainties, GeoBIM, Tunnelling

1. BACKGROUND

Still, and often, unforeseen geological and geotechnical conditions are pointed out for causing delays and more costly infrastructure projects, for instance tunnels. A recent example is the road project Bypass Stockholm, Sweden, where rising costs of 10% (300 mill Euro) and 4 years delay was announced in 2019. A limited openness between different stakeholders being reluctant sharing knowledge and data is one of the reasons, often governed by contract issues. A more technical reason is the limited investigation programs. No matter how many boreholes or geophysical profiles that are carried out, there will still be non-investigated volumes along the tunnel, with potential surprising conditions during construction as an effect. Often this is handled by allocating risk money for unforeseen conditions in budgets.

However, a more scientific or more clever way to treat the limited amount of data is to apply uncertainty knowledge and methodology directly on the geological conditions. In a recent R&D project an algorithm and a methodology for producing robust uncertainty maps for bedrock models, based on 1) individual uncertainties assigned to each data point, and 2) the distance to the nearest investigation point, has been developed.

Implementing such an uncertainty tool and methodology already during the investigation phase and continuously update the uncertainty maps during the design phase and the construction phase would allow for both a better communication climate in the project and limit the number of claim issues. As an obvious example the client could include a 3D geological model accompanied by an uncertainty model (with "certain uncertainties)" in a baseline report in the tender document, Ericsson (2019). If so, the known and reliable uncertainties would clarify the risk levels and proper costs could be assigned to those.

2. UNCERTAINTY ALGORITHM

The algorithm that has been developed calculates both a 3D bedrock model and an accompanying uncertainty map. The method is a modification of the GemPy algorithm, Varga (2018). The method for quantifying the uncertainties of the 3D bedrock model (or any geological surface feature) is based on basically two calculation steps:

1) Geostatistical (Kriging) interpolation between point data to a 3D surface (for example a bedrock surface). The geostatistical interpolation also results in a spatial uncertainty value (variance) which is increasing with the distance between the investigation points.

2) Iterative Monte Carlo simulation where all investigation points included in each simulation is randomly varied in a predefined uncertainty interval. In the project 1000 simulations have been used for calculating how the uncertainty in single investigations points are propagating to other parts of the model.

The results from those two steps are then weighted together to a total uncertainty value, expressed as standard deviation (m) in each cell of the model (1 x 1 m) of the interpolated surface, see figure 1.

Figure 1 *Left*: Uncertainty dependent on the distance between boreholes (from Kriging variance). *Center*: Uncertainties dependent on the individual uncertainties in original investigation point data (from simulation). *Right*: Total weighted uncertainty (std dev, m). Note the total high uncertainty in the mid area, although close to a sounding point. This is caused by a high uncertainty of that specific sounding data.

3. METHODOLOGY

3.1 The GeoBIM database concept

A prerequisite for efficiently working with an uncertainty model methodology is to keep good order and careful quality assurance of all data, together with easy access to all subsurface information. In the project the GeoBIM concept was used for this, Svensson et al (2019). The GeoBIM concept is a completely digital system from planning to final delivery of a digital geotechnical model, capable of handling all data formats used in the geotechnically related subsurface disciplines, accessible via a standard web browser, see figure 2. In the field, after quality check of the raw data, the field engineer (or best skilled staff) assigns a quality estimation of the data that is uploaded, see figure 3. This information then always follow the data whatever it is used for.

Svensson M., Friberg O., 2022, GeoBIM for handling geological and geotechnical uncertainties in tunnelling, World Tunnelling Congress, Copenhagen

GeoBIM for handling geological and geotechnical uncertainties in tunnelling - ITA Bookshop

https://library.ita-aites.org/wtc/2229-geobim-for-handling-geological-and-geotechnical-uncertainties-in-tunnelling.html

Thanks to project funders

TYRÉNS

BG Branschsamverkan i Grunden

BeFo
STIFTELSEN BERGTEKNISK FORSKNING
ROCK ENGINEERING RESEARCH FOUNDATION

SBUF®
SVENSKA BYGGBRANSCHENS UTVECKLINGSFOND
The development fund of the Swedish construction industry

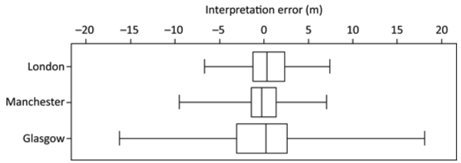
TIM KEARSEY

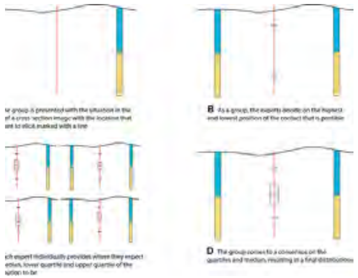
Communicating model uncertainty to stakeholders - practical examples and lessons learnt

British Geological Survey

There are many ways to calculate uncertainty of geological models

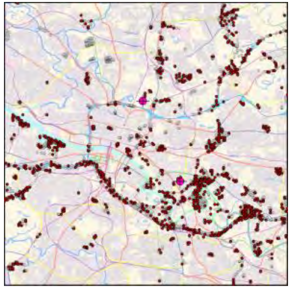
Qualitative - based on expert judgement

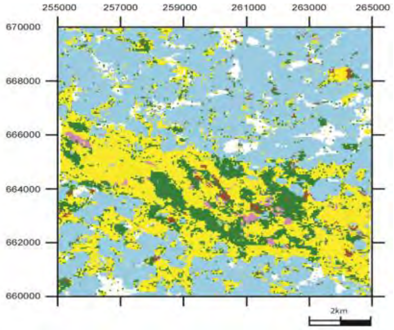




Charles H. Randle, Clare E. Bond, R. Murray Lark, Alison A. Monaghan; Can uncertainty in geological cross-section interpretations be quantified and predicted?. *Geosphere* 2018;; 14 (3): 1087–1100.
doi: https://doi.org/10.1130/GES01510.1

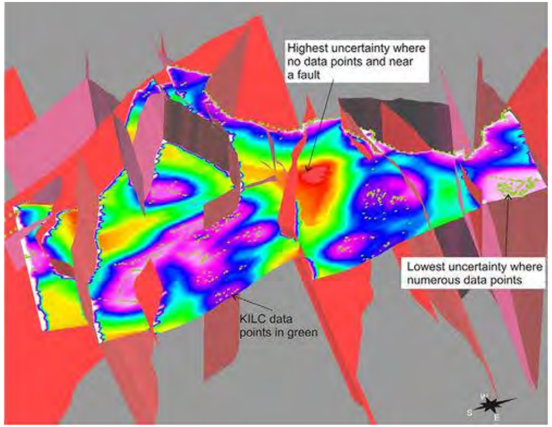
Bootstrap Excluding 50% of the input boreholes and, re-running the model and test the model against excluded data



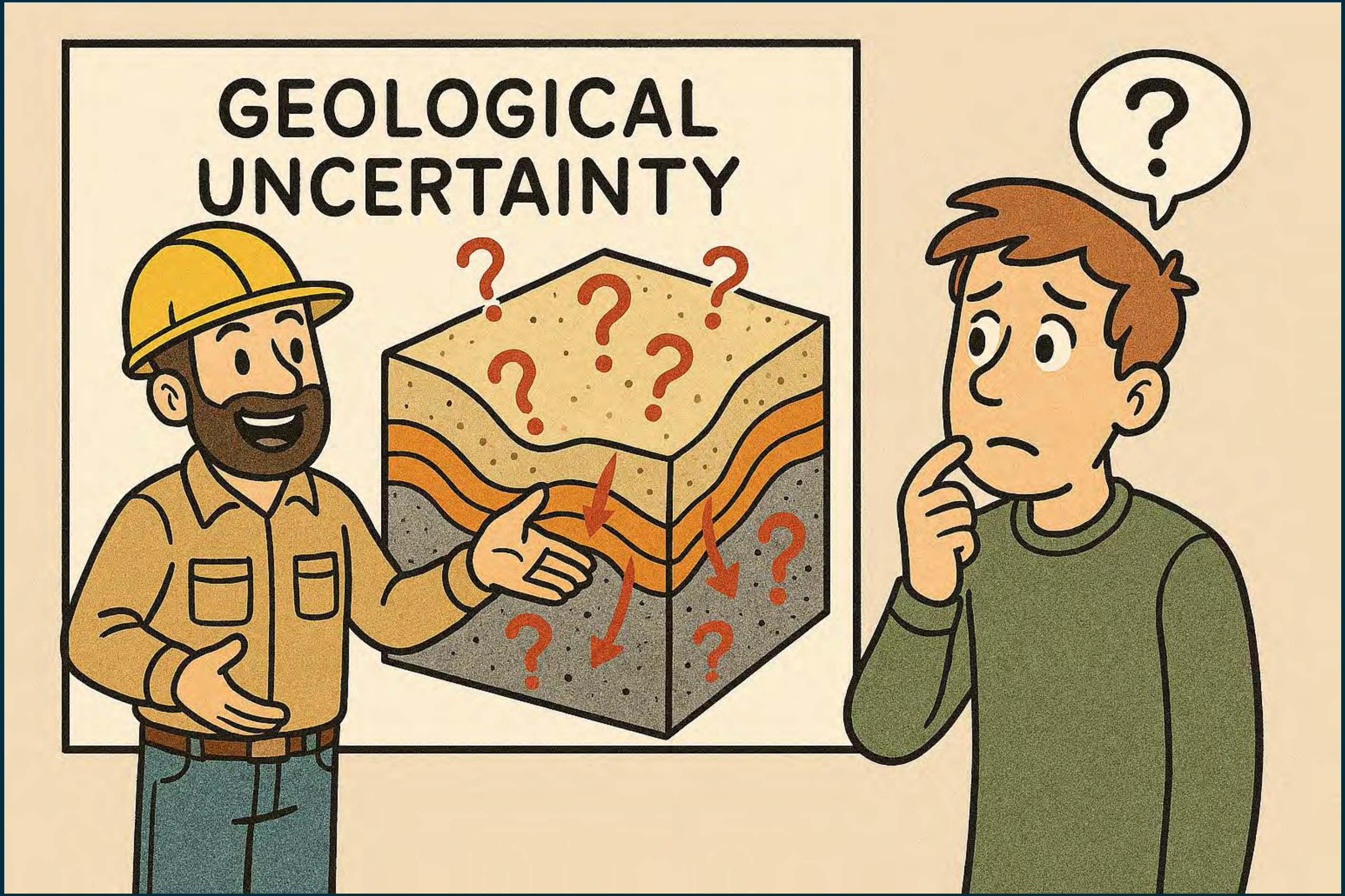


Kearsey, Timothy; Williams, John; Finlayson, Andrew; Williamson, Paul; Dobbs, Marcus; Marchant, Benjamin; Kingdon, Andrew ; Campbell, Diarmad. 2015 Testing the application and limitation of stochastic simulations to predict the lithology of glacial and fluvial deposits in Central Glasgow, UK. *Engineering Geology*, 187. 98 - 112. 10.1016/j.enggeo.2014.12.017

Information Entropy or similar which factor complexity against data density



Lelliott, M.R., Cave, M.R. and Wealthall, G.P., 2009. A structured approach to the measurement of uncertainty in 3D geological models.

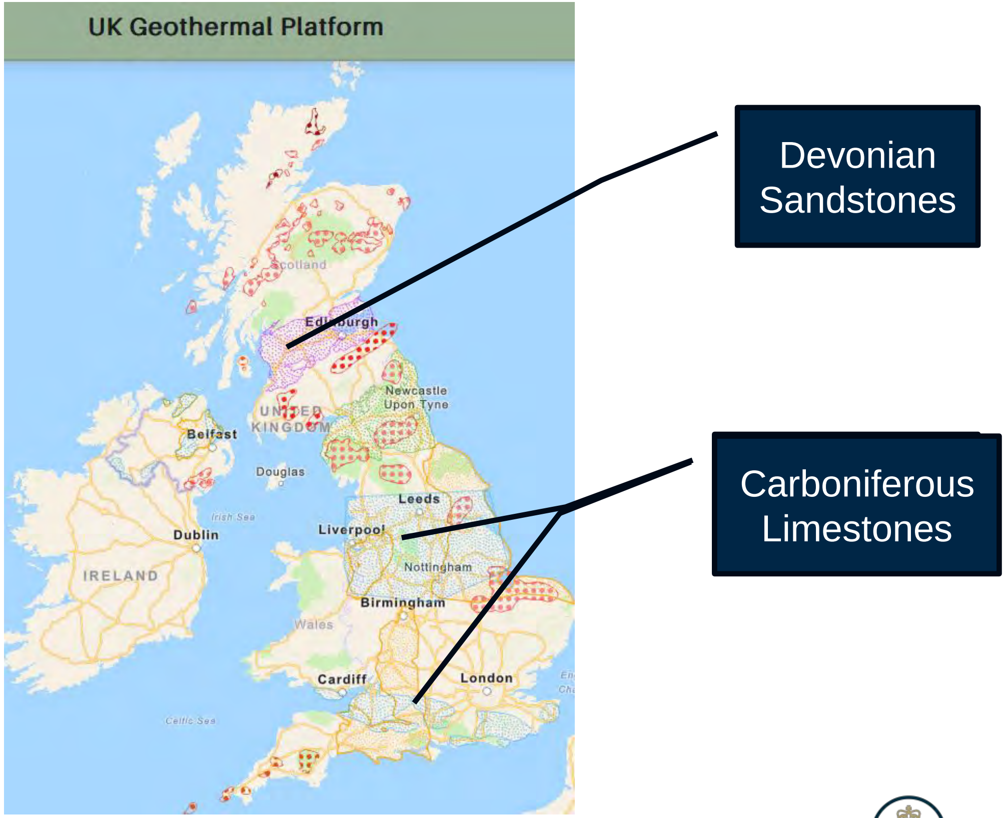

GEOLOGICAL UNCERTAINTY
?

Deep Geothermal

The question

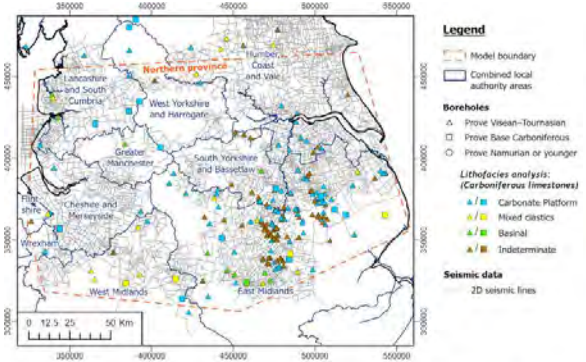
- What is the deep geothermal resource for sedimentary basins in the UK at 4-6km depth

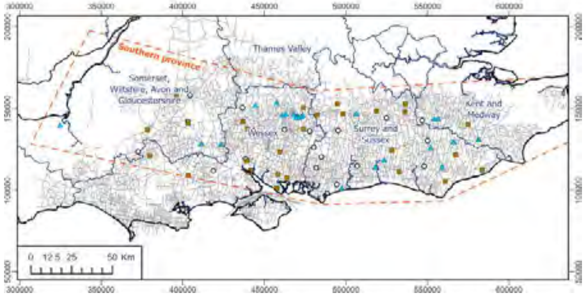
- Targets:
  - Lower Carboniferous Limestones (England)
  - Devonian Sandstones (Scotland)

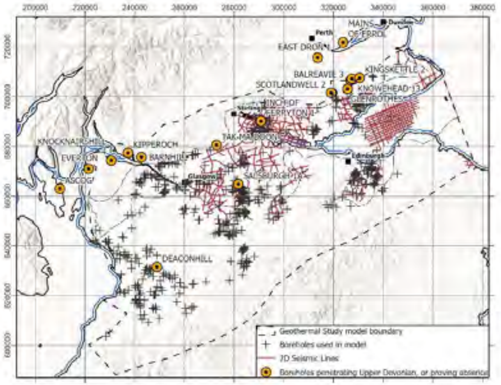


Challenge

- Lack of wells and seismic data
- Only a few wells hit the top of the target and fewer prove its thickness
- Seismic was focused on shallower strata so we had variable quality pick for the target

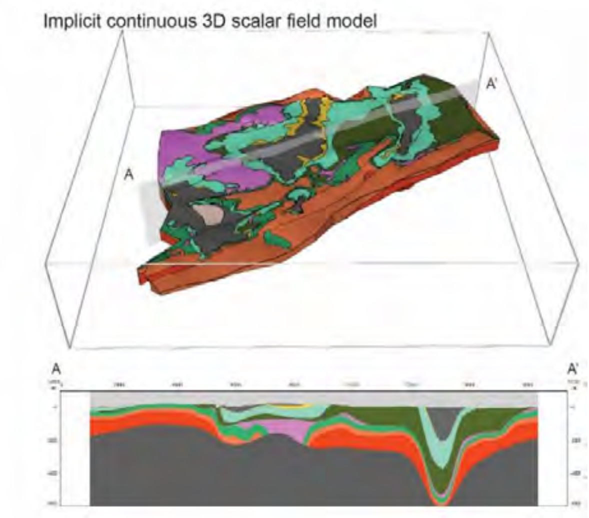


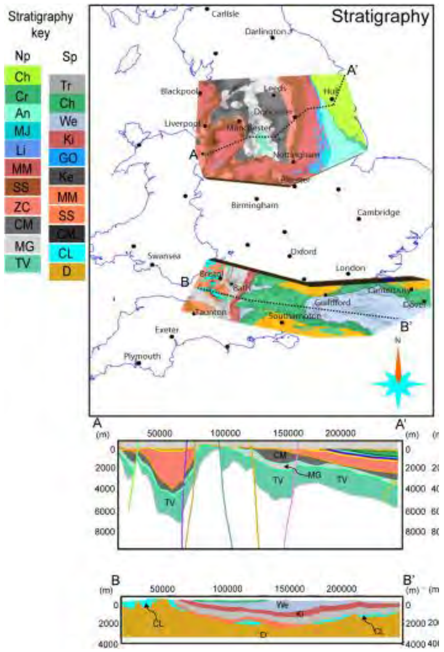




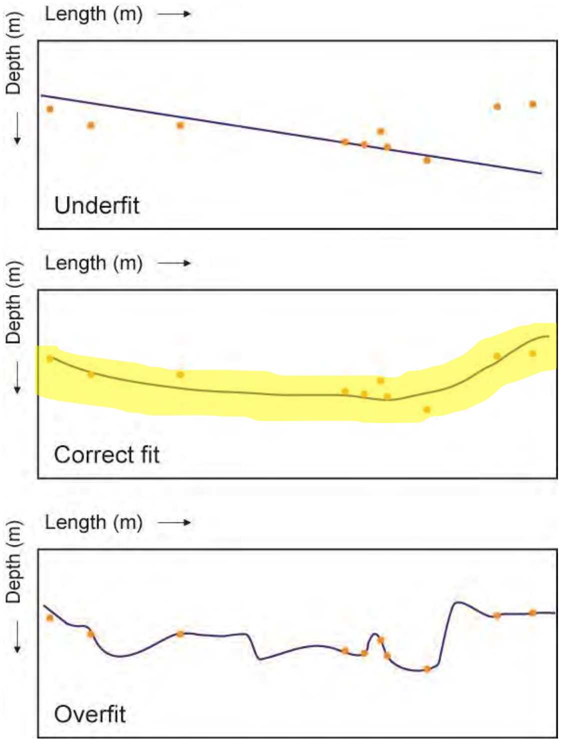
The models

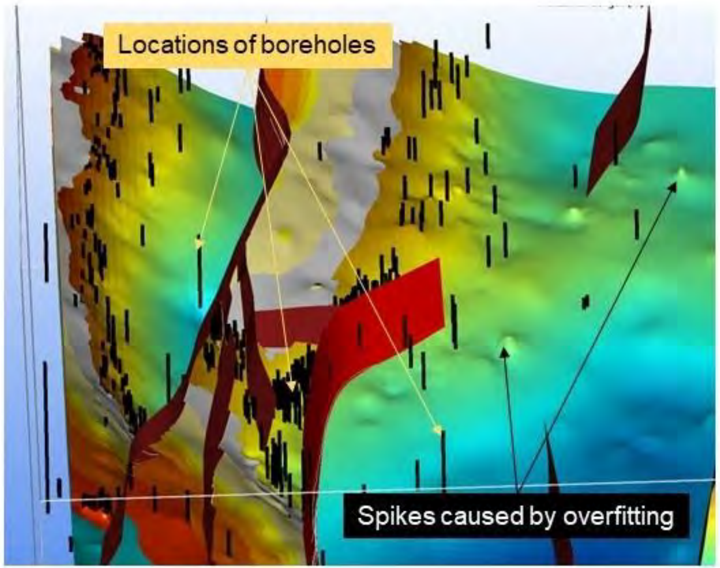
- Models were created using AspenSKUA / SKUA GOCAD
- Both built using the implicit workflows
- These use a lot of data in from the strata above to constrain the target strata





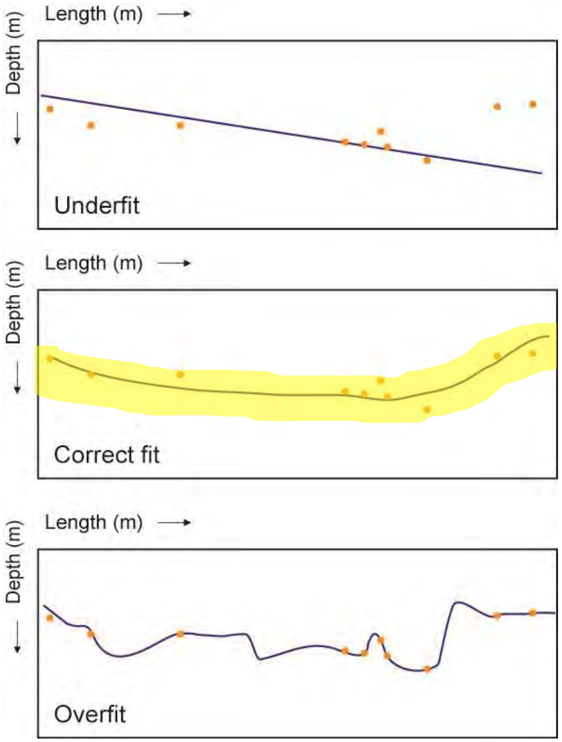
Using well miss match





https://www.linkedin.com/pulse/can-making-3d-geological-models-match-observations-actually-kearsey/?trackingId=SClg6QuIRQOceauxIyTjgQ%3D%3D

Using well miss match

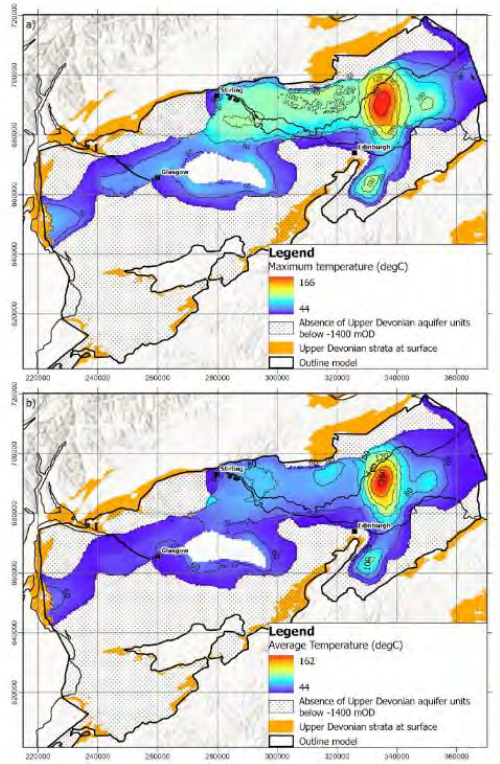


Combined local authority (England and Wales)	Depth range to ECI (m)	Uncertainty on depth (m) (n=number of wells)	Thickness range(m)	Estimated Temperature Range (°C)	HIP P50 (PJ)*	Tentative Heat rec P50 (kW) [kW/km^2]	Mean Domestic Annual Heat demand (kW/km2)
East Midlands	400–4200	44 ± (n = 144)	0–2200	10–140	355,000	36,995,000 [5919,000]	1245,000
Humber, Coast and Vale	1000–4600	47 ± (n = 13)	0–1900	40–140	193,000	20,078,000 [3212,000]	689,000

Jones, D.J.R.; Randles, T.; Kearsey, T.; Pharaoh, T.C.; Newell, A.. 2023 Deep geothermal resource assessment of early carboniferous limestones for Central and Southern Great Britain. *Geothermics*, 109, 102649. https://doi.org/10.1016/j.geothermics.2023.102649

Integration with thermal modelling

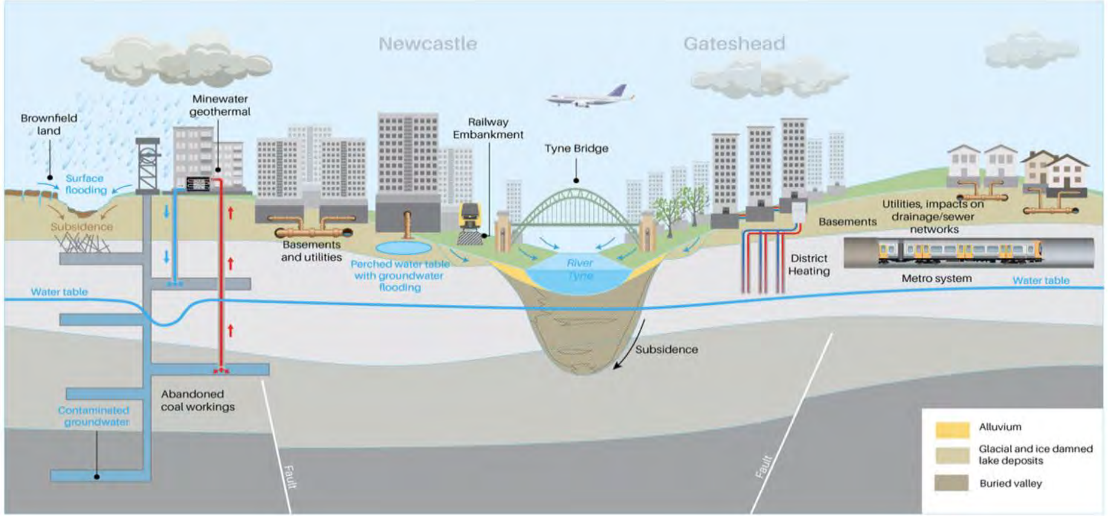
- We could integrate the +/- depth values with heat in place modelling
- Which meant that we had better control over all the inputs into the heat resource model
- It also meant that we could communicate the drill depth uncertainty in units that potential drillers could understand



Groundwater flooding

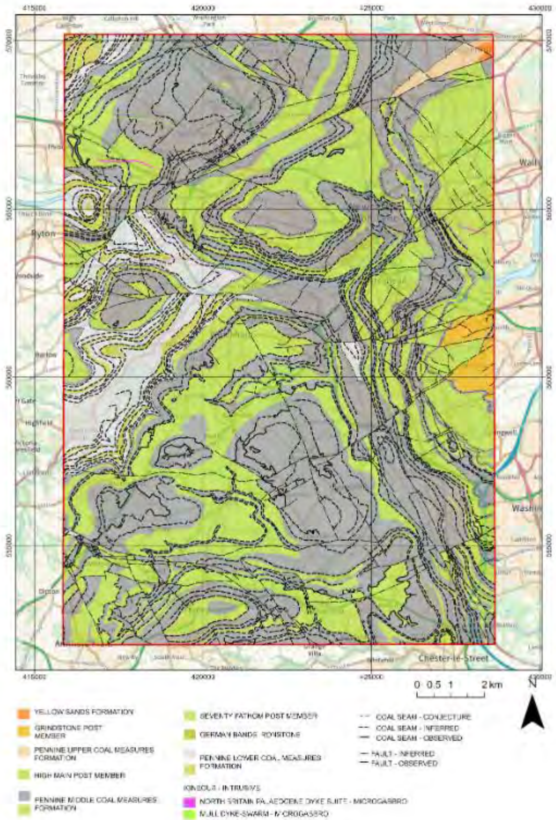
The question

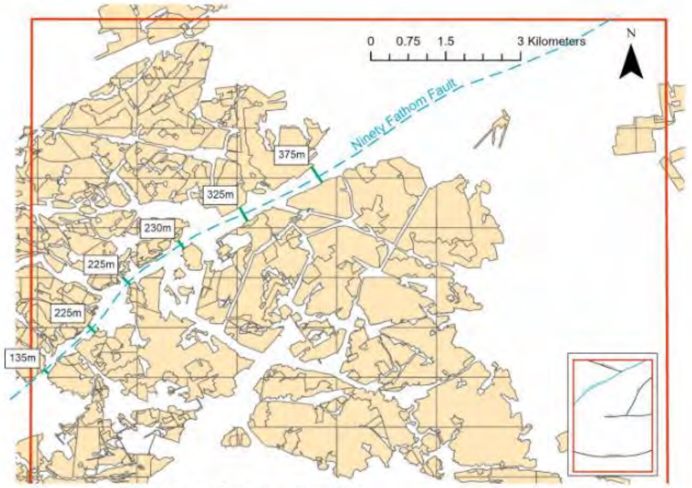
- Underlain by Carboniferous Coal Measures
- Legacy of underground mine workings
- Local issues with groundwater flooding
- Interest in mine water for heating systems
- Complex superficial deposits
- Inconsistencies in BGS geology maps of the area



The data

- Model 20km x 15km
- 173 boreholes
- 3D mine plan data from 7 underground coal seams

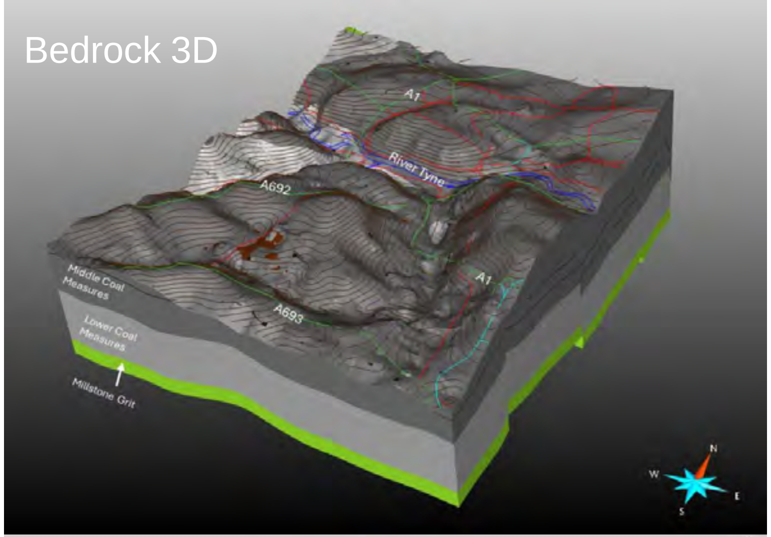


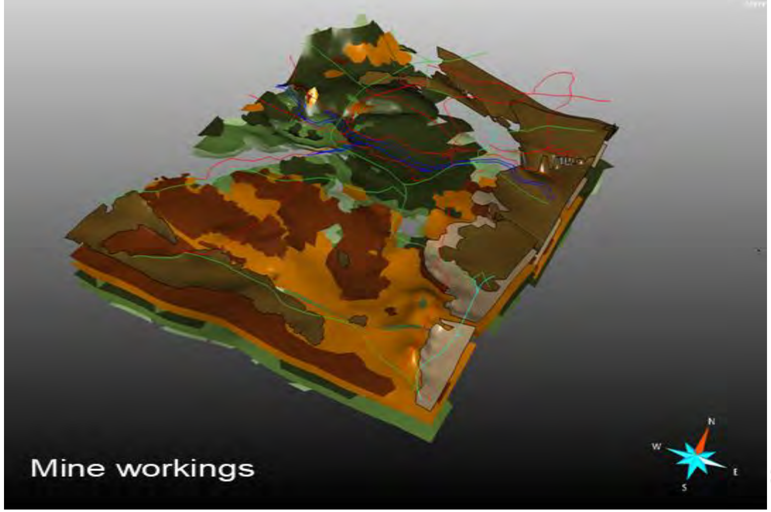


Brockwell underground workings

Bedrock and coal mining

- Models were created using AspenSKUA / SKUA GOCAD
- Built using the implicit workflows modelling
- To feed in to groundwater flooding hazard mapping





Kearsey, T.; Arkley, S.; Callaghan, E.; Murphy, B.; Reeves, T.; Terrington, R.. 2025 *3D geological model report of the bedrock geology underlying the Gateshead area - Project Groundwater Northumbria.* Nottingham, UK, British Geological Survey, 44pp. (Project Groundwater Northumbria series, CR/24/123N)

Communicating uncertainty

- The model was to feed into groundwater flooding risk maps
- These use rules such as distance from surface to highlight areas of risk of flooding
- By using well mismatch as to provide an estimate of vertical error the hydrogeologists could adapt their rules so the uncertainty was taken into account

https://britain.iah.org/files/2025/08/Slides-Ineson-2024.pdf

Summary

- Most stakeholders want to know uncertainty but want it in terms of -/+
- Not fitting your model exactly to markers and then using the miss match provides a good estimate of vertical error
- It can be easily integrated in to other applications

THANK YOU

Any questions?

Real world case studies

- Deep geothermal resources (Carboniferous limestone and Devonian Sandstones)
  - Jones, D.J.R.; Randles, T.; Kearsey, T.; Pharaoh, T.C.; Newell, A.. 2023 Deep geothermal resource assessment of early carboniferous limestones for Central and Southern Great Britain. *Geothermics*, 109, 102649. 10.1016/j.geothermics.2023.102649
  - Kearsey, T.I.; Receveur, M.; Monaghan, A.A.. 2024 *Modelled hot sedimentary aquifer geothermal potential of Upper Devonian strata in the Midland Valley of Scotland.* Nottingham, UK, British Geological Survey, 43pp. (OR/24/030)

- Groundwater flooding associated with abandoned coal mines
  - Kearsey, T.; Arkley, S.; Callaghan, E.; Murphy, B.; Reeves, T.; Terrington, R.. 2025 *3D geological model report of the bedrock geology underlying the Gateshead area - Project Groundwater Northumbria.* Nottingham, UK, British Geological Survey, 44pp. (Project Groundwater Northumbria series, CR/24/123N)

Uncertainty calculation of explicit 3D geological models in geologically complex regions and its incorporation into BIM exports of the models for further exploration and design works

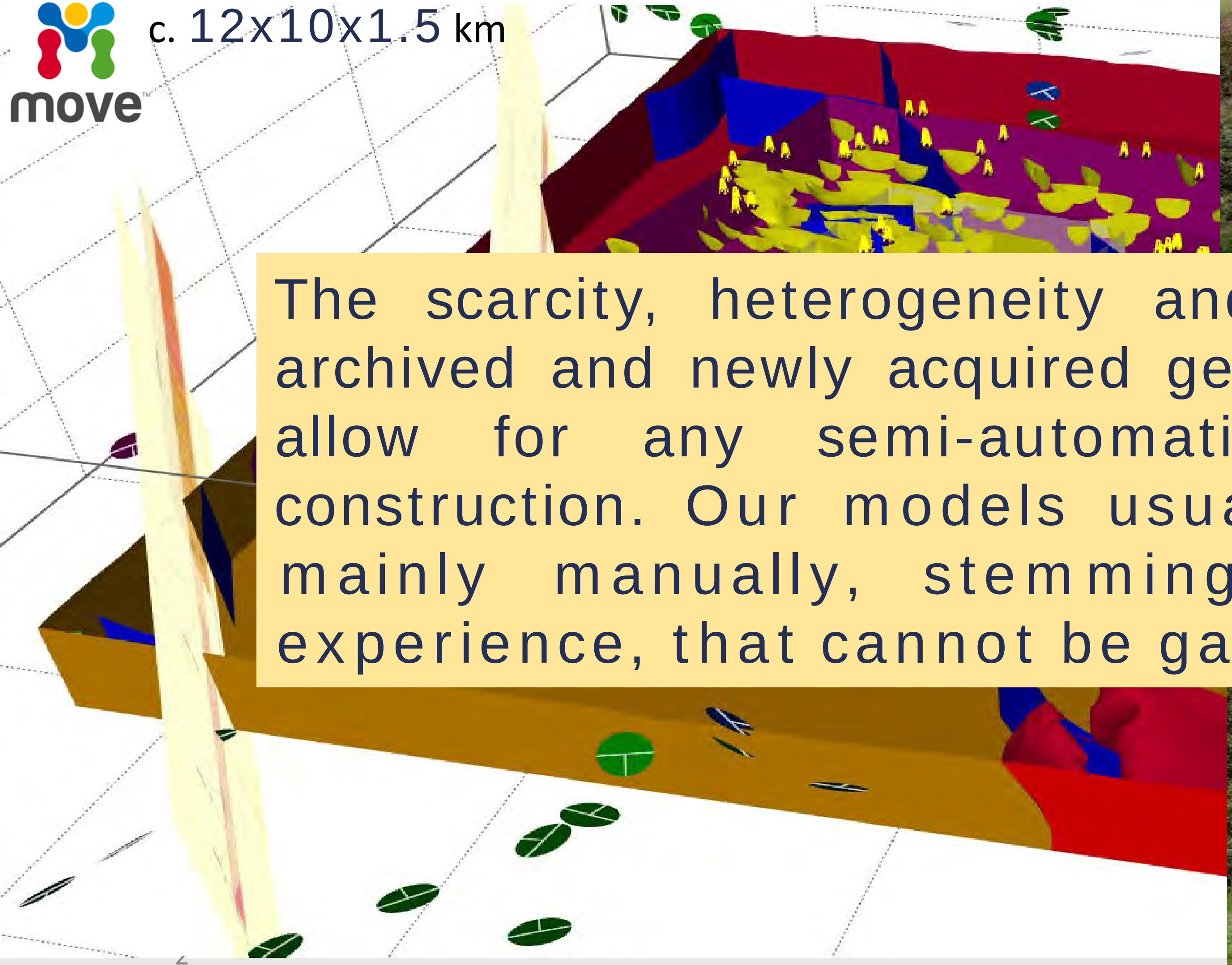
Jan Franěk [(1)], František Staněk [(1)], Zdeněk Rudovský [(2)], Jan Jelínek [(1)]

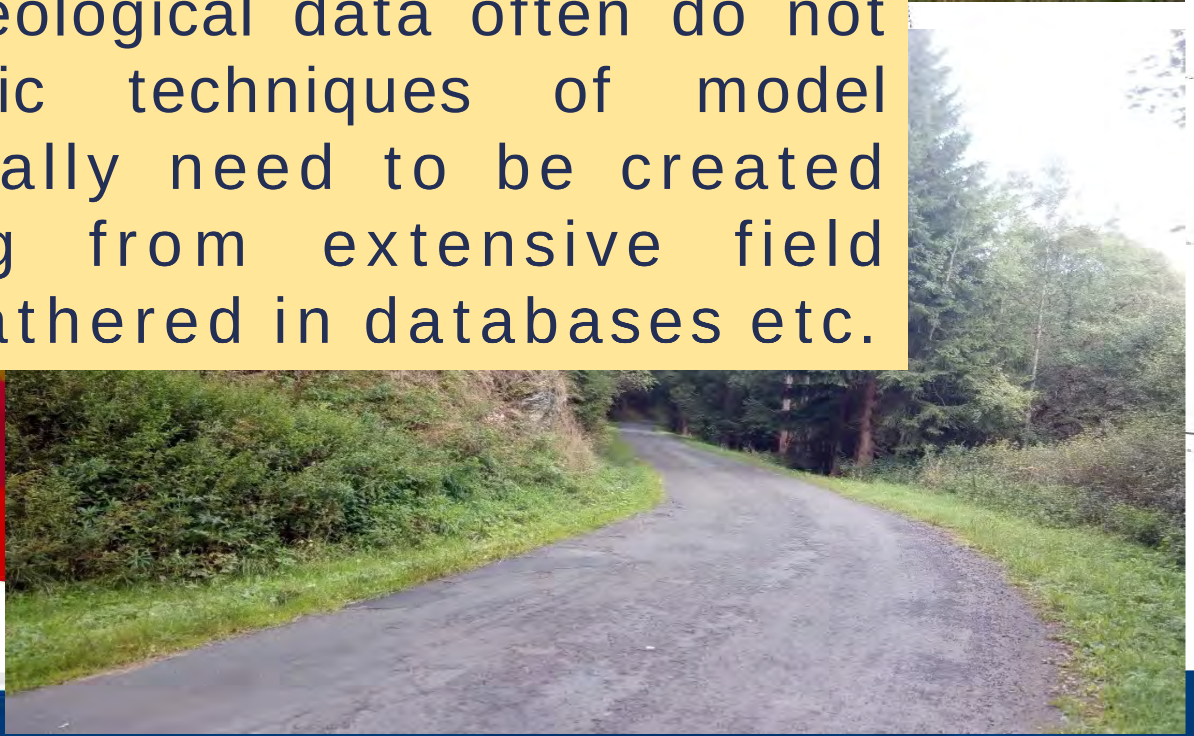
(1) - Czech Geological Survey
(2) - Czech Technical University in Prague

Model uncertainties at the CGS

Geological models mainly for large constructions

c. 12x10x1.5 km





The scarcity, heterogeneity and complexity of available archived and newly acquired geological data often do not allow for any semi-automatic techniques of model construction. Our models usually need to be created mainly manually, stemming from extensive field experience, that cannot be gathered in databases etc.

BIM – interdisciplinary tool

- **BIM IFC exports** – to combine geol. models with construction planning of tunnels or large buildings and to deliver the rock environment comfortably to engineers and architects, possibly populated with geotechnical parameters

Geological native 3D model

Integration of geological bodies, surfaces and primary data into the designer's software in accordance with ISO and other conventions respected by non-geologists

Universally understandable 3D construction site model in the IFC open data format

Geological models into BIM

2 types of objects are derived from the geological model and exported into IFC file format:

- **Voxels** – e.g. 10 x 10 x 1 m in size, allowing to capture detailed variations in various geological and geotechnical parameters but simplifying geometries.

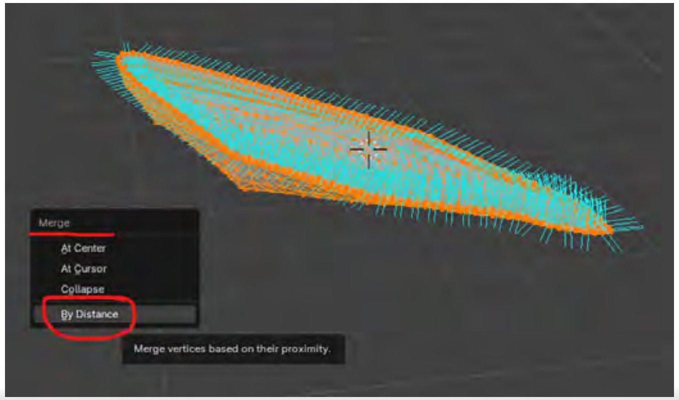
  Exported via home-made VBA script using MS Excel sheet as input data describing individual voxels

- **Quasi-homogeneous volumes plus unclosed meshes** – preserving almost precisely original geometries from native geological model, but keeping only very generalized parameters of individual rock / soil volumes

  Meshes from MOVE sw. are first manually corrected in Blender sw. and then exported into IFC format using Blender BIM addon

Each exported object bears graphical and non-graphical information, which is later extended by geotechnical parameters of the modelled rocks and soils

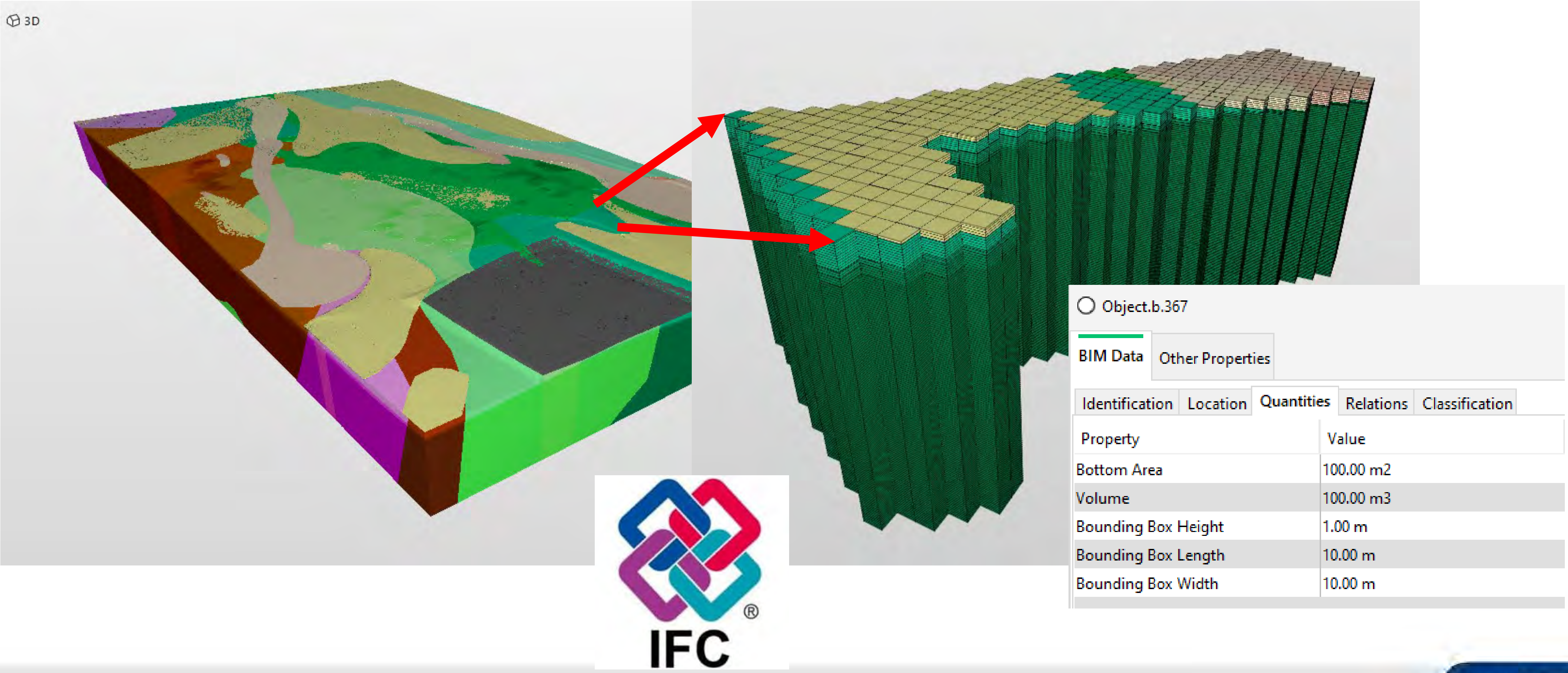
ISO 16739:2018



BIM models – 2 types of geological volumes

X0 quasihomogeneous units (objects), c. 2x1 km

> 2 mil. voxels (objects), e.g. 10x10x1 m each



BIM model as integrated database

Identification	Location	Issues	Quantities	Material

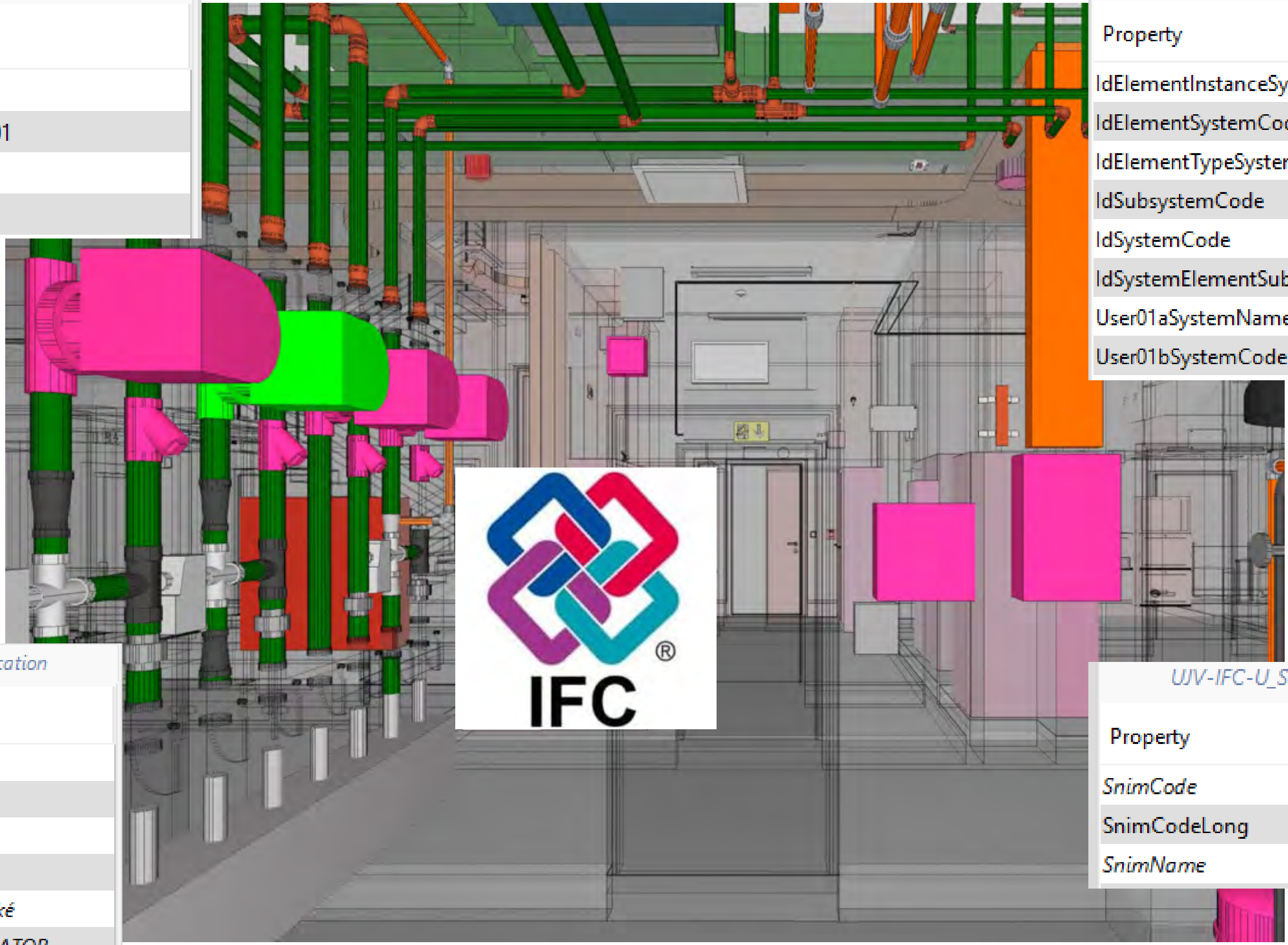
Property	Value
Site	EDUII site
Building	D09.ZWA01
Floor	1NP
Federated Floor	(ASR) 1NP

Location

UJV-IFC-U_System-Subsystem

Property	Value
IdElementInstanceSystemC...	2
IdElementSystemCode	001acw.1.2
IdElementTypeSystemCode	001acw.1
IdSubsystemCode	1-02t-XX-XX
IdSystemCode	SY23.1-003hhwx
IdSystemElementSubsyste...	SY23.1-003hhwx-001acw.1....
User01aSystemName	Vytápění : Vytápění teplovo...
User01bSystemCode	SY23.1

System



UJV-056-Pump-IFC-U_TechnicalSpecification

Property	Value
CS_SCHEDULEID	1,028,800
CS_SCHEDULETYPEID	1,028,738
Typ média (i)	Topná voda
Typ napojení	*závit*
Typ ovládání	*ruční/automatické*
UJV_FilterIfcCategory	*IfcPump.CIRCULATOR*

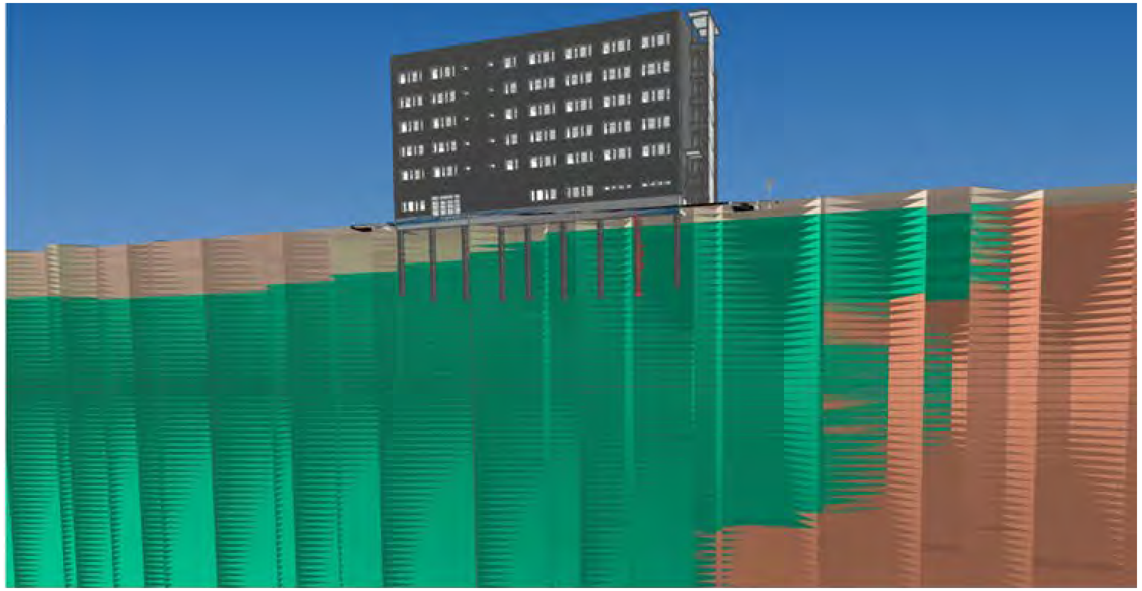
Specification

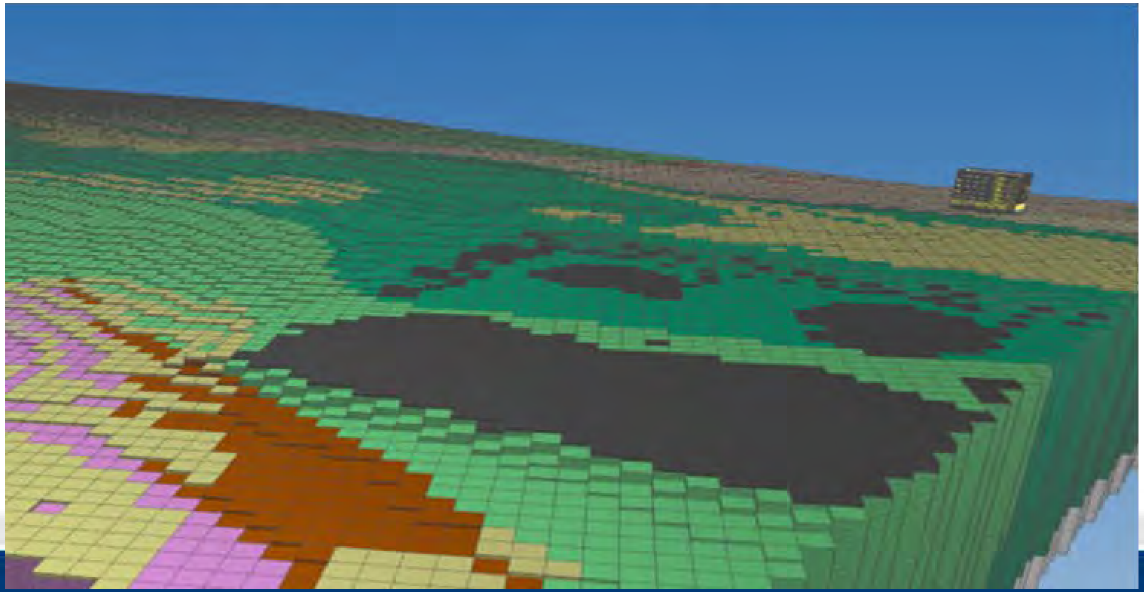
UJV-IFC-U_SNIM-Classification-Identification

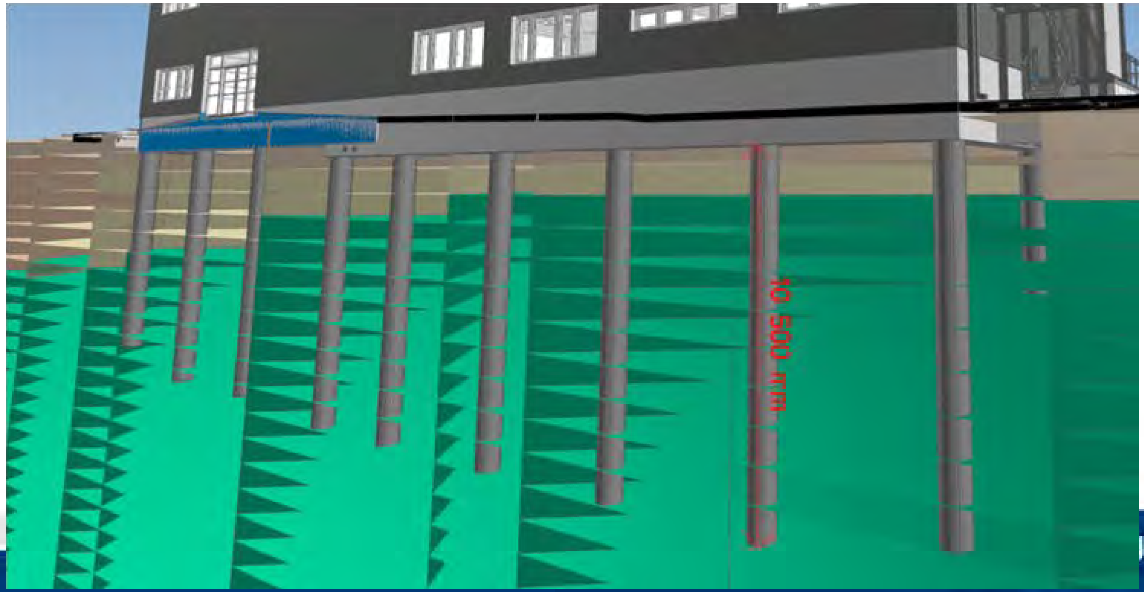
Property	Value
SnimCode	*COa00*
SnimCodeLong	COa00.0001.2
SnimName	*Čerpadlo : čerpadlo cirkulač...*

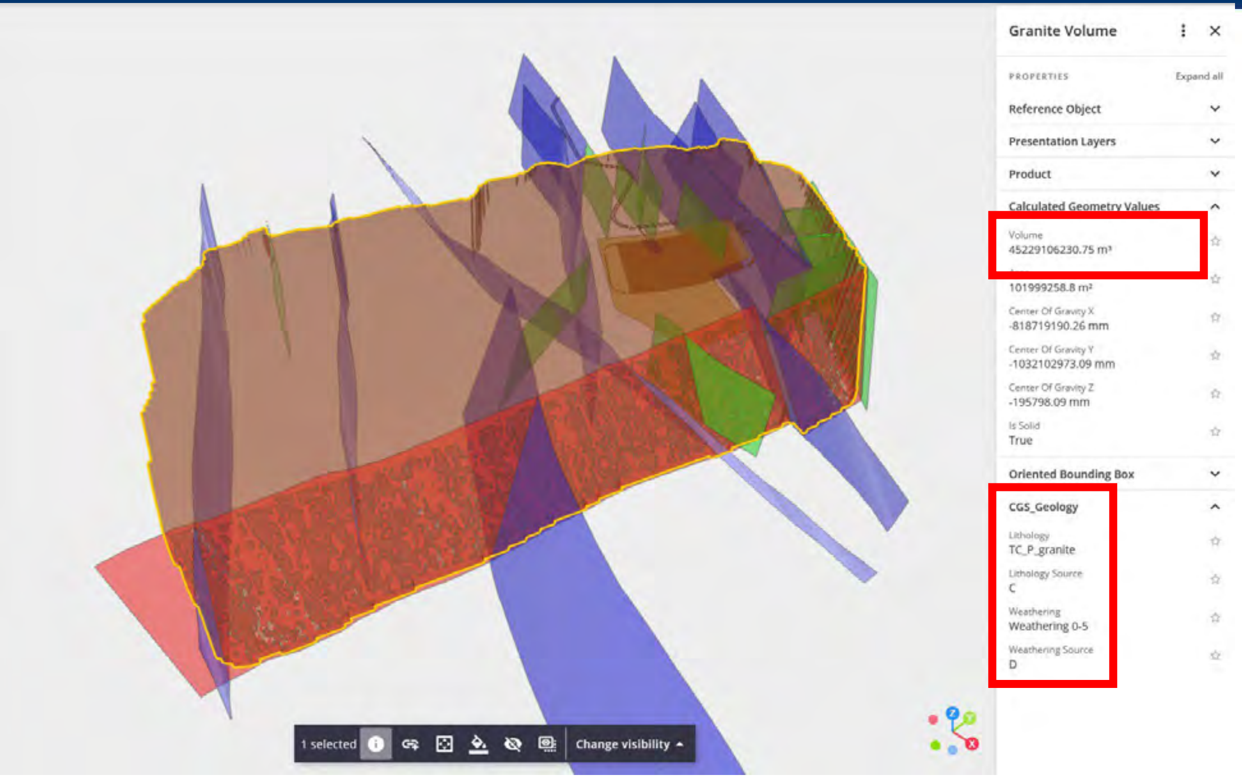
Classification

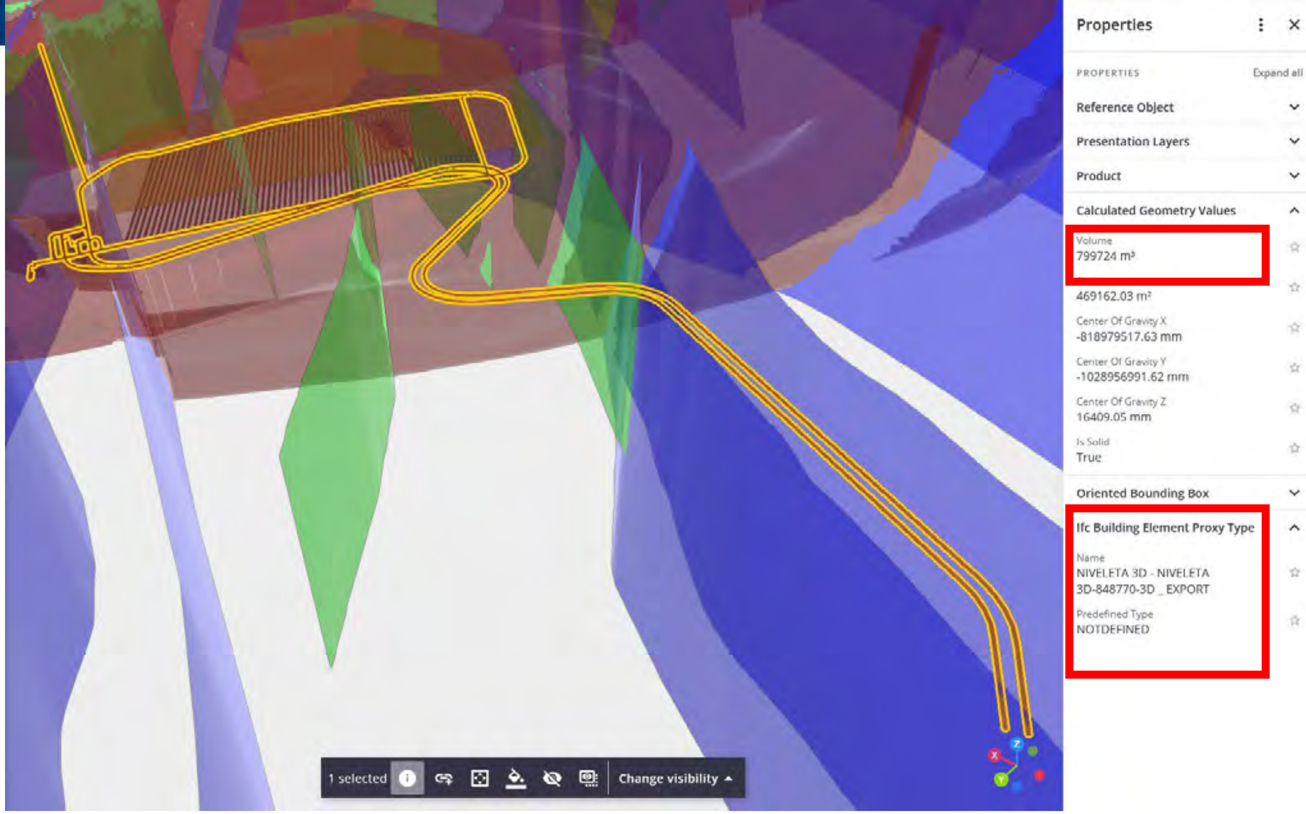
Federated model of a construction site








Granite Volume
PROPERTIES
Expand all
Reference Object
Presentation Layers
Product
Calculated Geometry Values
Volume
45229106230.75 m³
101999258.8 m²
Center Of Gravity X
-818719190.26 mm
Center Of Gravity Y
-1032102973.09 mm
Center Of Gravity Z
-195798.09 mm
Is Solid
True
Oriented Bounding Box
CGS_Geology
Lithology
TC_P_granite
Lithology Source
C
Weathering
Weathering 0-5
Weathering Source
D
1 selected
Change visibility


Properties
PROPERTIES
Expand all
Reference Object
Presentation Layers
Product
Calculated Geometry Values
Volume
799724 m³
469162.03 m²
Center Of Gravity X
-818979517.63 mm
Center Of Gravity Y
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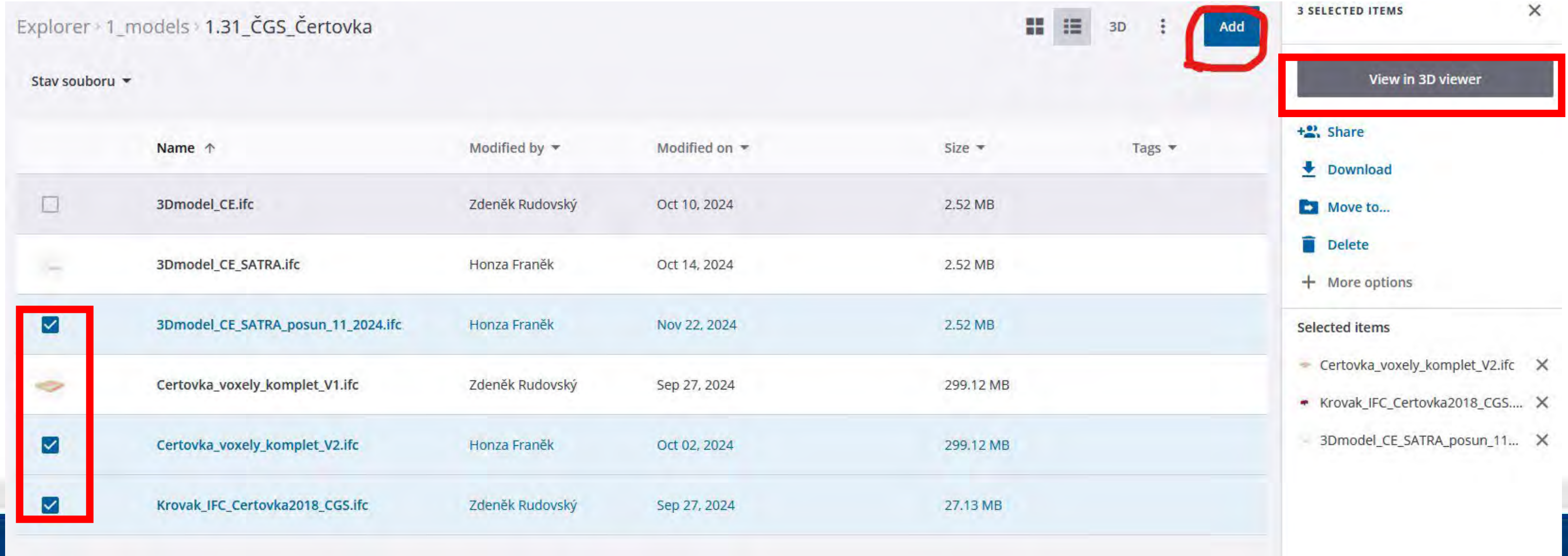
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3Dmodel_CE_SATRA_posun_11_2024.ifc Honza Franěk Nov 22, 2024 2.52 MB
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Certovka_voxely_komplet_V2.ifc Honza Franěk Oct 02, 2024 299.12 MB
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3 ways of delivering uncertainties of a single geological model

Uncertainty of a geological model was incorporated into the federated BIM project as:

1. **Voxelized calculated uncertainty** across the modelled volume, in our case according to Staněk et al. (2025) – ***as scalar property of each voxel***

2. **Classified expert estimate** of uncertainty of individual meshed volumes – quasihimigeneous blocks – ***as text property of each watertight mesh***

3. Incorporation of **source spatial geoscientific data** to allow for visual assessment of uncertainty and also for any later check of model reliability according to source data – ***as 3D objects containing links to archives / PDFs etc.***

(1) and (2) serve for active user work with the federated model – for filtering and visualization of individual BIM model objects

1. Uncertainty is calculated according to Staněk et al. (2025)

Staněk, F., Franěk, J., Jelínek, J., Žáček, V. (2025): **Estimating relative uncertainty of geological 3D models with low density of input data in geologically complex regions.** Earth Science Informatics. ISSN 1865-0473. http://doi.org/10.1007/s12145-025-01778-0

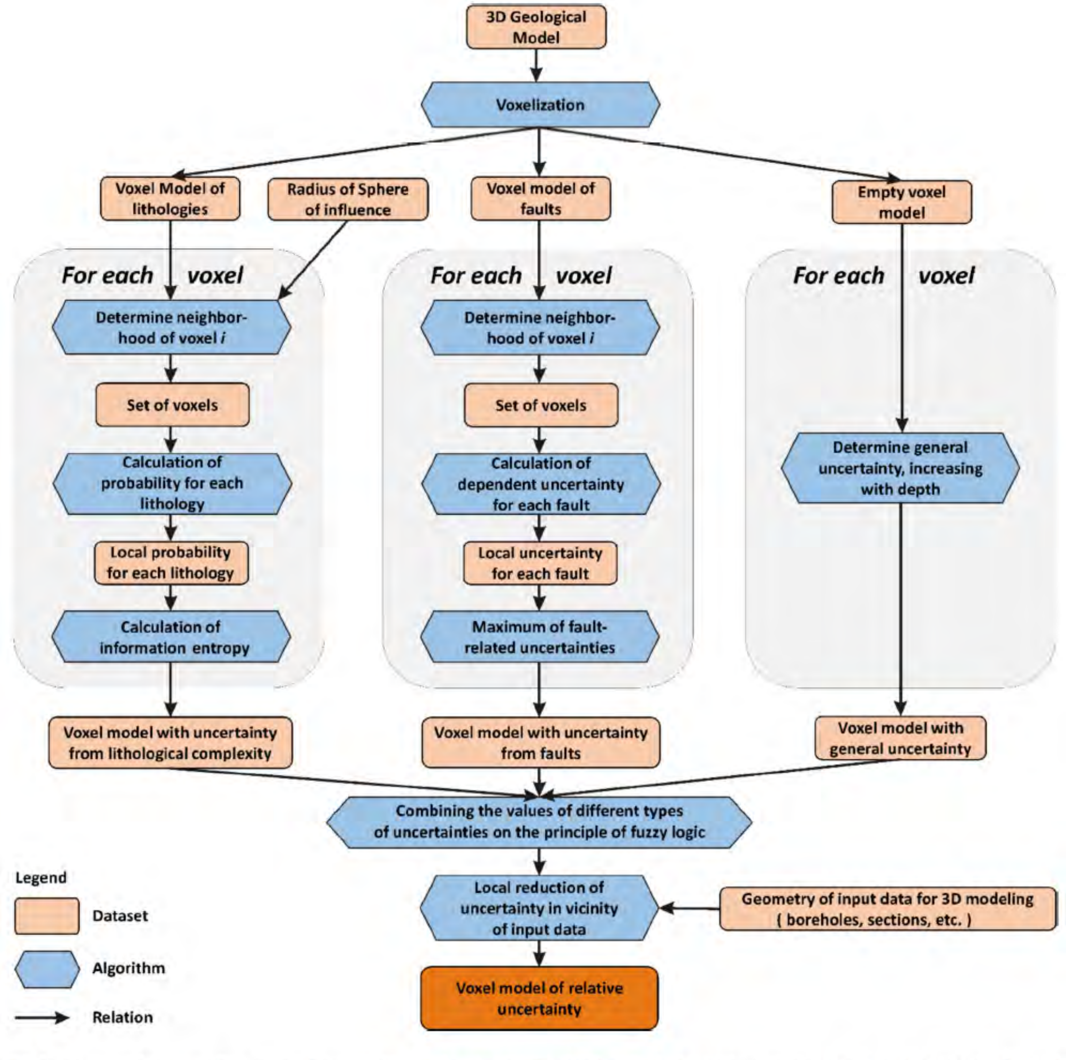
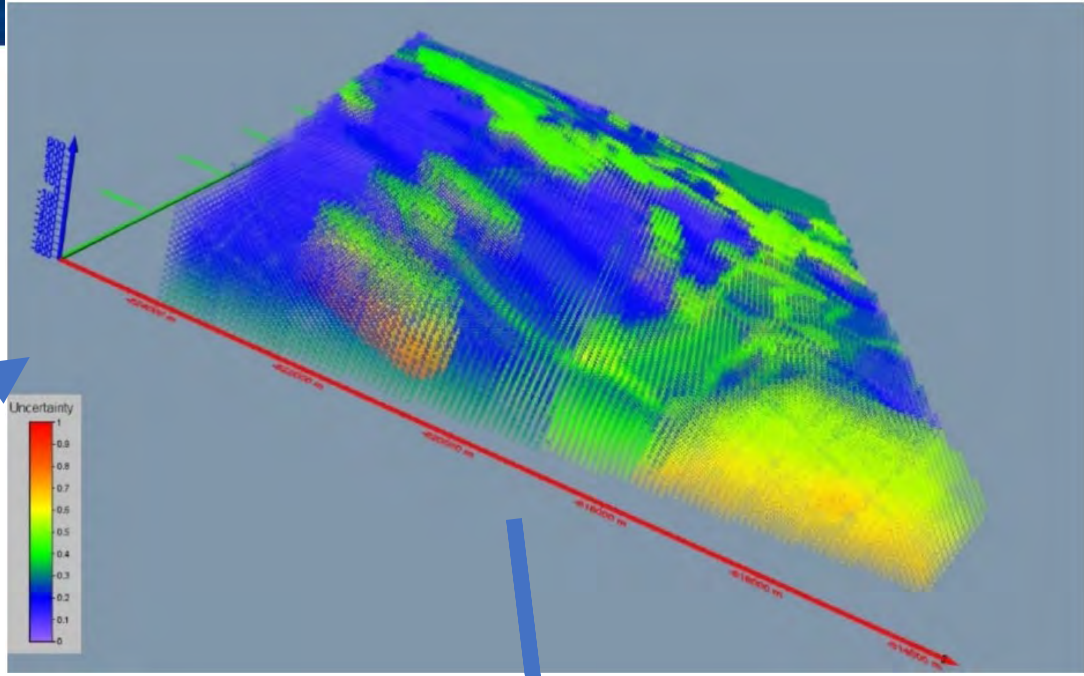
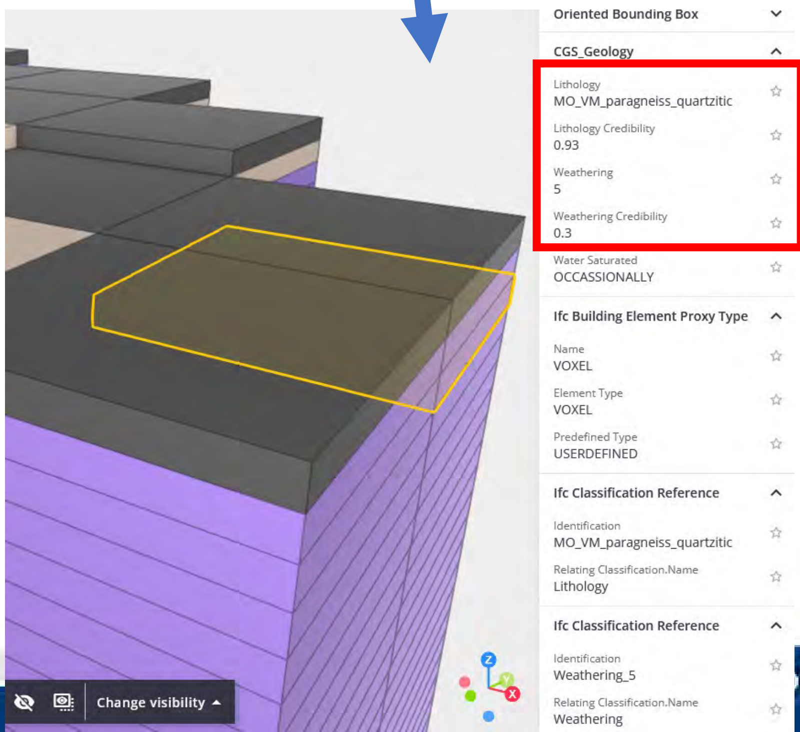
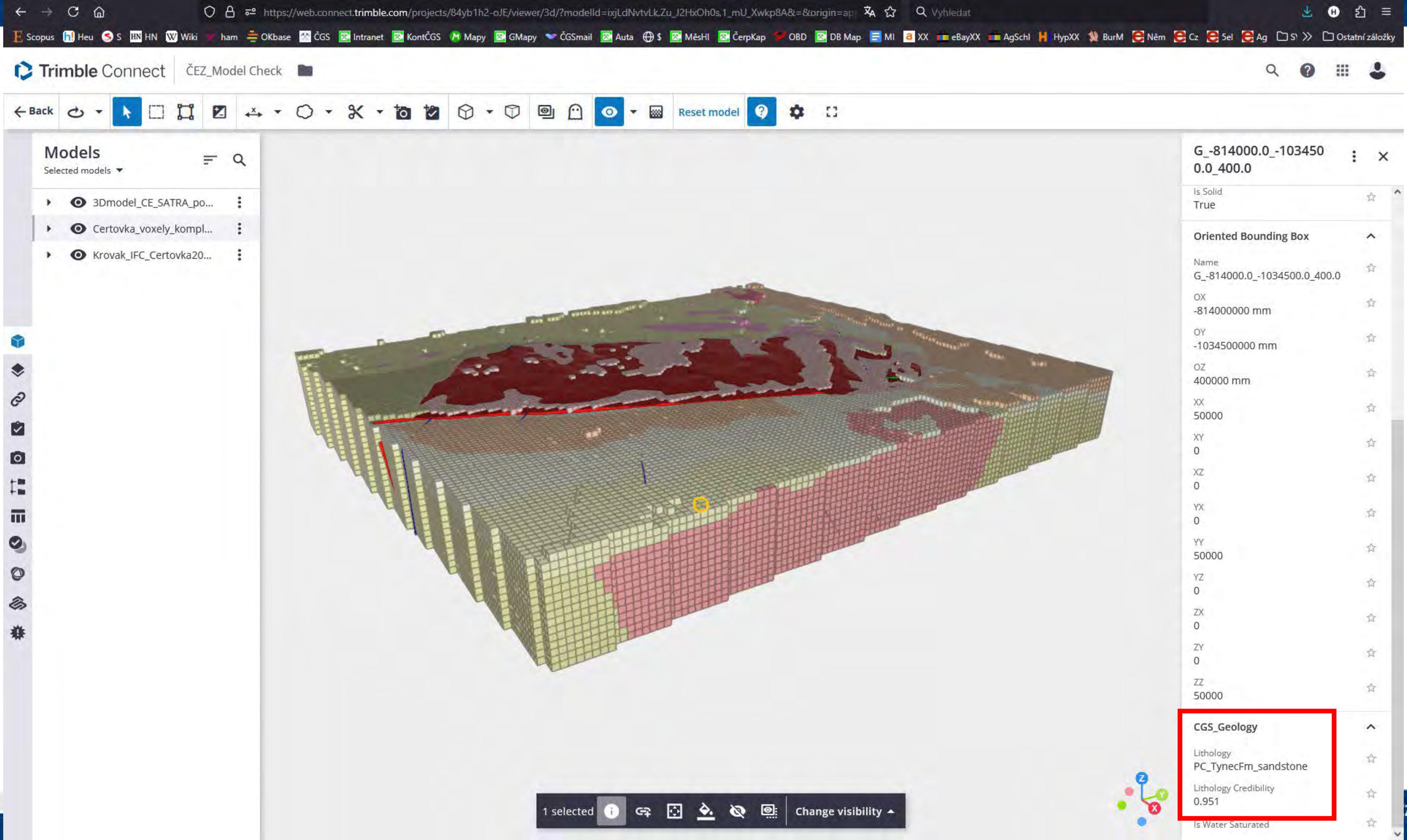


Fig. 4 Diagram of the workflow of the determination of the uncertainty of 3D geological models, including the related algorithms. Legend: orange – input data, blue – algorithms, brown – final output







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Lithology Credibility
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Is Water Saturated
1 selected
Change visibility

2. Classified expert estimate for quasihomogeneous volumes

Lithology Source & Weathering Source - definition of values of information category

A - the boundaries of the body are defined precisely, from surface mapping or from numerous geophysical data and numerous sufficiently deep and well-described boreholes

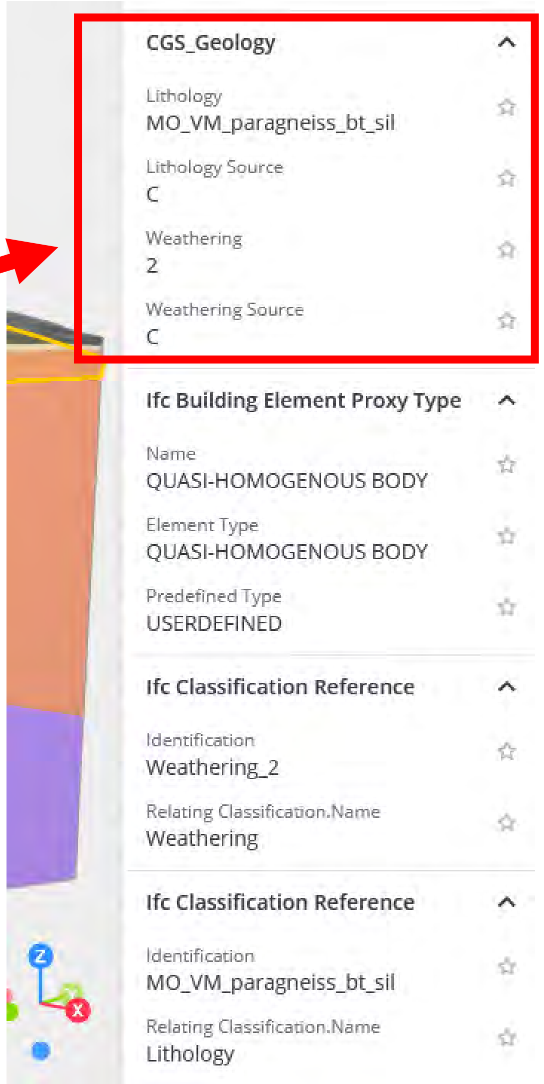
B - the boundaries of the body are defined relatively precisely, from surface mapping or from a small amount of geophysical data and numerous sufficiently deep and well-described boreholes

C - the boundaries of the body are partly defined relatively precisely, e.g. from surface mapping, and partly qualifiedly estimated from numerous geophysical data supported only by a smaller amount / poorer quality borehole descriptions

D - the boundaries of the body are defined imprecisely, qualifiedly estimated from a smaller amount of geophysical data supported only by a smaller amount / poorer quality borehole descriptions

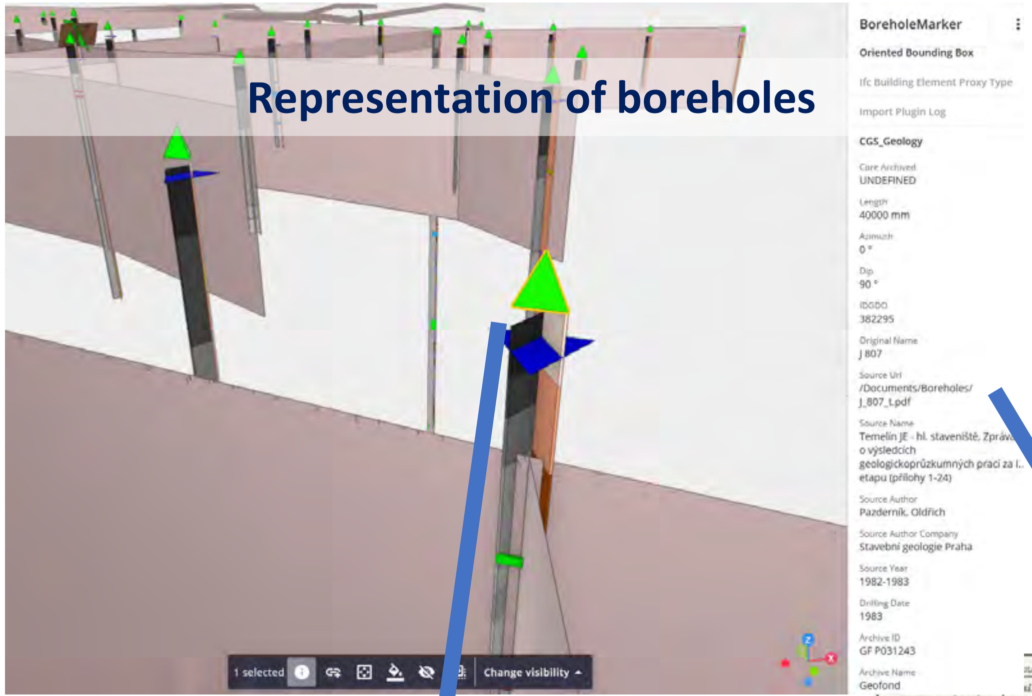
E - the boundaries of the body are defined significantly imprecisely, are only roughly qualifiedly estimated from insufficiently high-quality geophysical data supported only by a smaller amount / poorer quality borehole descriptions

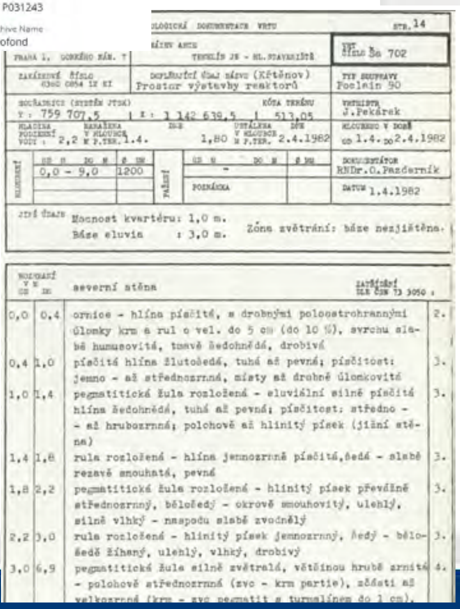
F - the entire rock body is hypothetical, its position and dimensions are only roughly estimated from insufficiently high-quality / insufficiently deep-reaching geophysical data supported by only a small number / poor quality borehole descriptions



3. Integration of primary geoscientific data into BIM

Representation of boreholes




...OLOGICKÁ DOKUMENTACE VRTU STR. 14

TEMELÍN JE - HL. STAVENIŠTĚ

ČÍSLO Ša 702

DOPLŇUJÍCÍ ÚDAJ NÁZVU (Křtěnov) Prostor výstavby reaktorů

TYP SOUPRAVY Foclain 90

Y : 759 707,5 | X : 1 142 639,5 | KÓTA TERÉNU 513,05

J.Pekárek

2,2 M P.TER. 1.4. 1,80 M P.TER. 2.4.1982

OD 1.4. DO 2.4.1982

0,0 - 9,0 1200

DOKUMENTÁTOR RNDr.O.Pazderník

POZNÁMKA

DATUM 1.4.1982

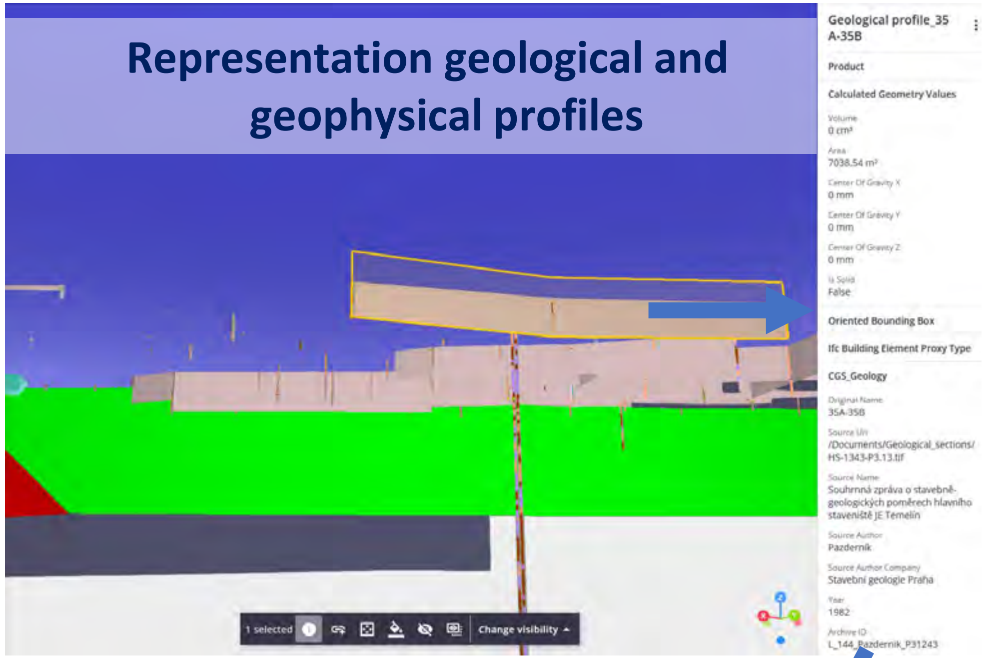
Mocnost kvartéru: 1,0 m. Zóna zvětrání: báze nezjištěna.

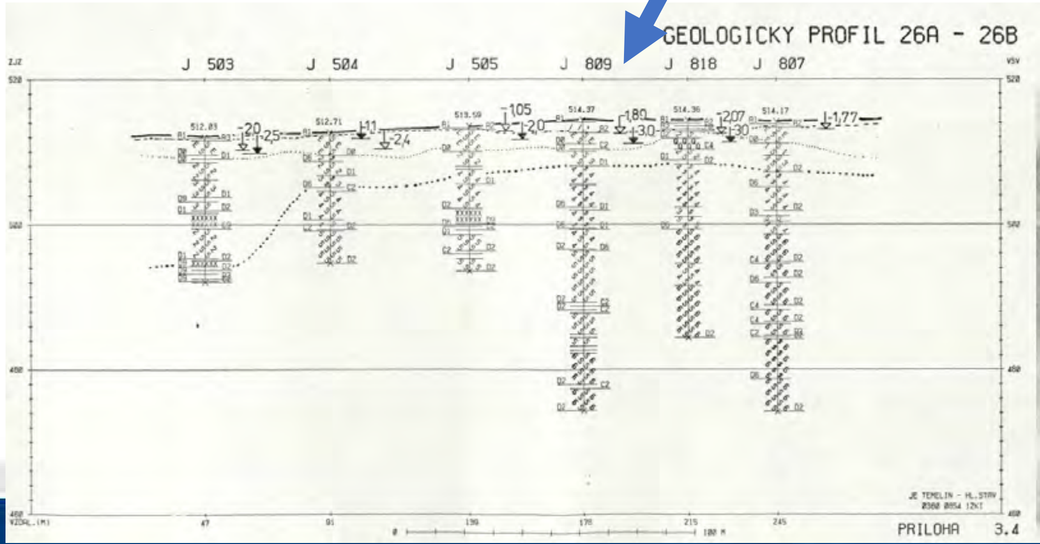
Báze eluvia : 3,0 m.

severní stěna

0,0	0,4	ornice - hlína písčitá, s drobnými poloostrohrannými úlomky krm a rul o vel. do 5 cm (do 10 %), svrchu slabě humusovitá, tmavě šedohnědá, drobivá	2.
0,4	1,0	písčitá hlína žlutošedá, tuhá až pevná; písčitost: jemno - až střednozrnná, místy až drobně úlomkovitá	3.
1,0	1,4	pegmatitická žula rozložená - eluviální silně písčitá hlína šedohnědá, tuhá až pevná; písčitost: středno - - až hrubozrnná; polohově až hlinitý písek (jižní stěna)	3.
1,4	1,8	rula rozložená - hlína jemnozrnně písčitá, šedá - slabě rezavě smouhatá, pevná	3.
1,8	2,2	pegmatitická žula rozložená - hlinitý písek převážně střednozrnný, bělošedý - okrově smouhovitý, ulehlý, silně vlhký - naspodu slabě zvodnělý	3.
2,2	3,0	rula rozložená - hlinitý písek jemnozrnný, šedý - bělošedě žíhaný, ulehlý, vlhký, drobivý	3.
3,0	6,9	pegmatitická žula silně zvětralá, většinou hrubě zrnitá - polohově střednozrnná (zvc - krm partie), zčásti až velkozrnná (krm - zvc pegmatit s turmalínem do 1 cm).	4.

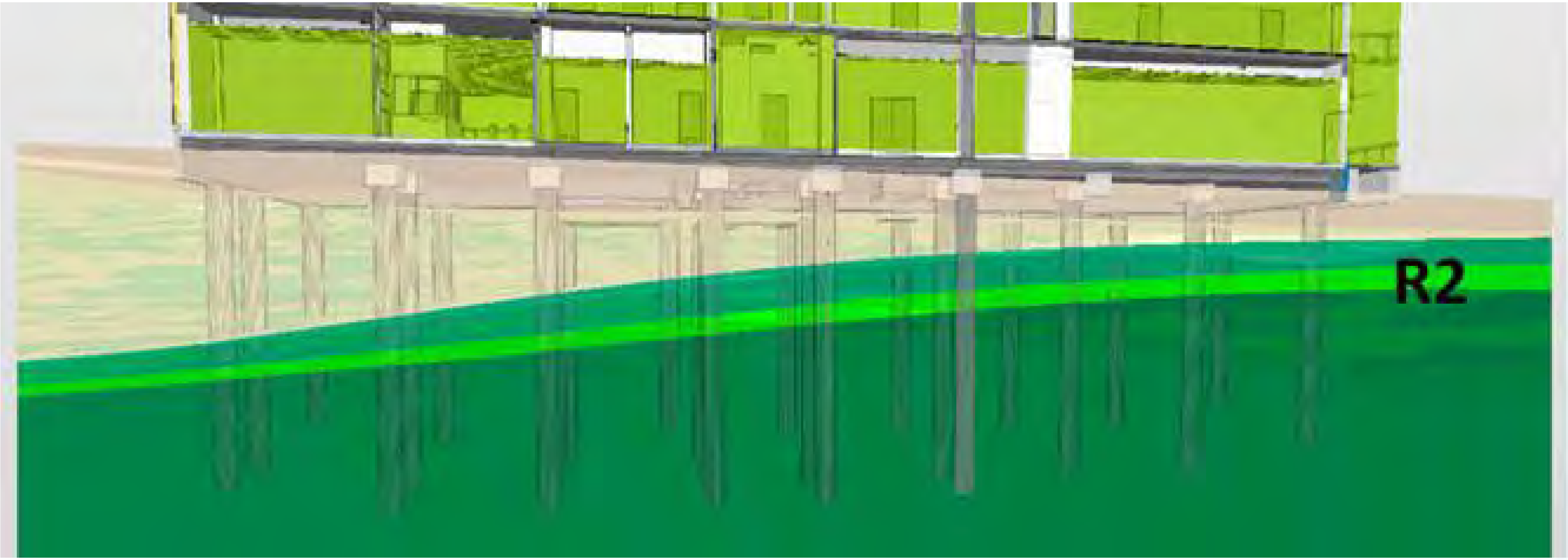
Representation geological and geophysical profiles





Money saving

According to Czech standard ČSN 73 6133 (starting with R2 class, i.e. bedrock strength 50-150 MPa) = shift of the building location + shorter piles = c. 1,3 mil. Kč (52.000,- EUR) expected money saving



Thank you for attention

How to make models look less certain

Overcoming image anchoring using visual cues to bring uncertainty into focus

Some rules to improve the effective visualisation of uncertainty in models

Stephen Tyson

Industry Mathematics and Physics

Motivation

- The simple act of seeing a geological model creates bias
- If uncertainty isn't somehow included in the visual, adding it later, or just talking about uncertainty will create conflict in your mind… which is usually resolved by going back to what you saw
- Your entire visual system is programmed to make things real
- … and AI visual interpretations are trained to extract and determine reality from images

This presentation considers how we can overcome the nature of your brain to make things real.. with some assistance from Seurat, Monet, Braque, and Wile E Coyote

The uncertainty narrative

1753 Dutch map of Australia

The label on the East coast says, *"I think that Van Diemen's Land [now Tasmania] could join with St Esprit's Land [Cape York] but there is no proof."*

Captain James Cook reached the east coast in April 1770 and claimed the land for Britain.

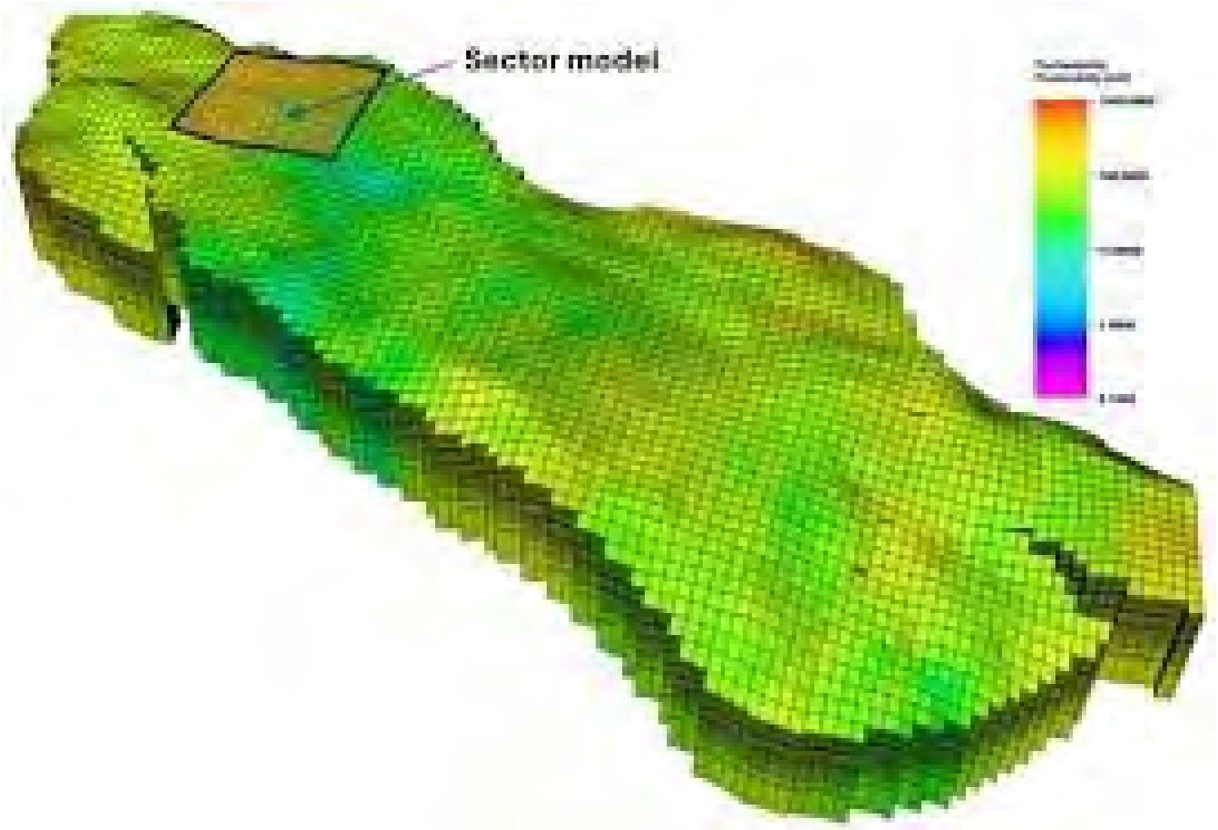
Emerging from fog and poor light

- The asset is real
- We can see some things clearly
- Different decisions need clarity on different information
    - Is it two ships or one big ship? (Navigation and collision avoidance)
    - Are these objects friends or foes? (Military engagement)

Image Anchoring and Persistence

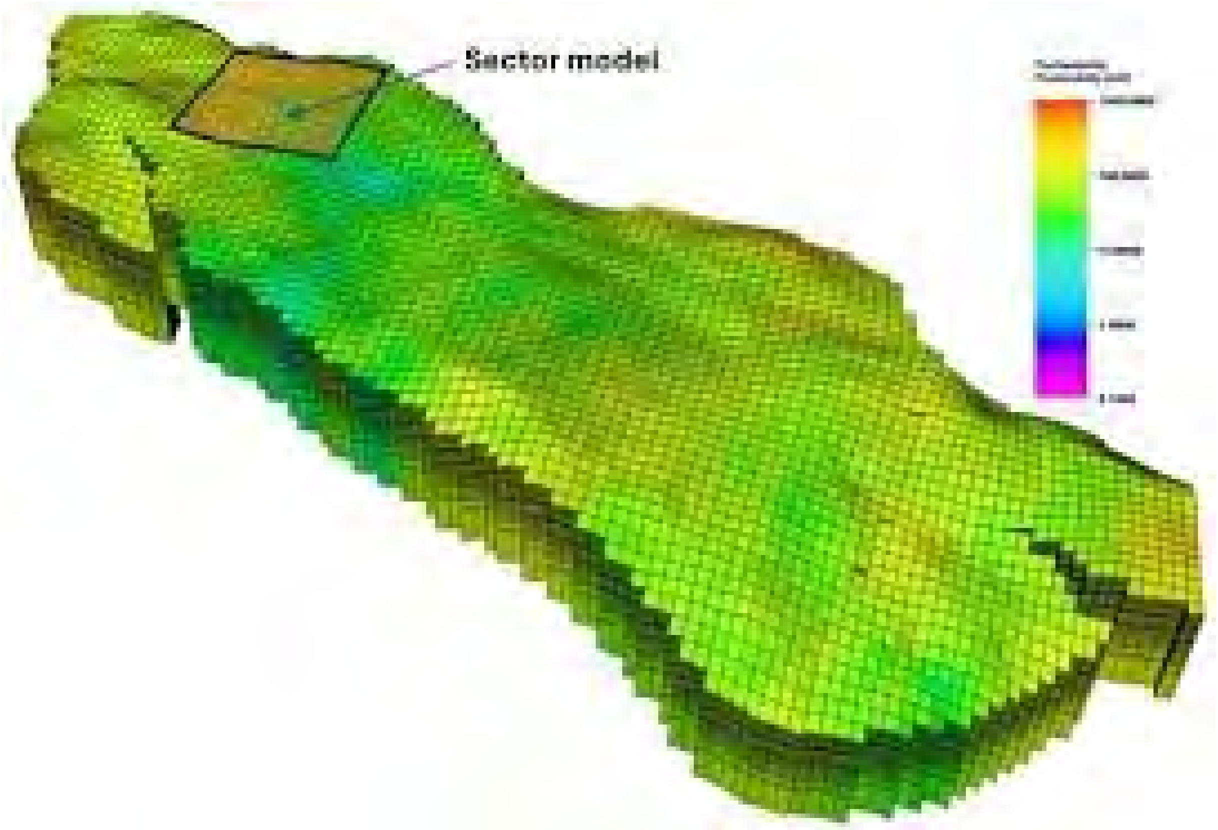
Why do some people see things that others don't?

Image Anchoring and Persistence



- It's very common to see images like this in presentations and reports.
- Why do we even do this?
- Because we can?
- Or because we don't realise **that it tells us very little… and starts the process of misrepresentation**

Image Anchoring and Persistence



- Once an image has been seen, it can't be unseen
- Your mind will make this real
- The observer can handle parametric uncertainty with colour changes
- The observer cannot manage structural (shape) changes due to significant cognitive overload
- **Solution: Don't use 3D models to communicate without guidelines**

Perceptual Contamination

How your efforts to communicate uncertainty are undermined

Perceptual Contamination

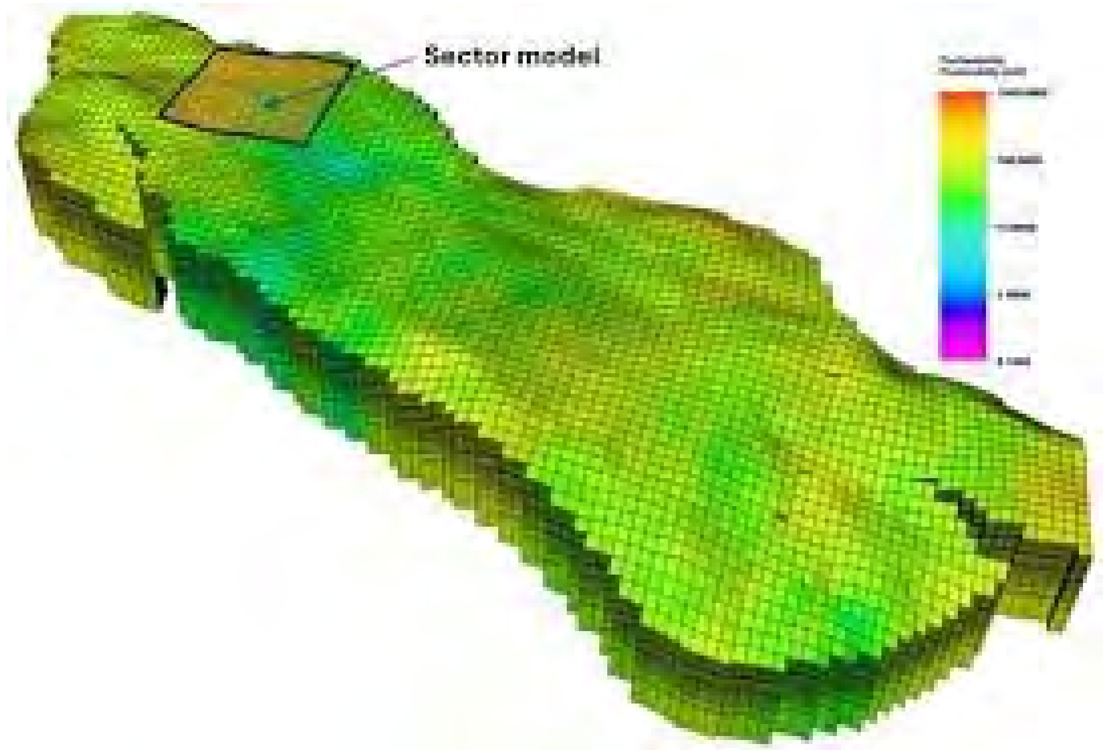
- You know that the 3D model on your computer has structural and property uncertainties…. so why take a screenshot?
- Once it leaves you, the screenshot that you put in a presentation or a report has no metadata to inform anyone of its shortcomings
- Advertisements must show warnings if the product may not be exactly as advertised – to avoid litigation

Product Warnings

"Serving suggestion."
"For illustration purposes only."
"Product may vary."
"Images are simulated."

There are good legal reasons for these warnings

Product Warnings



"Subsurface asset suggestion."
"For illustration purposes only."
"Asset geometry may vary."
"Images are simulated."
"Approved use is limited to…"
"Use by date"

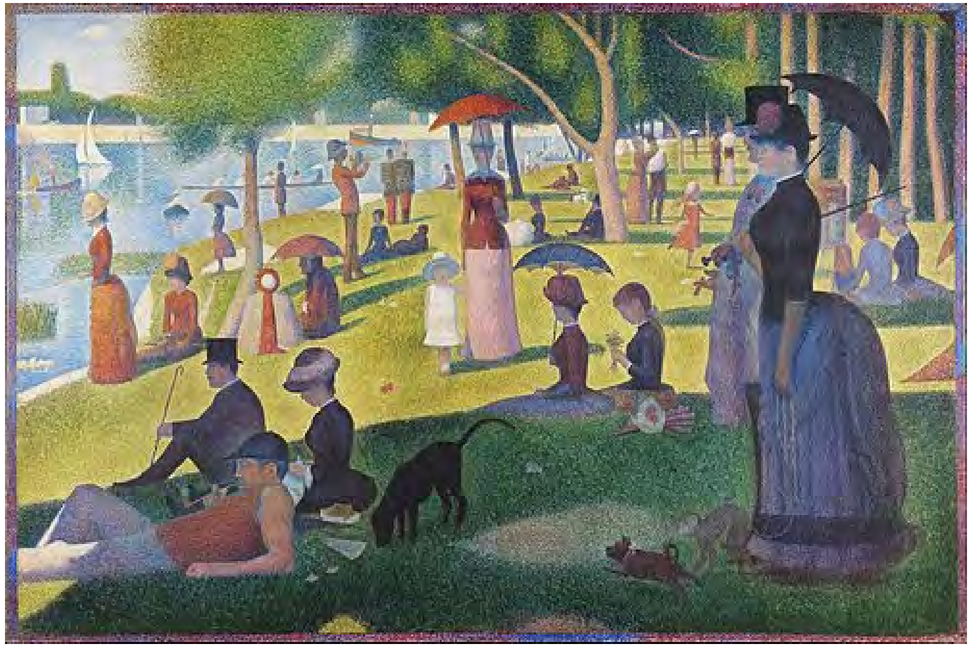
There are good legal reasons for these warnings…

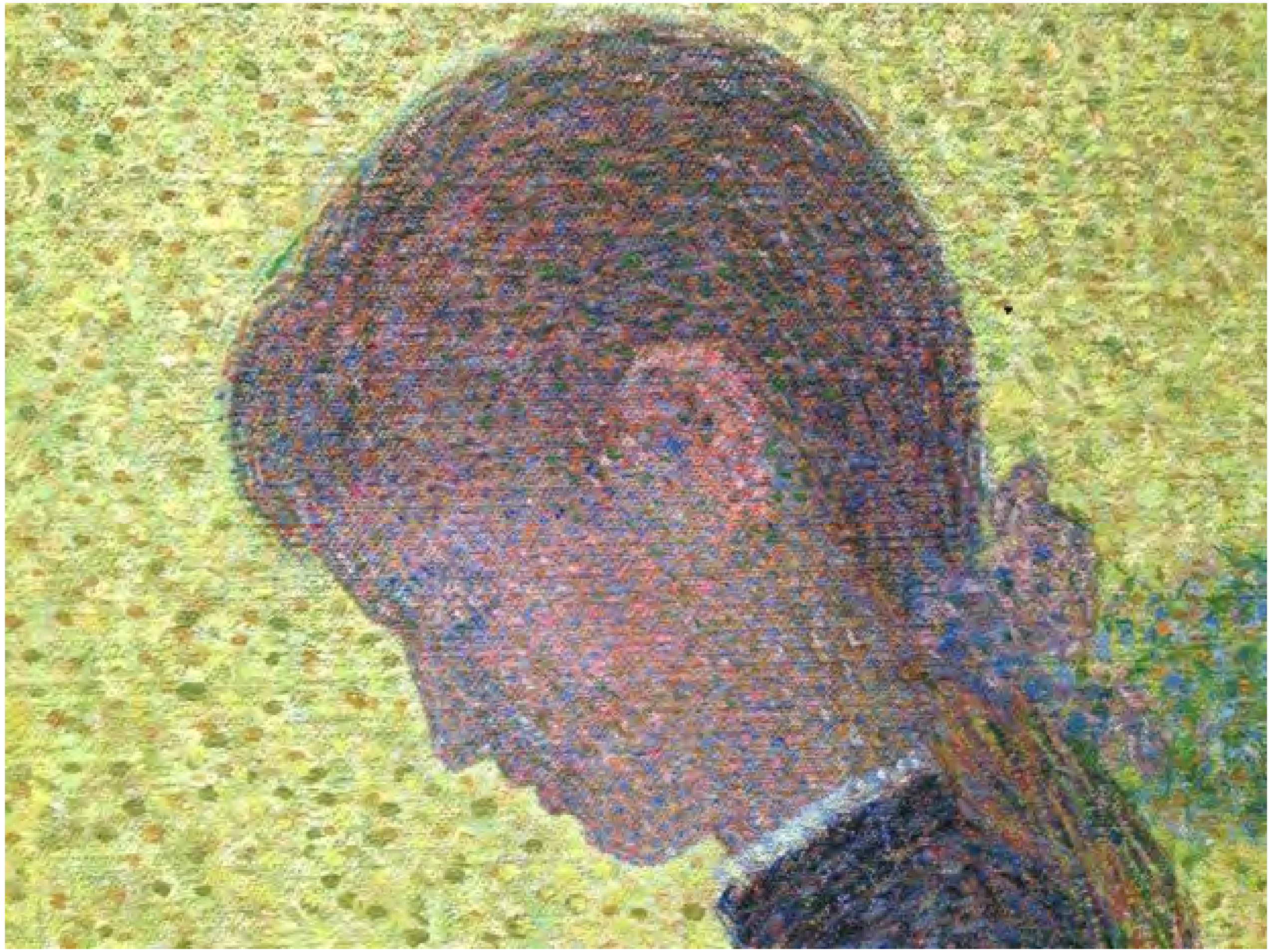
How we interpret images

And how this supresses uncertainty…

Seurat

How can we overcome your brain's desire to make things real?

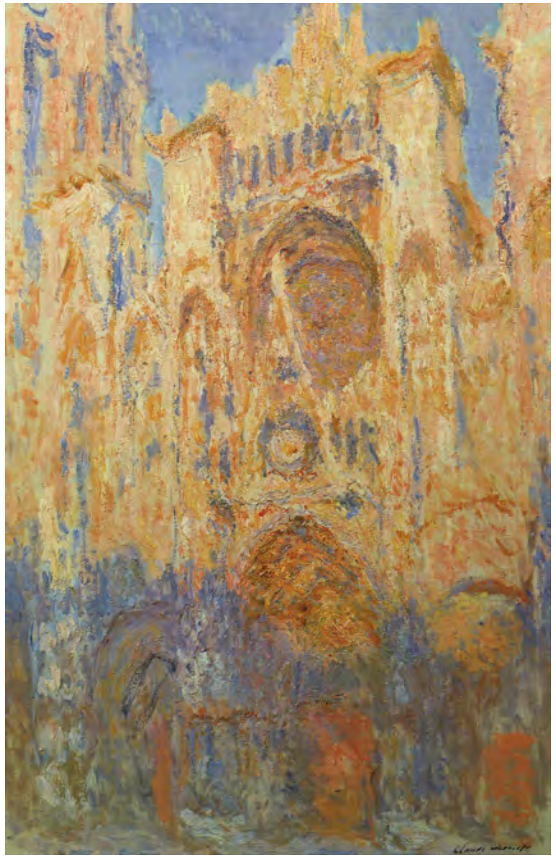




Parametric uncertainty

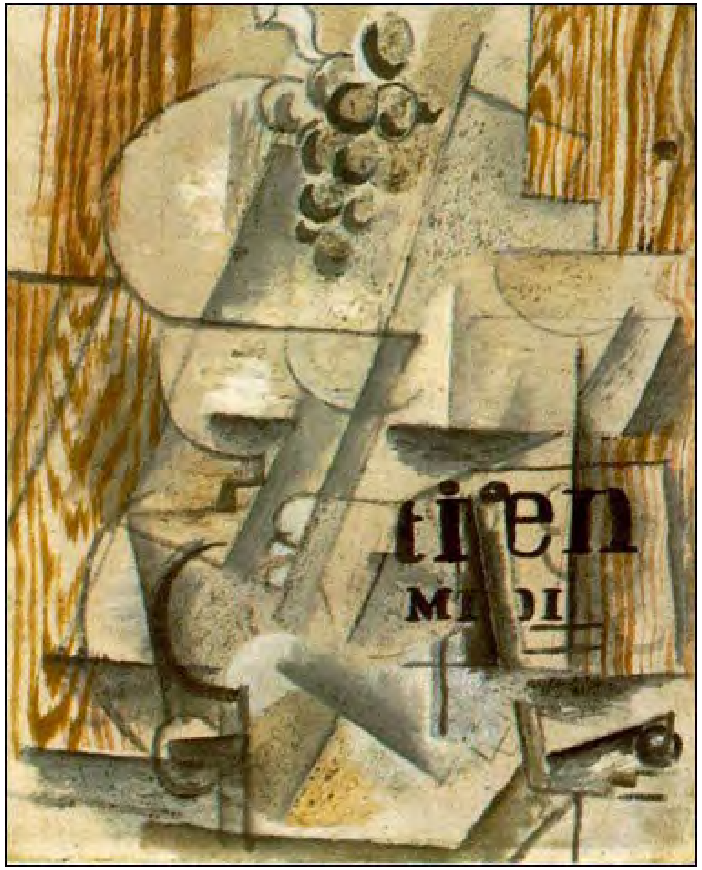
Rouen Cathedral, Monet






Geometric uncertainty

Georges Braque



Structural Uncertainty

“If a model is made up of objects and properties where the properties are normally displayed as colours, most observers have no problem with changes in property values. They have massive issues if the shape or location of the object changes in response to new information”

We tolerate property uncertainty.

We resist structural uncertainty.

Why colour changes are easy

When a property (represemted by colour) changes:

- The object's identity remains stable.
- Its boundaries don't move.
- Its topology doesn't change.

The brain encodes this as: "Same thing, new state."

This is cognitively cheap and it fits the object permanence model our brains evolved with.

Why shape/location changes are disturbing

When geometry changes:

- Boundaries move.
- Volume changes.
- Topology might change.
- Spatial relationships shift.

Now the brain must ask: Is this still the same object?

That’s expensive.

You’ve crossed from parametric uncertainty to ontological uncertainty.

Think; *“Is this bird blue?”* compared to *“Is it a bird or is it a plane?”*

Guidelines for visual integrity

Can we agree on a set of rules to reduce the misleading effects of visualisation?

Laws of Cartoon Motion – Chuck Jones

1. Any body suspended in space will remain in space until made aware of its situation.
2. Any body in motion will tend to remain in motion until solid matter intervenes suddenly.
3. Any body passing through solid matter will leave a perforation conforming to its perimeter.
4. The time required for an object to fall 20 stories is greater than or equal to the time it takes the character to say, “Uh-oh.”
5. All principles of gravity are negated by fear.
6. As speed increases, objects can be in several places at once.
7. Certain bodies can pass through solid walls painted to resemble tunnel entrances. Others cannot.
8. Any violent rearrangement of feline matter is impermanent.
9. Everything falls faster than an anvil.
10. For every vengeance, there is an equal and opposite revengefulness.

What makes these rules interesting…

They're not arbitrary. They encode deeper animation principles:

- Anticipation
- Exaggeration
- Timing
- Audience awareness
- Psychological causality

Cartoon physics runs on:

- Knowledge
- Emotion
- Narrative timing
- Comic expectation

Not force, mass, and inertia.

Insight

If cartoon physics has laws to clarify the communication of narrative

Can uncertainty modelling have laws to clarify the communication of cognition?

Laws of Uncertainty Perception

1. A model with unknown regions will be perceived as complete unless uncertainty is made visually unavoidable.
2. Observers anchor on the most visually stable region – this should be the region of least uncertainty
3. Uncertainty not explicitly encoded will be interpreted as precision.
4. It is easier to interpret a wrong coherent model over a correct ambiguous one.
5. The sharper the boundary, the stronger the implied knowledge.
6. Transparency implies possibility, not probability.
7. Multiple overlaid possibilities are perceived as noise unless structured.
8. Discrete alternatives are easier to understand than continuous uncertainty.
9. Property variation doesn't threaten identity.
10. Structural variation challenges identity, so structural uncertainty increases cognitive load nonlinearly.
11. Human visual inference assumes spatial stability by default so boundary changes force causal revision.

1. A model with unknown regions will be perceived as complete unless uncertainty is made visually unavoidable.

Humans auto-complete.

If you show a surface with a gap observers will mentally fill the gap.

If uncertainty matters, it must be encoded aggressively.

2. Observers anchor on the most visually stable region – this should be the region of least uncertainty

In partially known models:

The most visually stable geometry becomes the mental reference frame.

Everything else is interpreted relative to that anchor.

3. Uncertainty not explicitly encoded will be interpreted as precision.

Silence implies confidence.

If you draw a clean edge observers assume it is known.

The default is that perception = certainty.

4. It is easier to interpret a wrong coherent model over a correct ambiguous one.

This is the dangerous one.

Given:

1. A single clean but wrong surface or
2. A probabilistic cloud of truth

Most people will trust the clean surface.

Clarity beats accuracy in perception.

5. The sharper the boundary, the stronger the implied knowledge.

Crisp lines and high-quality 2D and 3D graphics imply

- Measurement
- Authority
- Confidence

Blur and lower quality images (think pencil sketches) implies doubt.

Line weight and image quality (particularly in hard copy) is epistemology

6. Transparency implies possibility, not probability.

If you show a translucent region observers assume:

> "It might be here."

Not:

> "It is 63% likely to be here."

Opacity communicates plausibility, not distribution.

7. Multiple overlaid possibilities are perceived as noise unless structured.

If you overlay 100 possible geometries observers do not see probability.

They see chaos.

You may need to talk observers through your portfolio of possible structural models.

The visualization's structure must organise multiplicity to assist the observer

8. Discrete alternatives are easier to understand than continuous uncertainty.

“Three possible shapes” is easier than

“An infinite distribution of shapes.”

Quantisation aids comprehension.

9. Property variation doesn’t threaten identity.

- Changing colour, density, temperature, velocity is perceived as state change.
- Identity remains intact.

Real objects change colour and we’re comfortable with that

10. Structural variation challenges identity, so structural uncertainty increases cognitive load nonlinearly.

Small unknown region → manageable.

Large unknown region → conceptual collapse.

Past a threshold, the model ceases to feel “real”.

- This may be good
- It may also be unacceptable to your superiors

11. The human mind assumes spatial stability by default.

Space is treated as:

- Persistent
- Reliable
- Ground truth

If geometry moves or changes, trust and confidence drops…

…unless it is explicitly encoded into the narrative

Think:

“Here are some options we believe to be representative”

not

“Here is the geological model”

Conclusions

- Models become real once we create a visualization, so we need to be very careful when we share visuals to prevent perceptual contamination.
- Property uncertainty is much less challenging than structural uncertainty.
- 2D images are less susceptible to anchoring and have better options to communicate uncertainty.
- We should present and maintain multiple structural options to avoid anchoring.

Thank you, questions?

Laws of Uncertainty Perception

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2. Observers anchor on the most visually stable region – this should be the region of least uncertainty
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