



Royal  
Observatory of  
Belgium

## Seismological contribution to the EPOS.BE key ESFRI research infrastructures

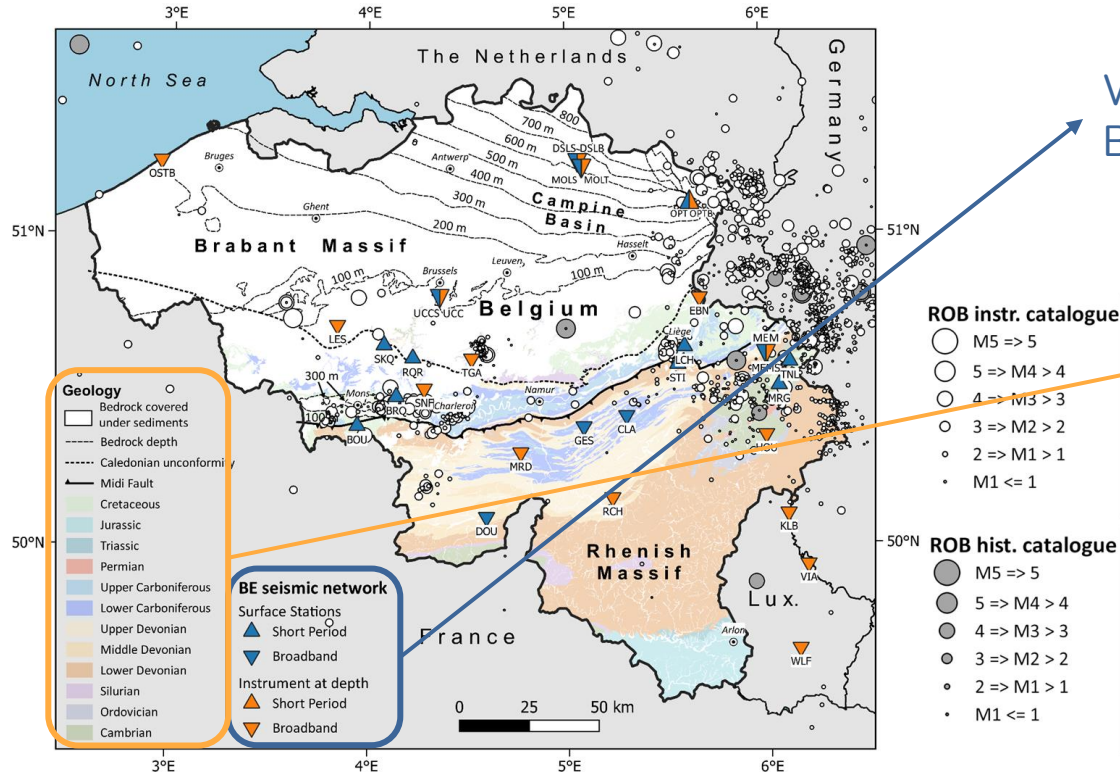
Martin Zeckra  
Koen Van Noten  
Thomas Lecocq  
Giovanni Rapagnani  
Bert Frederick  
Marie Heylen (ULB)  
Michel Van Camp  
*and the seismology.be crew*



Royal Observatory  
of Belgium



**SEISMOLOGY  
GRAVIMETRY**



WP 4.1 – WP 4.2 Upgrade of the Belgian seismic permanent network

WP 4.2 – Site-characterization of seismic permanent stations

**ROB instr. catalogue**

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**ROB hist. catalogue**

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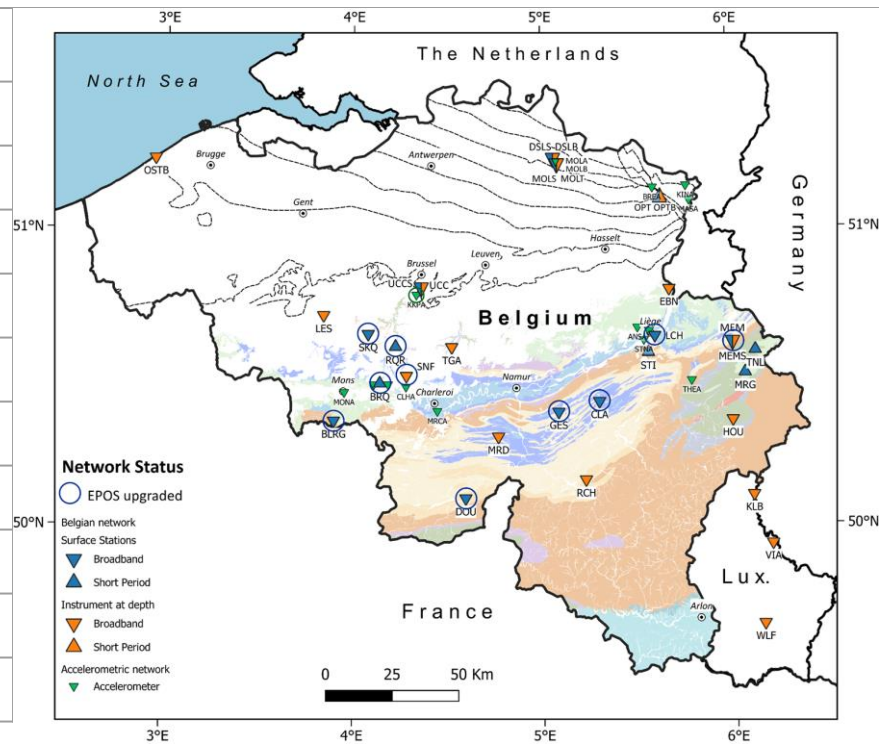
## Network upgrade

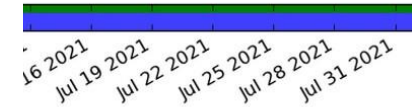
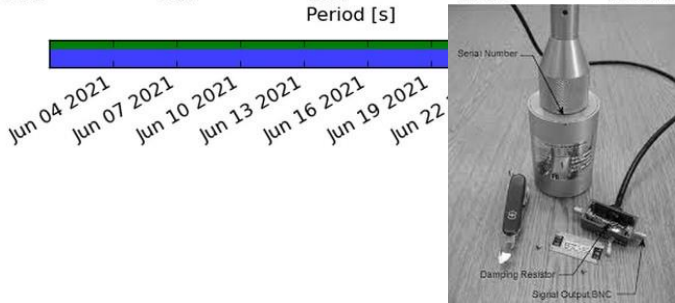
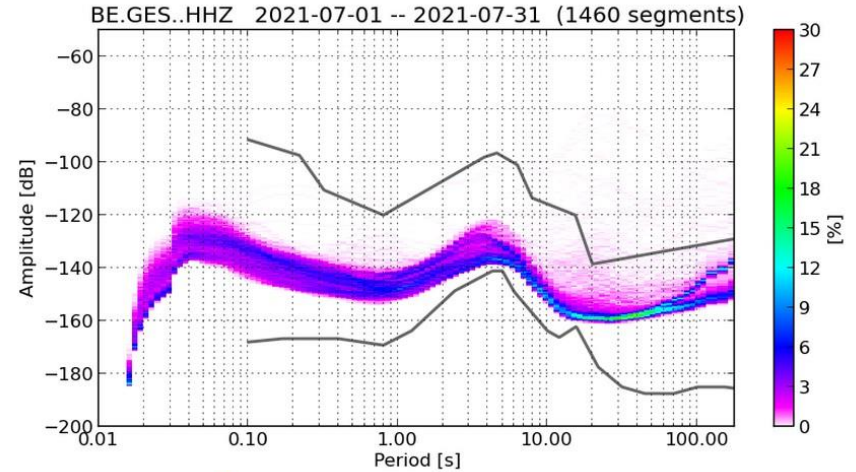
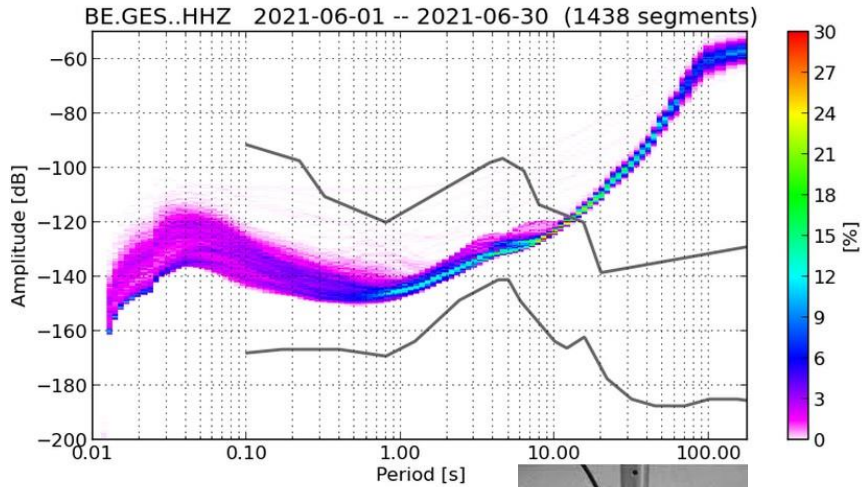
## Outline of station upgrades – WP 4.1

Code	Site	Renewal date	EPOS.BE Funded instruments (~111 k€)
DOU	Dourbes	17.06.2021	Nanometrics Centaur datalogger
GES	Gesves	01.07.2021	Nanometrics Trillium Compact Posthole
SNF	Seneffe	05.08.2021	Nanometrics Trillium Compact Posthole + Nanometrics Centaur datalogger
CLA	Clavier	13.08.2021	Nanometrics Trillium Compact Posthole
MEM	Membach	09.09.2021	Nanometrics Centaur datalogger
LCH	La Chartreuse (Liège)	24.02.2022	Nanometrics Trillium Compact Posthole + Nanometrics Centaur datalogger
BOU →BLRG	Bougny → Blaregnies	07.09.2022/23.11.2022	Nanometrics Trillium Compact Posthole + Nanometrics Centaur datalogger
SKQ	Steenkerque	10.05.2023	Nanometrics Trillium Compact Posthole + Nanometrics Centaur datalogger
RQR	Ronquières	23.05.2023	Nanometrics Centaur datalogger
BRQ	Bracquignies	14.06.2023	Nanometrics Centaur datalogger

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## The Minions

(SmartSolo IGU-16HR 3C)



- 2019: 21 minions
  - 2020: extra battery charger
  - 2023: extra download modules and batteries
- (~28 k€)

## Minion involved projects

*(Backbone for research)*

### ROB:

- EPOS.BE (BELSPO)
- GeoCamb (BELSPO-Brain)
- FaultCollab (FED-tWIN)
- SeismoCave (ROB)
- Outreach (Nerdland)

### Belgium:

- ULB
  - Lectures
  - Master Students
  - ISTremor
- GSB (GeoCamb)
- ULiège
  - FaultCollab
  - SeismoCave
- Expertise - Vincotte

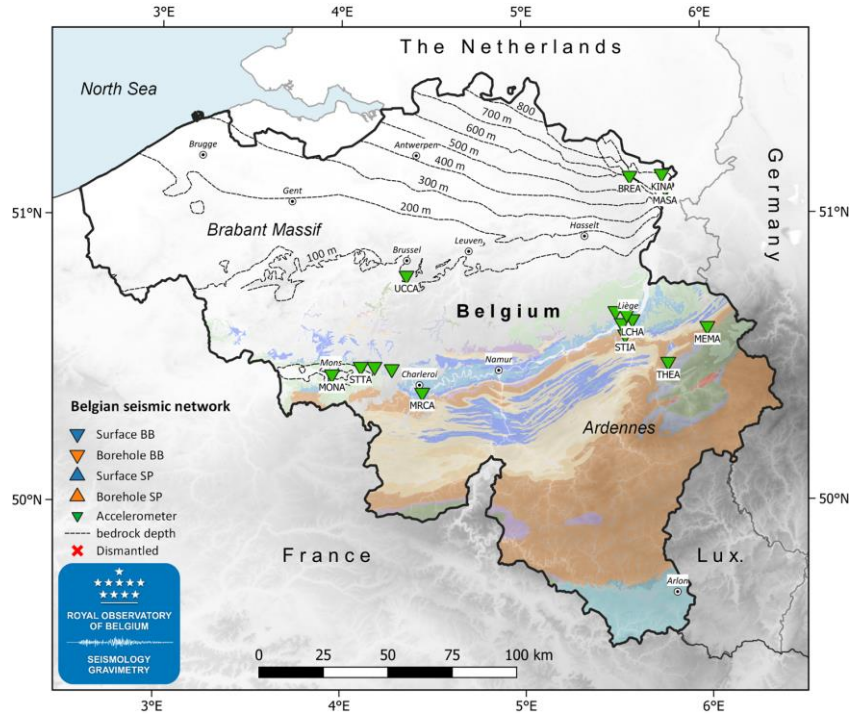
### International:

- BGR, Germany
- Uni Cologne, Germany
- LMU, Germany
- Iceland
  - ISTremor
  - SeismoVatna
- RESIF-FACT, France





## Accelerometric network upgrade – Plan Clarinval 2016



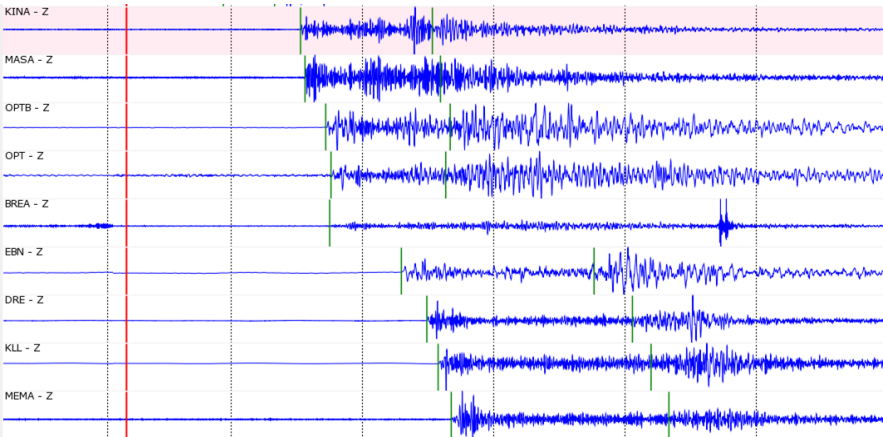
Past:  
Kinometrics ETNA sensors

Now:  
Nanometrics Titan





## Accelerometers: Clear data quality improvement !



4/6

### Main parameters

Date and time	2023-04-16 21:26:56 UTC 2023-04-16 23:26:56 Belgian time
Type	Earthquake
Magnitude	M <sub>L</sub> 2.5
Region	BRUEGGEN (DE)
Epicentral coordinates	51.230° N, 6.166° E Uncertainty ± 0.6 km
Depth of hypocenter	18.8 ± 0.5 km

Data source : ROB (Royal Observatory of Belgium)

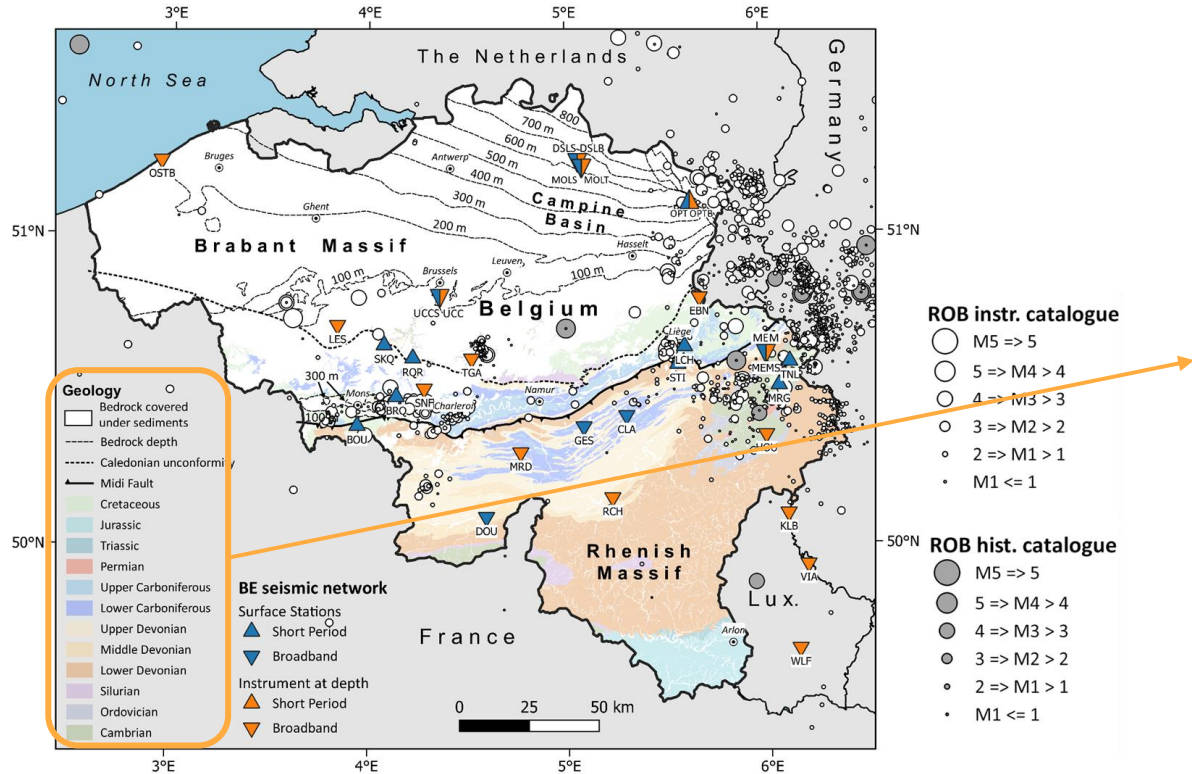
### Location map



### Quake measurements

#### MEASUREMENTS BY THE BELGIAN SEISMIC NETWORK

Code	Station	Place	Epicentral distance (km)	P-Wave arrival (hh:mm:ss.ss)	S-Wave arrival (hh:mm:ss.ss)	Maximal ground displacement (nm)
KINA	KINROOI		29	21:27:02.63	21:27:07.65	-
MASA	MAASEIK		30	21:27:02.80	21:27:07.96	-
OPTB	OPITTER		39	21:27:03.59	21:27:08.33	-
BREA	BREE		41	21:27:03.74	-	-
OPT	OPITTER		39	21:27:03.79	21:27:08.16	95.4
EBN	EBEN-EMAEL		59	21:27:06.47	21:27:13.81	615.7
MEMS	MEMBACH		70	21:27:08.27	21:27:16.60	157.1
MEMH	MEMBACH		70	21:27:08.29	21:27:16.67	-
MEMA	MEMBACH		70	21:27:08.37	21:27:16.66	-



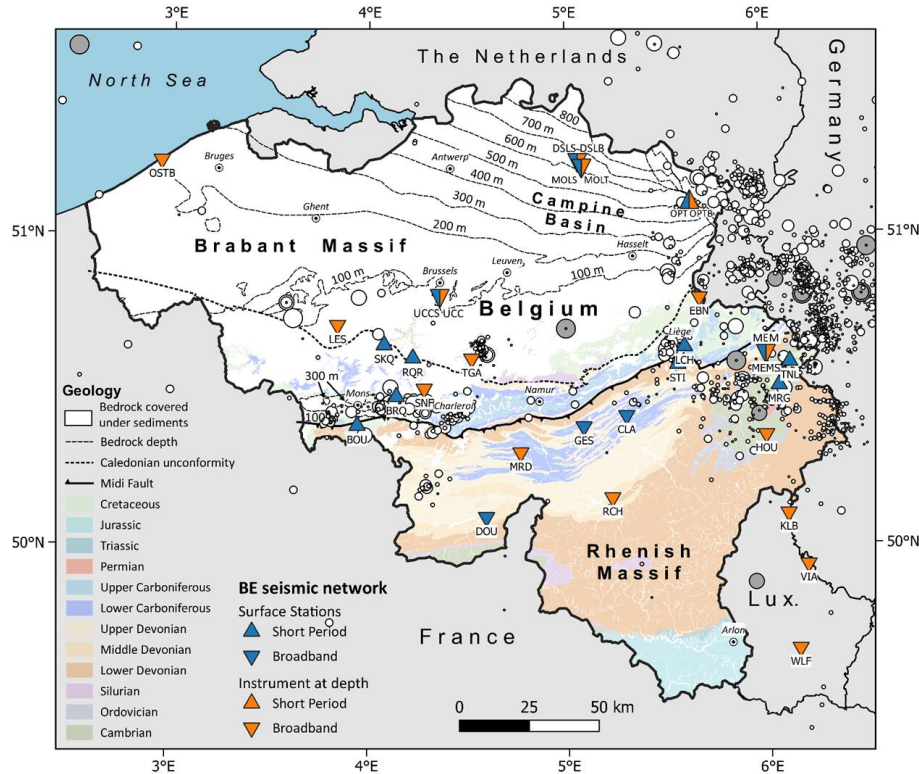
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WP 4.2 – Site-characterization of seismic permanent stations

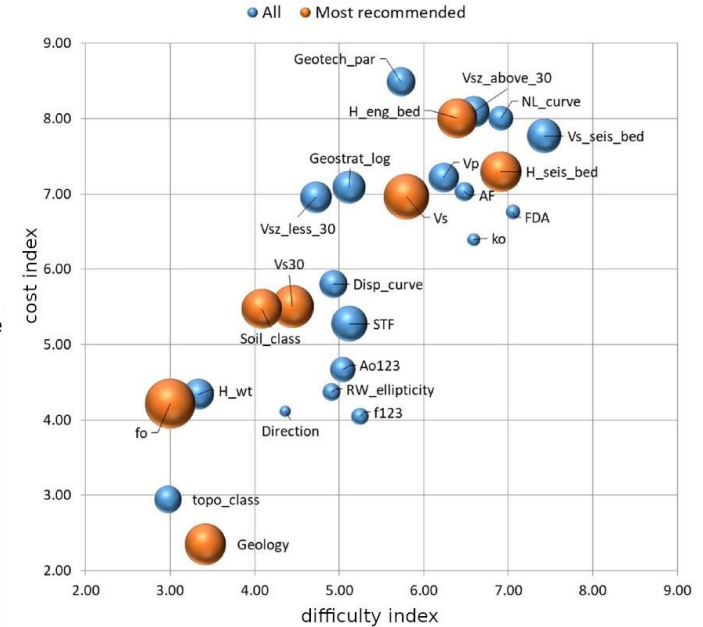


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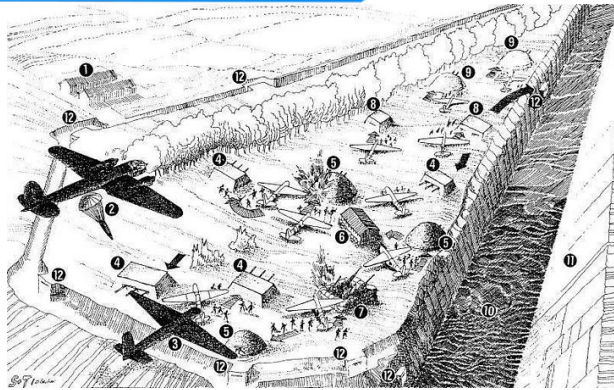
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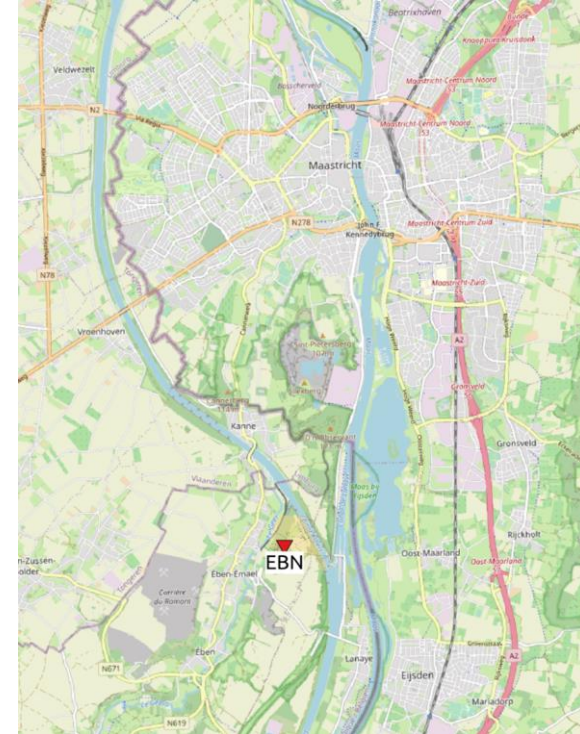
Cultrera, et al. (2021)

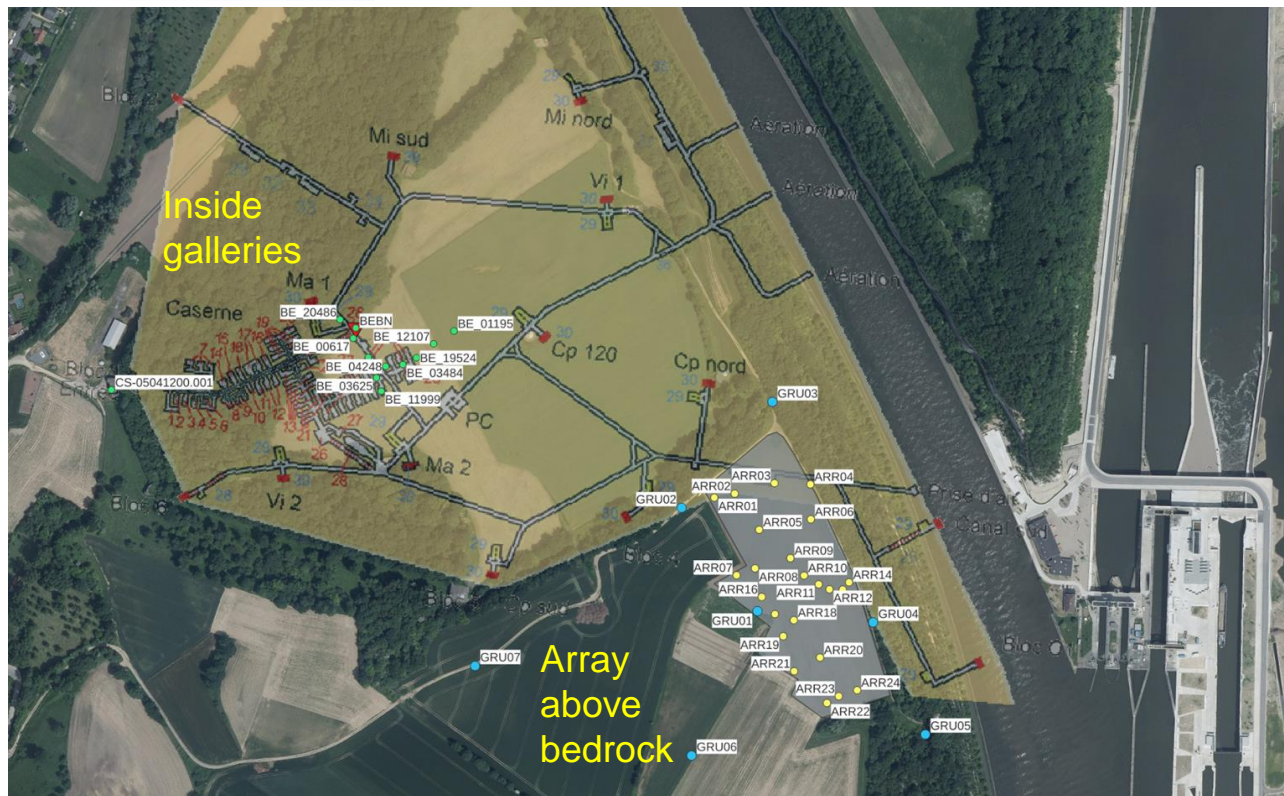


## Case-study Eben-Emael



Fort Eben-Emael (EBN)



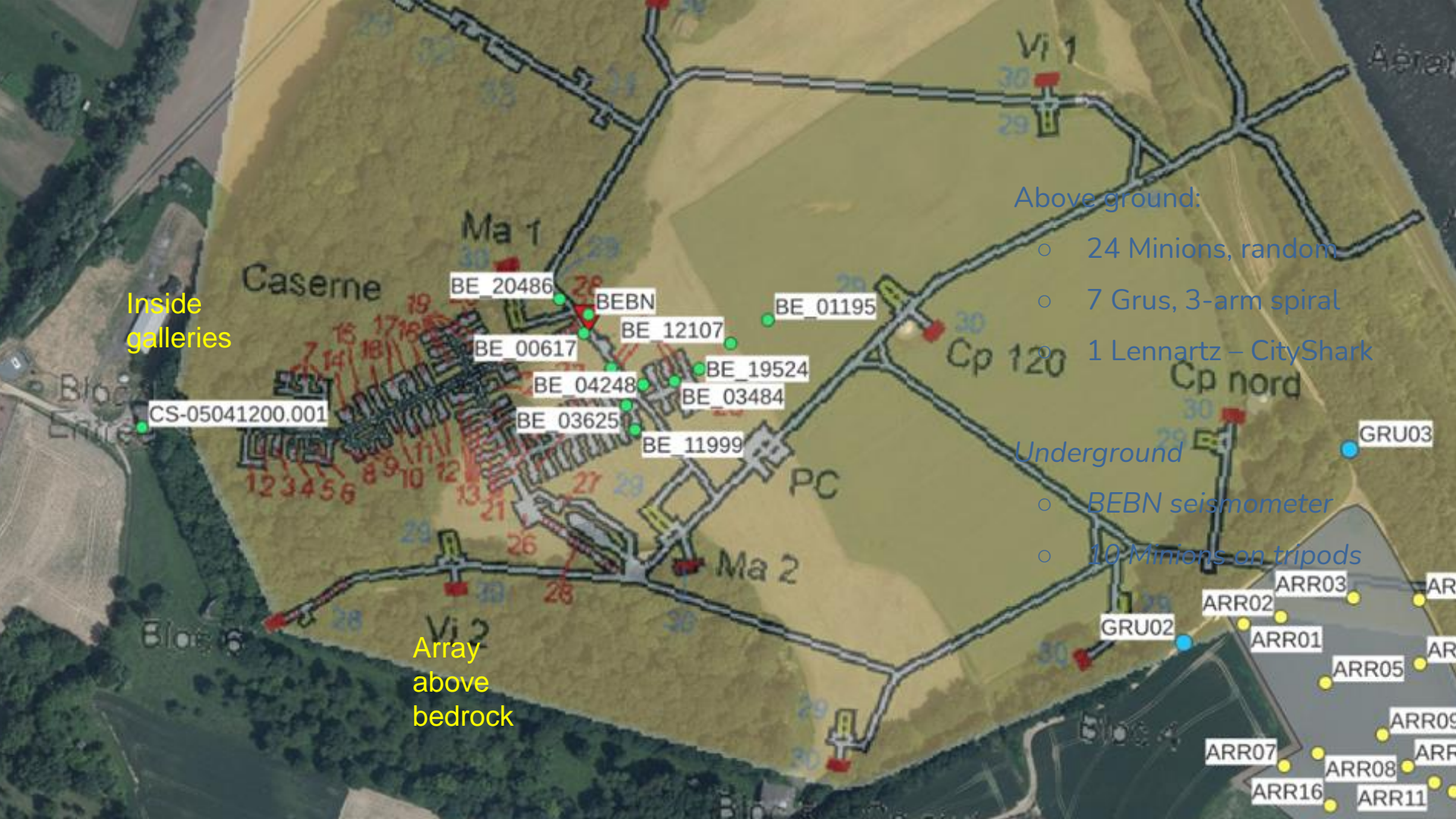


## Above ground:

- 24 Minions, random
- 7 Grus, 3-arm spiral
- 1 Lennartz – CityShark

## Underground

- *BEBN* seismometer
- 10 *Minions* on tripods



Inside galleries

Array above bedrock

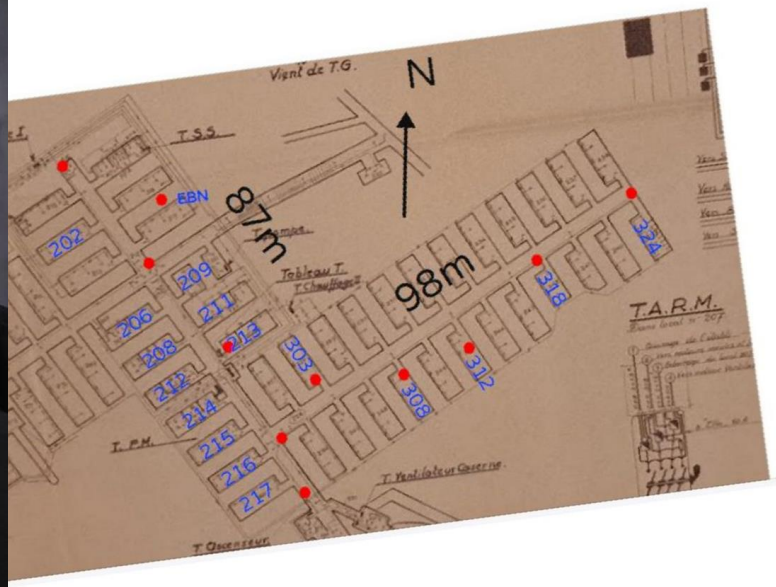
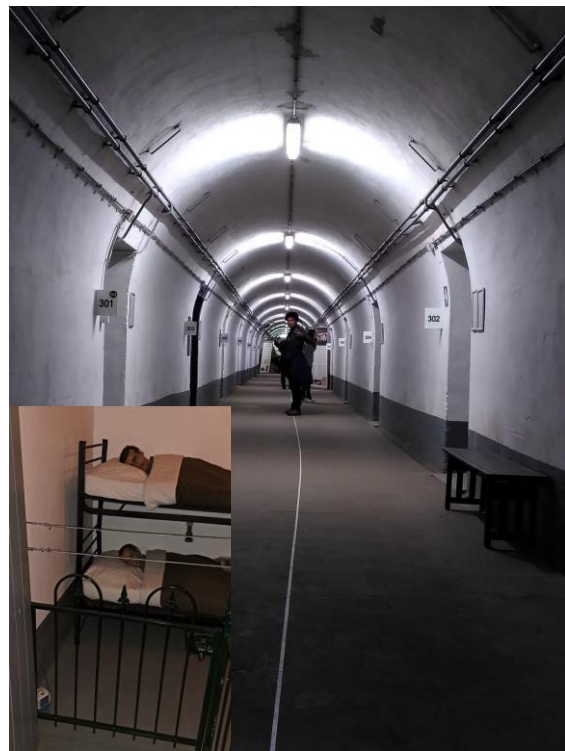
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Underground

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## Above ground:

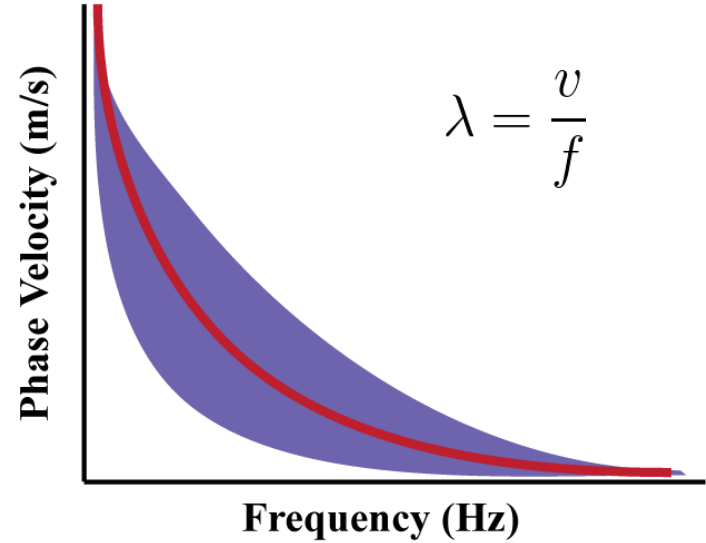
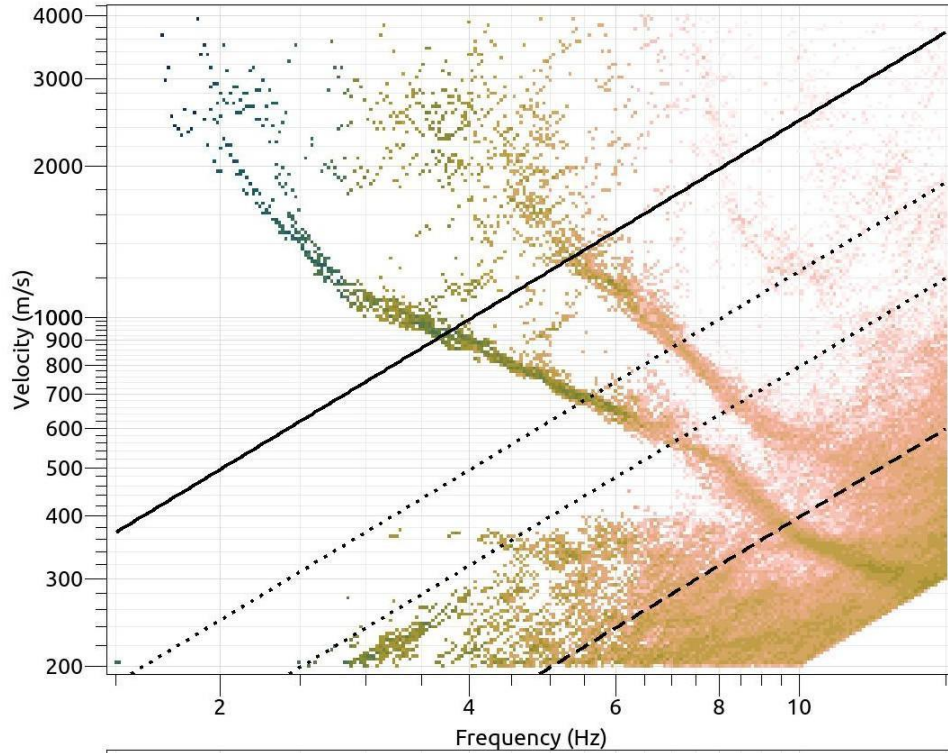
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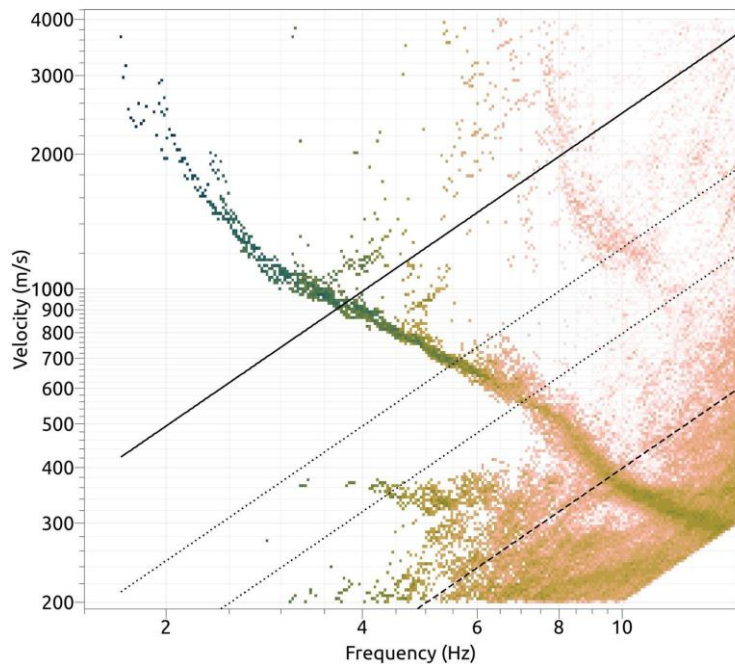
## Underground

- BEBN seismometer
- 10 Minions on tripods

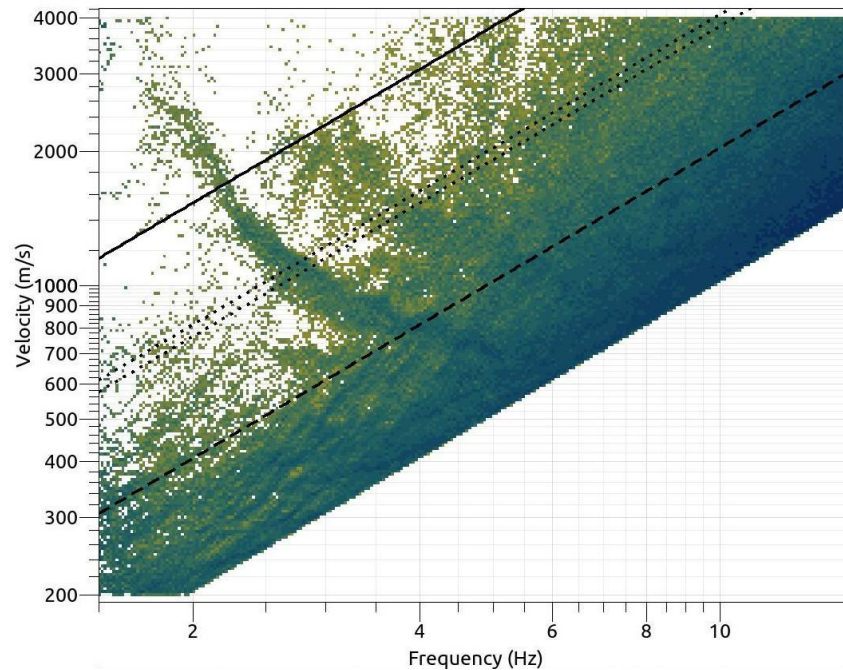


## Methods

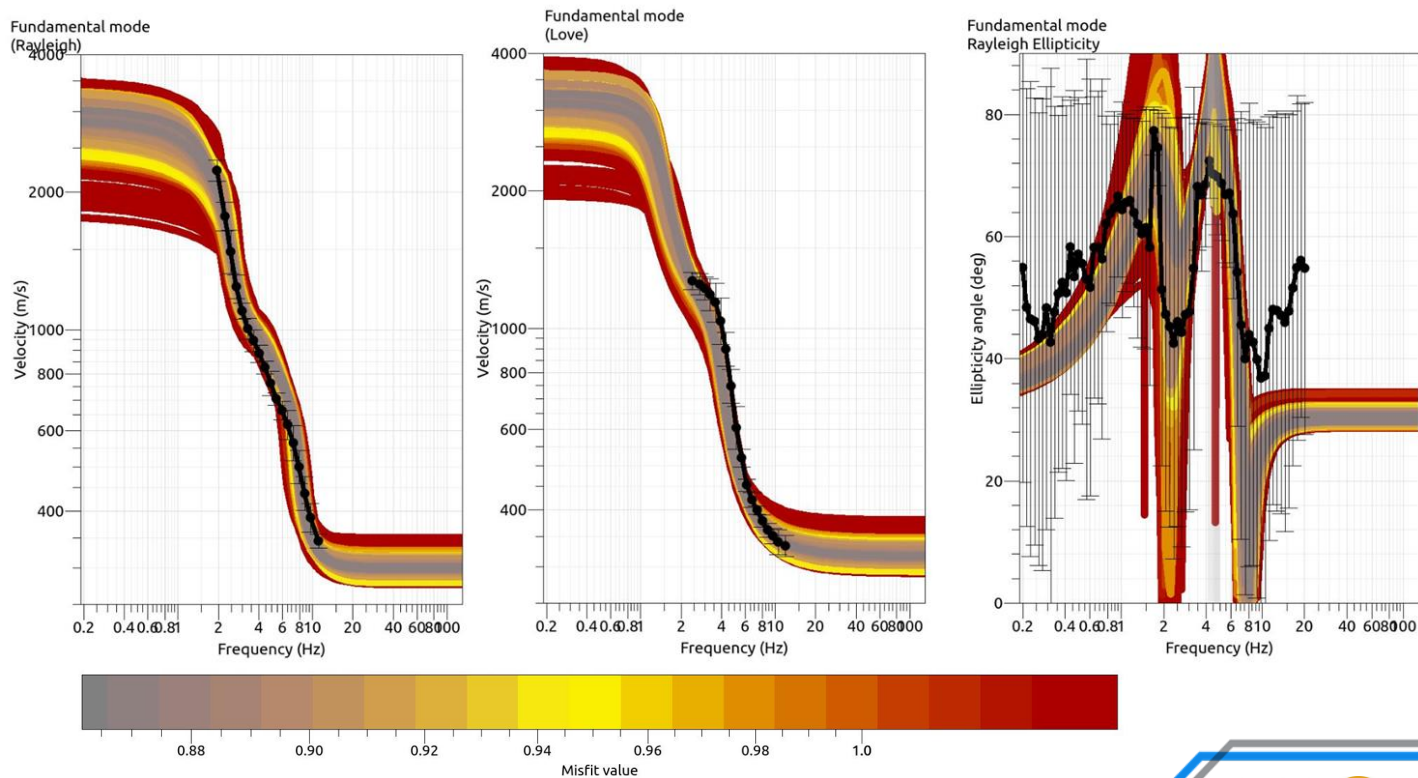


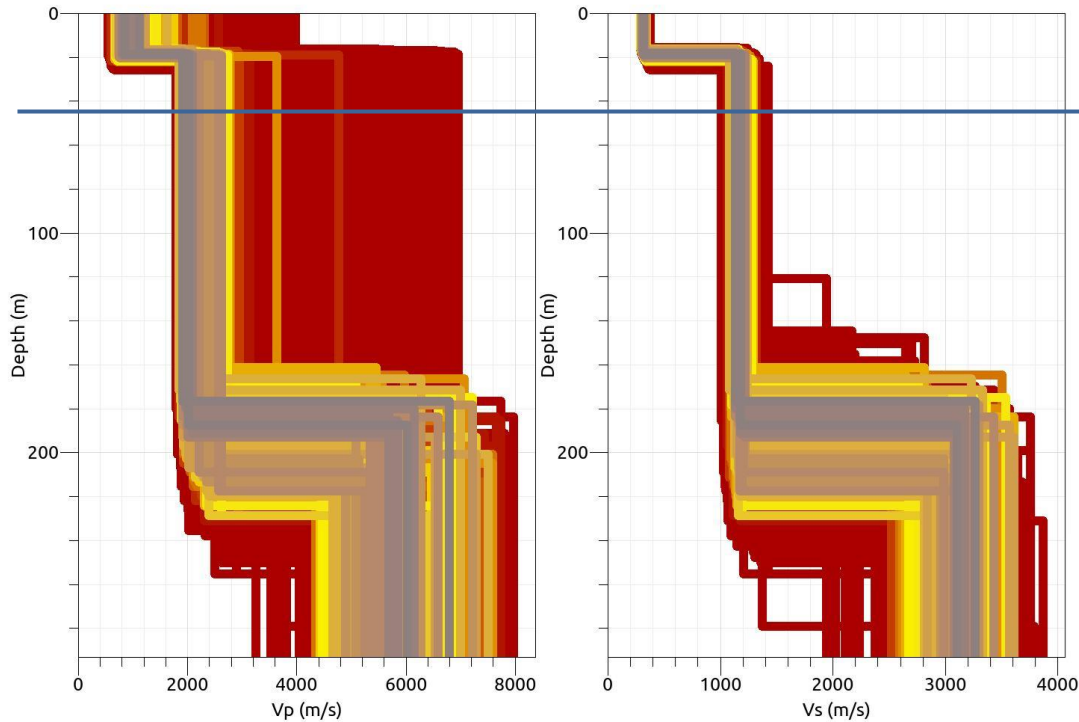


24 Minions



7 Grus

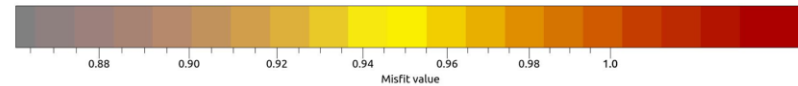




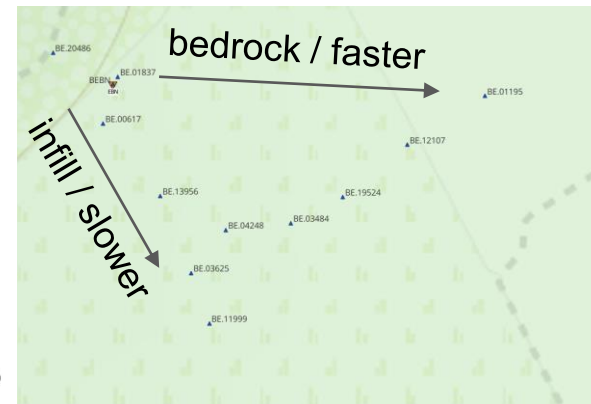
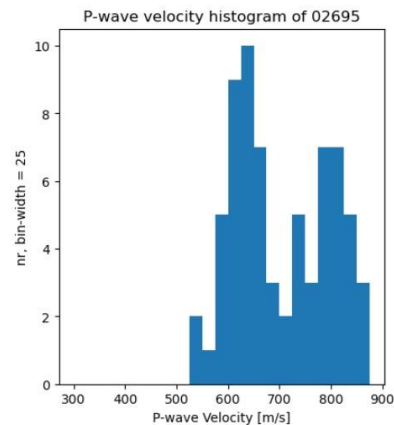
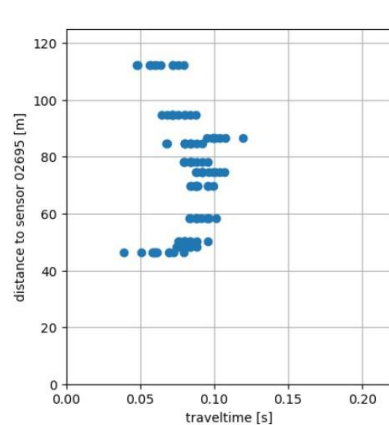
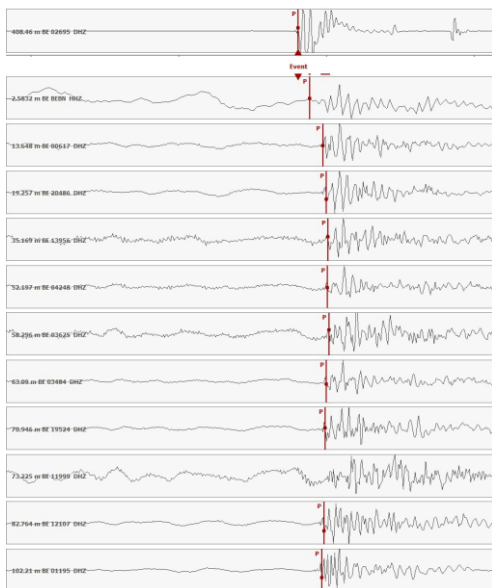
BEBN – Eben-Emael

EC8 – A (hard rock station)

$v_{S30}=1100$  m/s



## Active shots

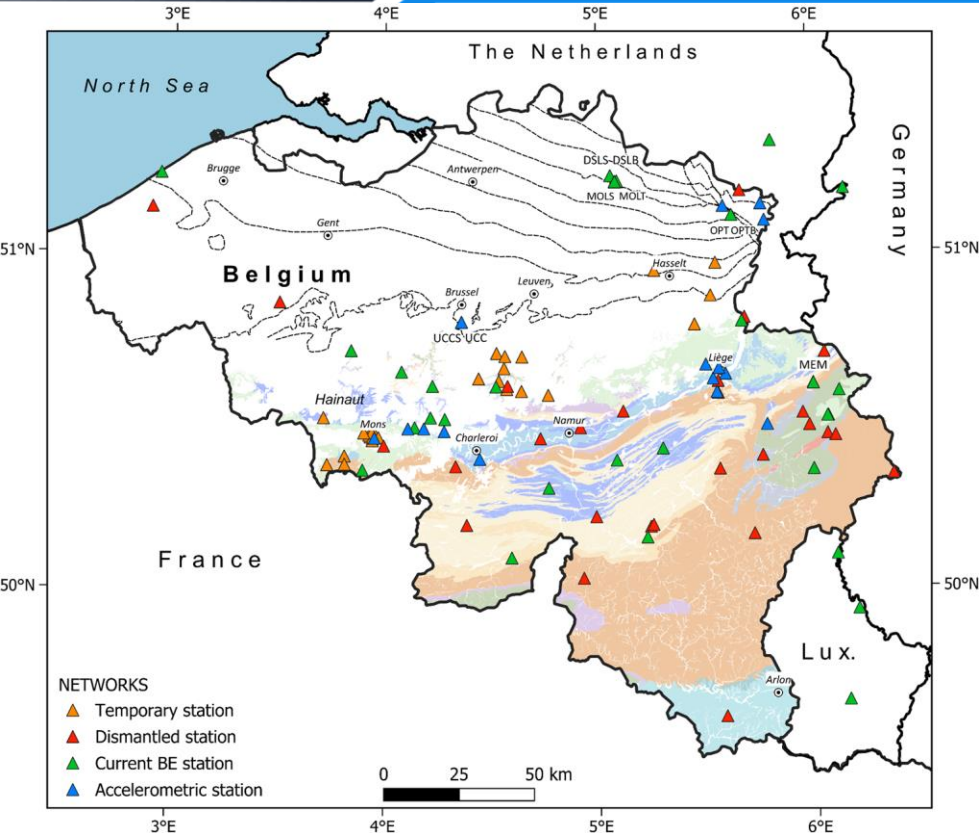




## Network results



Orfeus Stationbook parameters	CLA	EBN	GES	OPT	OPTB	RQR	SKQ	SNF	TGA	UCC	UCCB
<b>Geological Unit</b>	Limestone (Longpré formation)	Chalk (Upper Cretaceous, Maastrichtian)	Sandstone (Famennian, Ciney formation)	Fine sands (Mol formation)	Marine clays (Heers formation)	Slates (Brutia formation)	Mudstone - Siltstone (Steenkerque formation)	Limestone (Lives formation)	Shale (Mousty Formation)	Sands (Lede formation)	Quartzite/Slate (Tubize formation)
<b>Morphology Class</b>	T2	n/a	T1	T1	n/a	T1	T1	T1	T2	T1	n/a
<b>Ground Type EC8</b>	A (hard rock)	A (hard rock)	A (hard rock)	C (sedimentary deposits of hundreds of meters)	A (hard rock)	A (hard rock)	A (hard rock)	A (hard rock)	A (hard rock)	B (sedimentary deposits of tens of meters)	A (hard rock)
<b>Groundwater Depth [m]</b>	25 - 30	~ 20	~ 10		n/a	n/a	< 10	< 2	7	n.n.b.	n/a
<b><math>v_{S_{30}}</math> [m/s]</b>	2900	1100	982 +/- 32	362	846	> 800	1492 +/- 28	> 800	1188 +/- 170	280	1800
<b><math>f_0</math> [Hz]</b>	n/a	n/a	~ 50	0.28	n/a	n/a	n/a	n/a	n/a	0.90	n/a
<b>Amp(<math>f_0</math>)</b>	n/a	n/a	10	3.8	n/a		n/a		n/a	14	n/a
<b>Basin Flag</b>	False	False	False	True	n/a	False	False	False	False	True	n/a
<b>Bedrock Depth [m]</b>	0	0	0.3	356	0	0	0	0	0	115	0
<b>Description</b>											



## Site-characterization – WP 4.2

EPOS-BE knowledge transfer to site characterisation of

- Current network (45)
- Dismantled stations (29)
- Temporary networks (34)
- Accelerometric network (16)

[LINK](#)

- > BELSHAKE database (Brain.BE 2.0)
- > example for industrial networks
- > future stations

## Scientific output – WP 4.2

### Conferences:

- Combining active and passive seismic methods for non-invasive site characterization of the Belgian seismic network. Martin Zeckra, Koen Van Noten, Thomas Lecocq. The 3<sup>rd</sup> European Conference on Earthquake Engineering and Seismology (3ECEES). 04 - 09 September, Bucharest, Romania.
- Bedrock depth characterisation below public buildings with a geothermal interest using ambient seismic noise. Koen Van Noten, Martin Zeckra (presenter). The 3<sup>rd</sup> European Conference on Earthquake Engineering and Seismology (3ECEES). 04 - 09 September, Bucharest, Romania.

### Publications:

- Sensitivity, Accuracy and Limits of the Lightweight Three-Component SmartSolo Geophone Sensor (5 Hz) for Seismological Applications. Martin Zeckra, Koen Van Noten, Thomas Lecocq. Pre-print: <https://doi.org/10.31223/X5F073>

## (planned) Scientific output – WP 4.2

- ORFEUS Stationbook (EPOS.BE + Accelerometers)
- Site-characterization webpage (seismowiki inspired)
- EPOS-BE – paper (BEBN Cretaceous site-amplifications visible in felt reports)





Thanks you for  
the attention.

Merci.

Bedankt.

Dankeschön.