

# ET—ILIAS GWA Joint Meeting

*Cascina (Pi) Italy, 24—26 November 2008*

Search for **surface** site in Germany,  
**underground** detector configuration

Albrecht Rüdiger

AEI Hannover



# EINSTEIN TELESCOPE

gravitational wave observatory

CENTRAL FACILITY

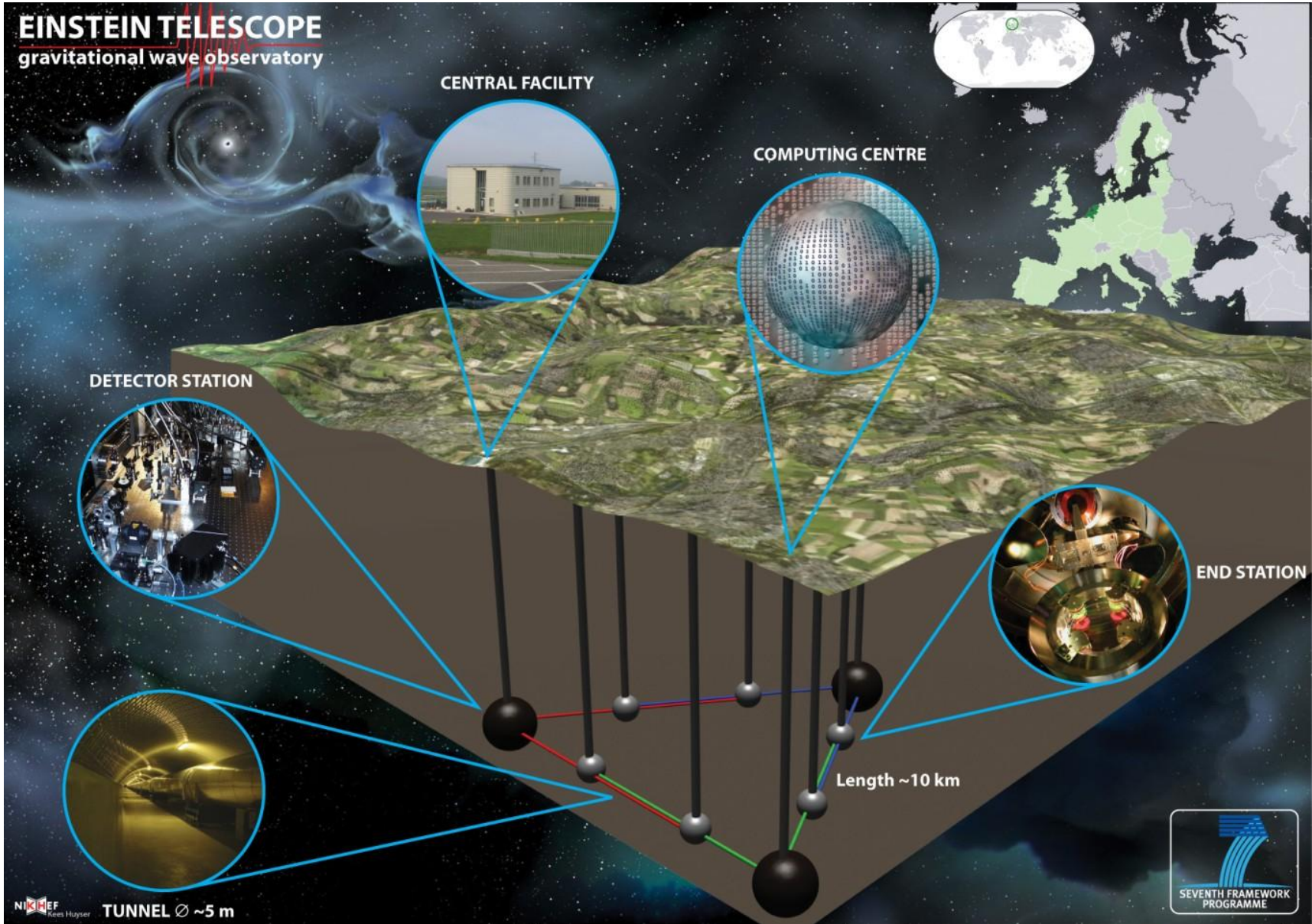
COMPUTING CENTRE

DETECTOR STATION

END STATION

Length ~10 km

TUNNEL  $\varnothing$  ~5 m



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gravitational wave observatory

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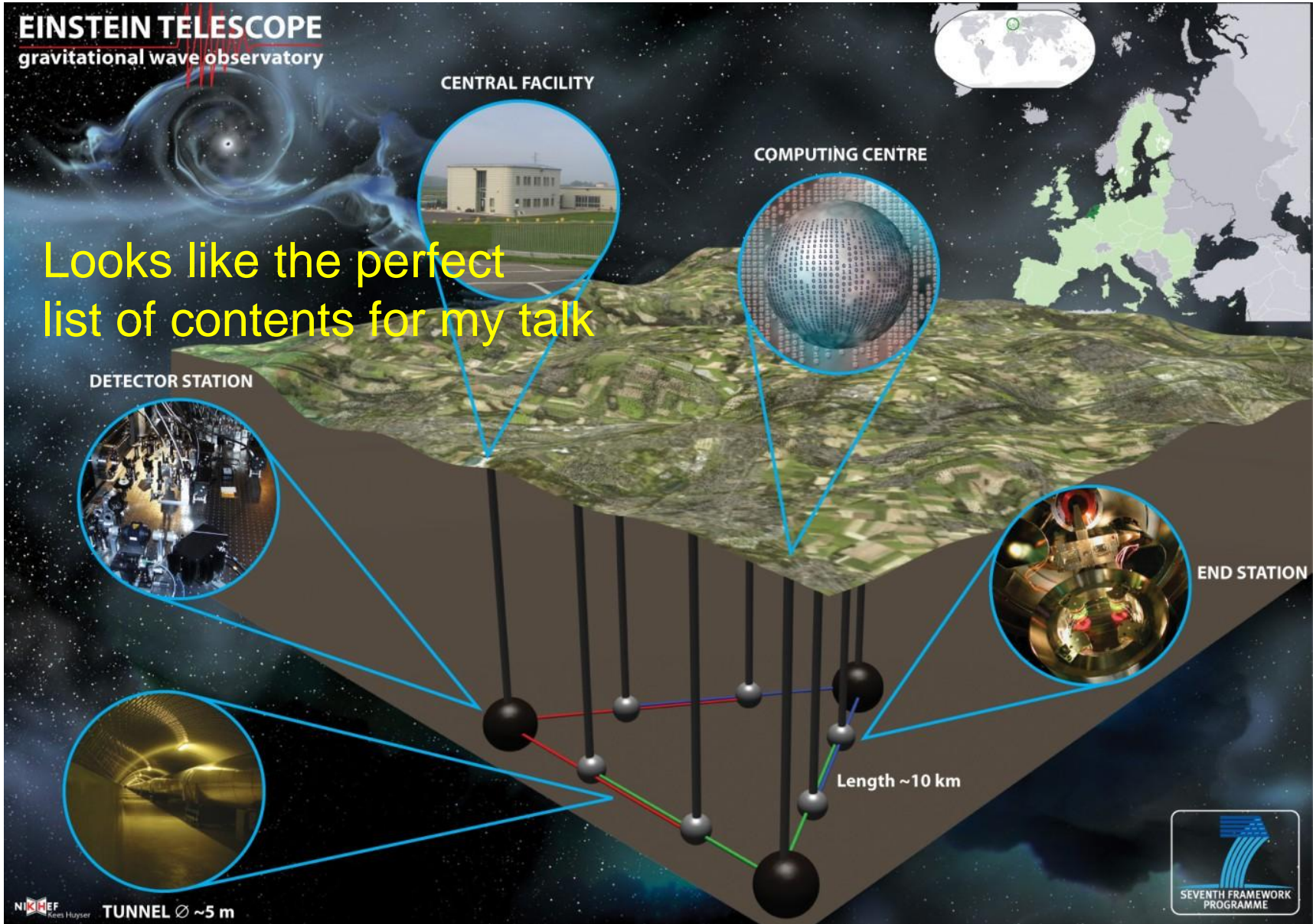
Looks like the perfect list of contents for my talk

DETECTOR STATION

END STATION

Length ~10 km

NKXEF Kees Huyser TUNNEL  $\varnothing$  ~5 m



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COMPUTING CENTRE



world wide

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Length ~10 km

Nikhef  Kees Huyser TUNNEL  $\varnothing$  ~5 m



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COMPUTING CENTRE



world wide



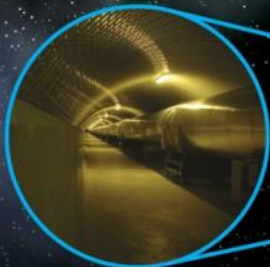
EU

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NKHEF Kees Huyser TUNNEL  $\varnothing$  ~5 m



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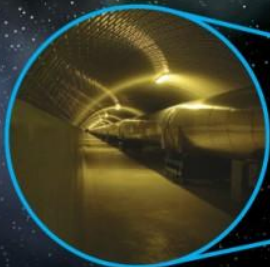
DETECTOR STATION



underground



END STATION



Length ~10 km

NEMO Kees Huyser TUNNEL  $\varnothing$  ~5 m



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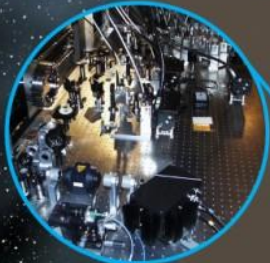
world wide



EU

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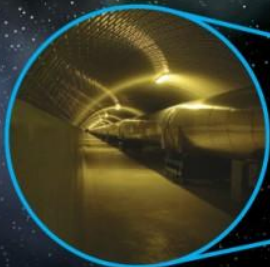
underground

END STATION



triangular

Length ~10 km



NEMO Kees Huyser TUNNEL  $\varnothing \sim 5$  m



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DETECTOR STATION



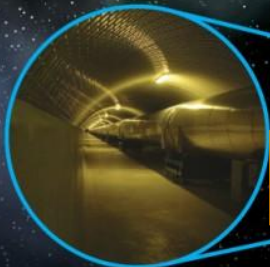
underground

END STATION



triangular

Length ~10 km



tunnel

NEMO Kees Huyser TUNNEL  $\varnothing \sim 5$  m





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gravitational wave observatory

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DETECTOR STATION

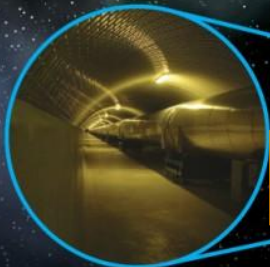


underground



END STATION

triangular



tunnel

Length ~10 km

NEMO Kees Huyser TUNNEL  $\varnothing \sim 5$  m



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gravitational wave observatory

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world wide



EU  
GE



Looks like the perfect list of contents for my talk

DETECTOR STATION



surface

underground



END STATION

triangular

Length ~10 km



tunnel

NEMO KECK HUYSER TUNNEL  $\varnothing \sim 5$  m



# Review of Site Search 1989 (Albrecht Rüdiger, 6 March 2007)

In the late years of the 1980s, a nationwide search for sites for the proposed 3 kilometer German GW detector was carried out, then later for the proposed British-German detector

The boundary conditions of this 1989 search are listed in the next slide



# Review of Site Search 1989

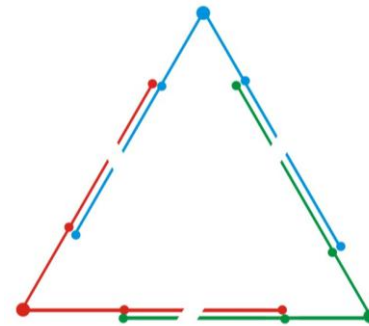
Boundary conditions were the following:

Location inside the **BRD** (before unification)

Arm length **3 km**

Installation **close to surface**

**Triangular** configuration

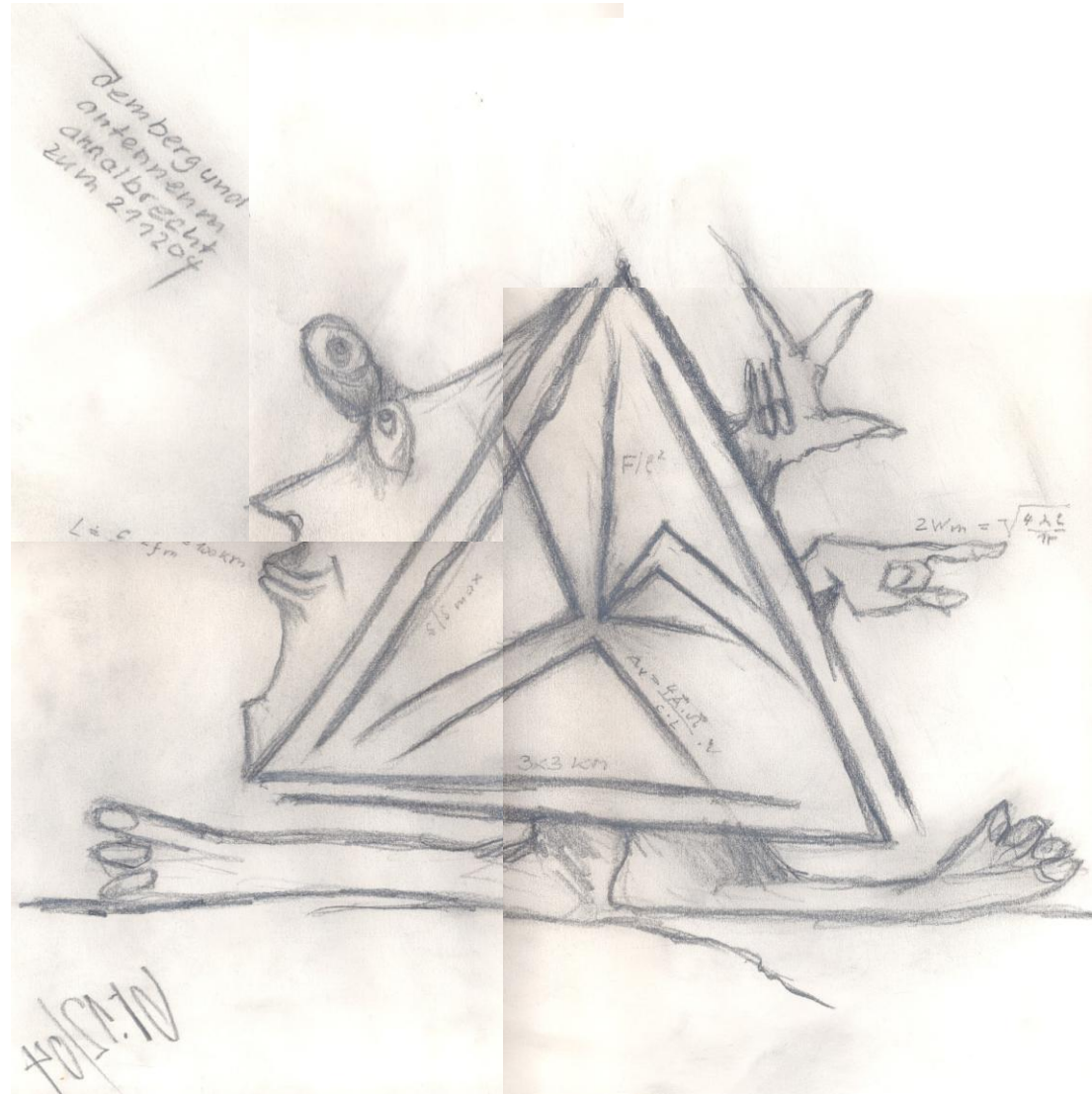


When I tried to explain the triangle  
to a professor of sociology of sports,

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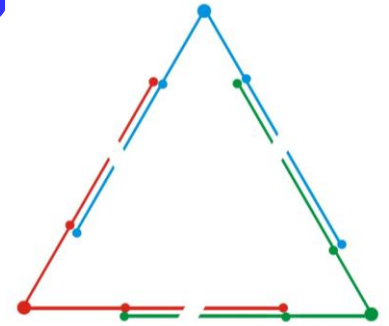
that's how he  
depicted me:

To the deep  
mine  
and antenna man  
Albrecht  
21.12.2004



# Why triangular configuration ?

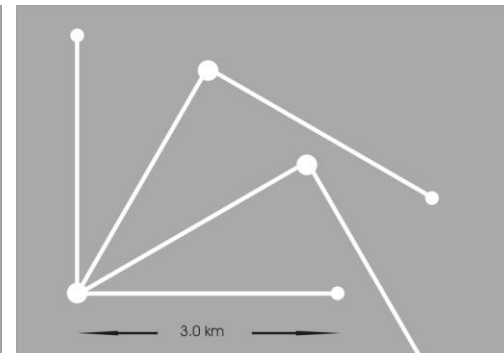
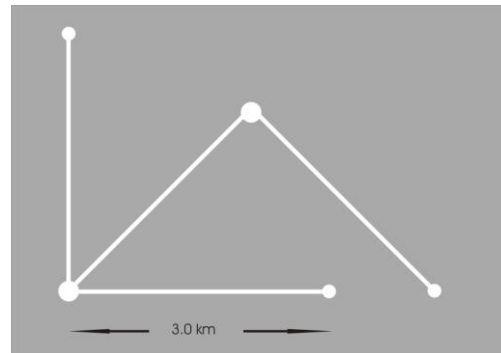
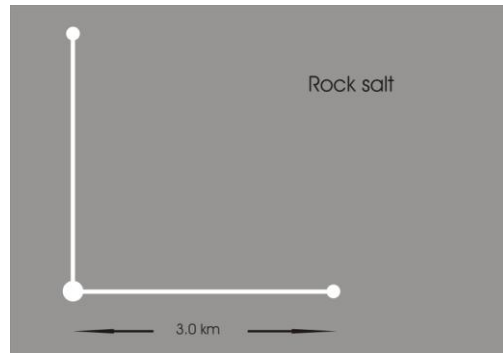
Make optimum use of **civil engineering** and **infrastructure** efforts



simple

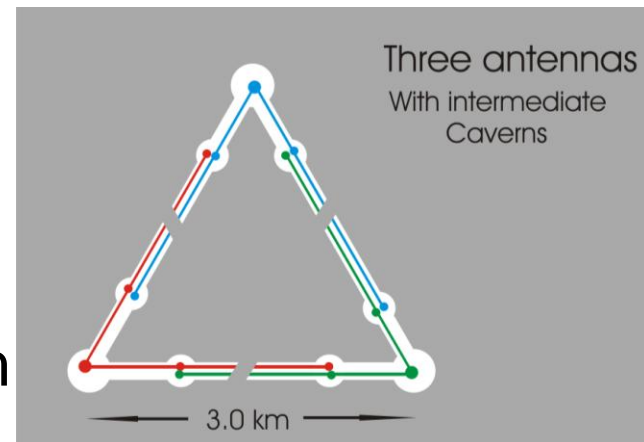
sufficient

redundant



wasteful in length of tunnels  
wasteful in area („footprint“)

therefore: triangular scheme  
became baseline of **surface** search

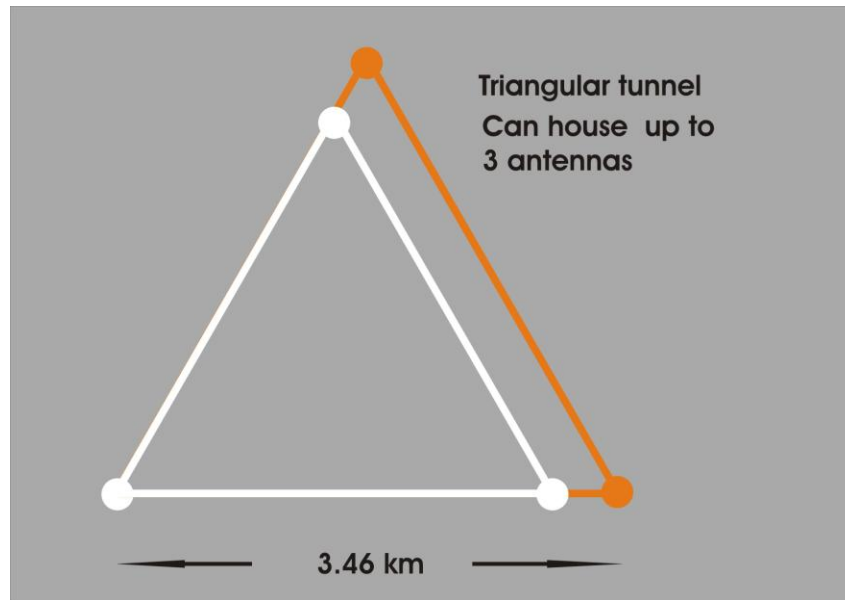


# Triangular encasement

saving space („footprint“)

and total tunnel (encasement) length

The price: **loss in response** by 13.4 %



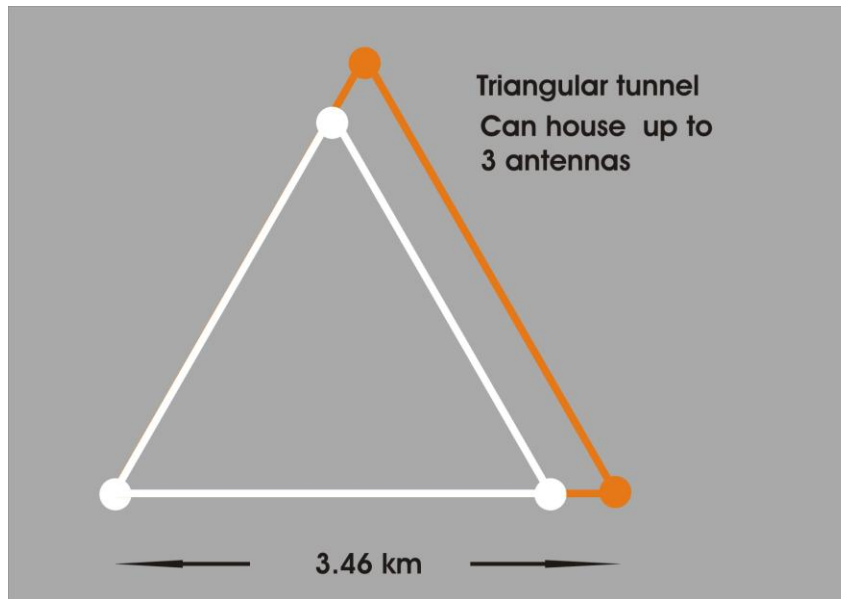


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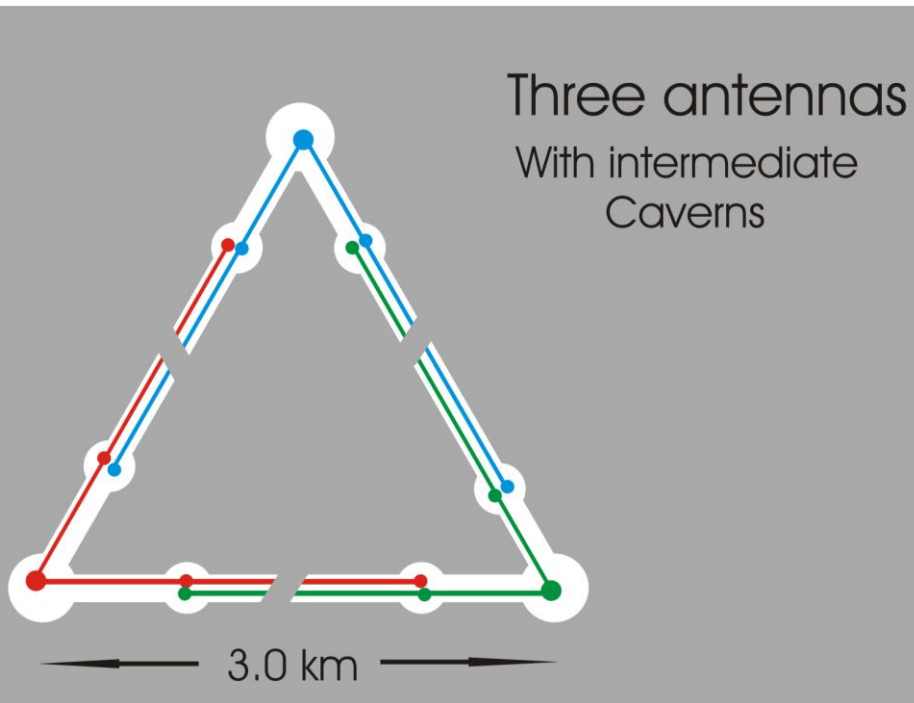
The price: **loss in response** by 13.4 %



make arms **longer** ??  
e.g. by these 13.4 %  
( $3 \times 3.46 < 4 \times 3$  km)  
(for lower frequencies)



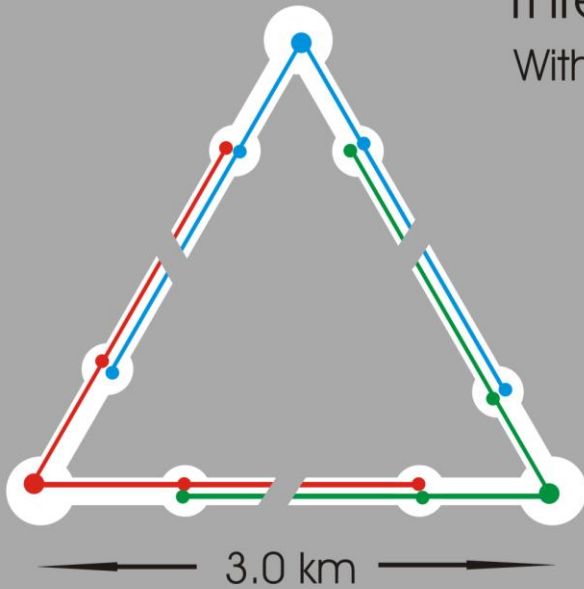
# Best usage of tunnels



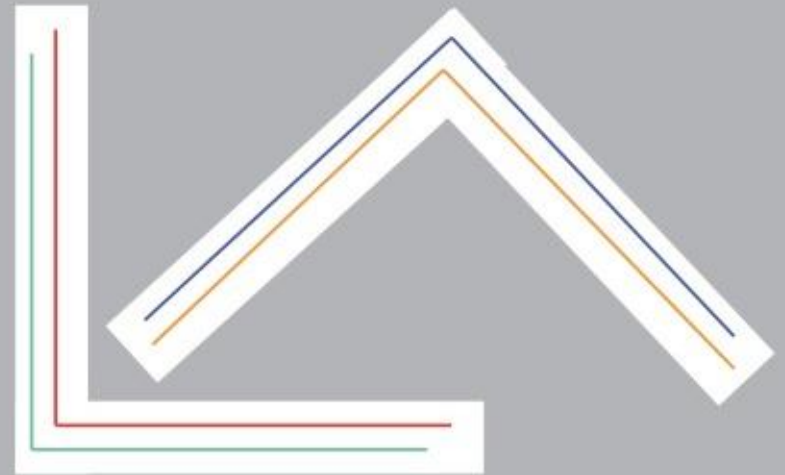
3-arm configuration,  
reduces „footprint“,  
reduces tunnel length

# Best usage of tunnels

Three antennas  
With intermediate  
Caverns



3-arm configuration,  
reduces „footprint“,  
reduces tunnel length



Four antennas

**Riccardo** argues (correctly, of course)  
that 4-arm configuration above has  
same response per total tunnel length

# Review of Site Search 1989

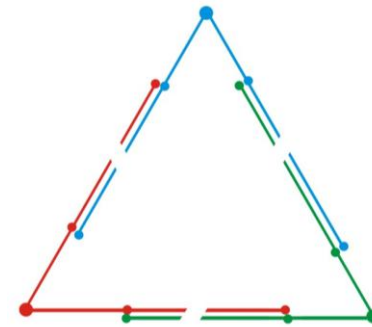
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**Triangular** configuration



Minimum work for levelling (**grading**) of ground

Sufficiently near to good **infrastructure**

Sufficiently low **seismic noise**

Sufficient distance from **man-made noise**



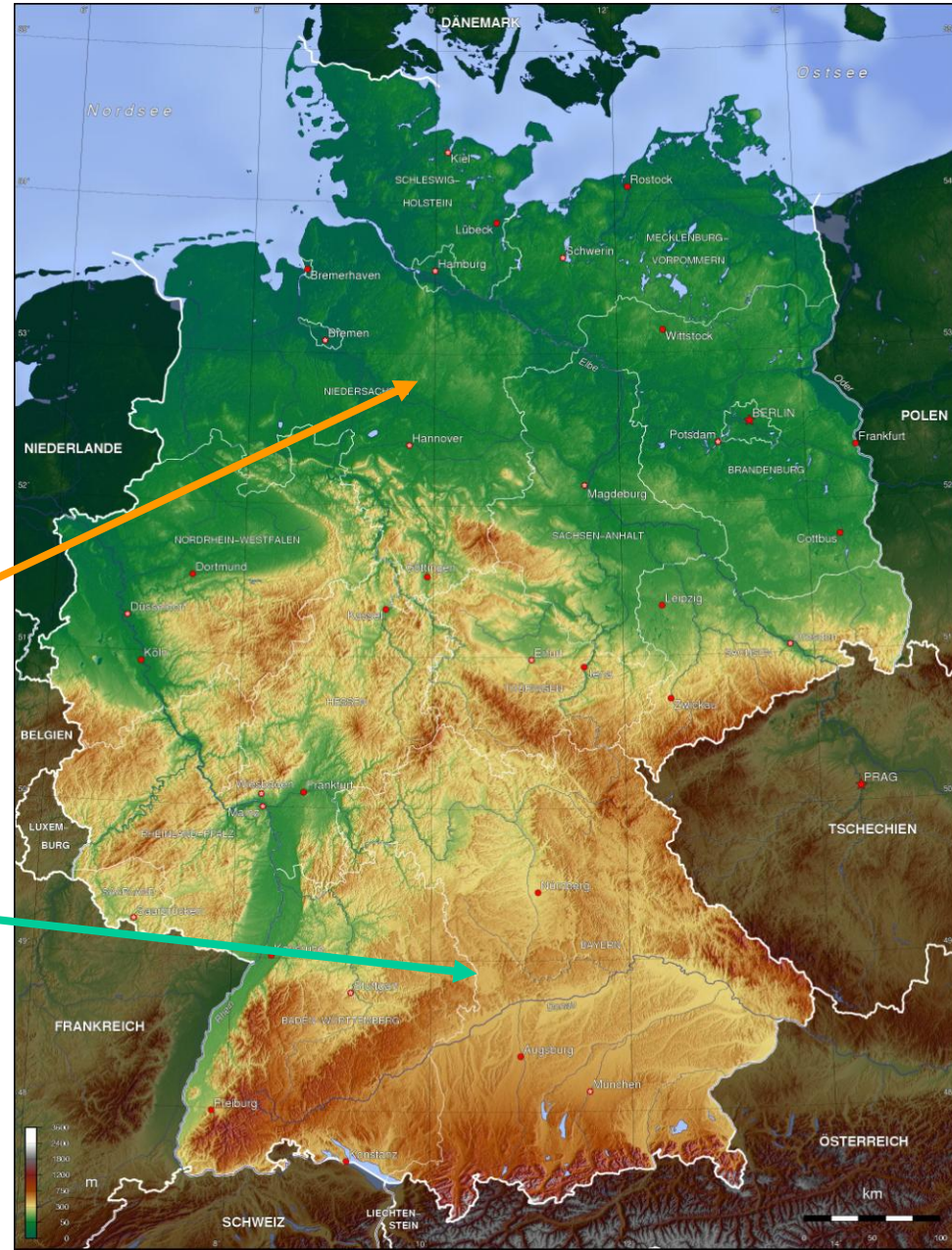
# Site Search 1989

The result:

In the heavily populated BRD, only few extended regions were found fulfilling the strict requirements

These were typically in the North of Germany (Niedersachsen) and along the Danube (Bavaria)

Two sites, one in Bavaria, one in Niedersachsen, were given closer scrutiny



# Review of Site Search 1989--92

Parallel to **surface** search, studied **underground**

Main objectives:

reduce seismic noise

acoustic noise

large caverns to reduce density noise (**Cella**)



# Review of Site Search 1989--92

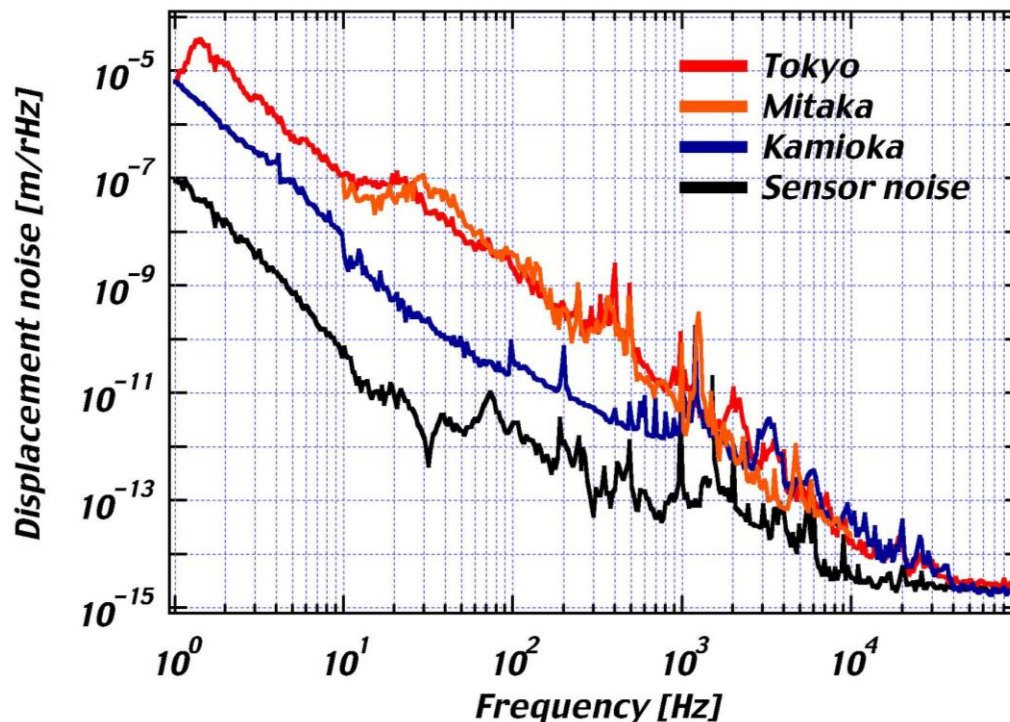
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typical reduction:  
2 powers of ten  
over wide range

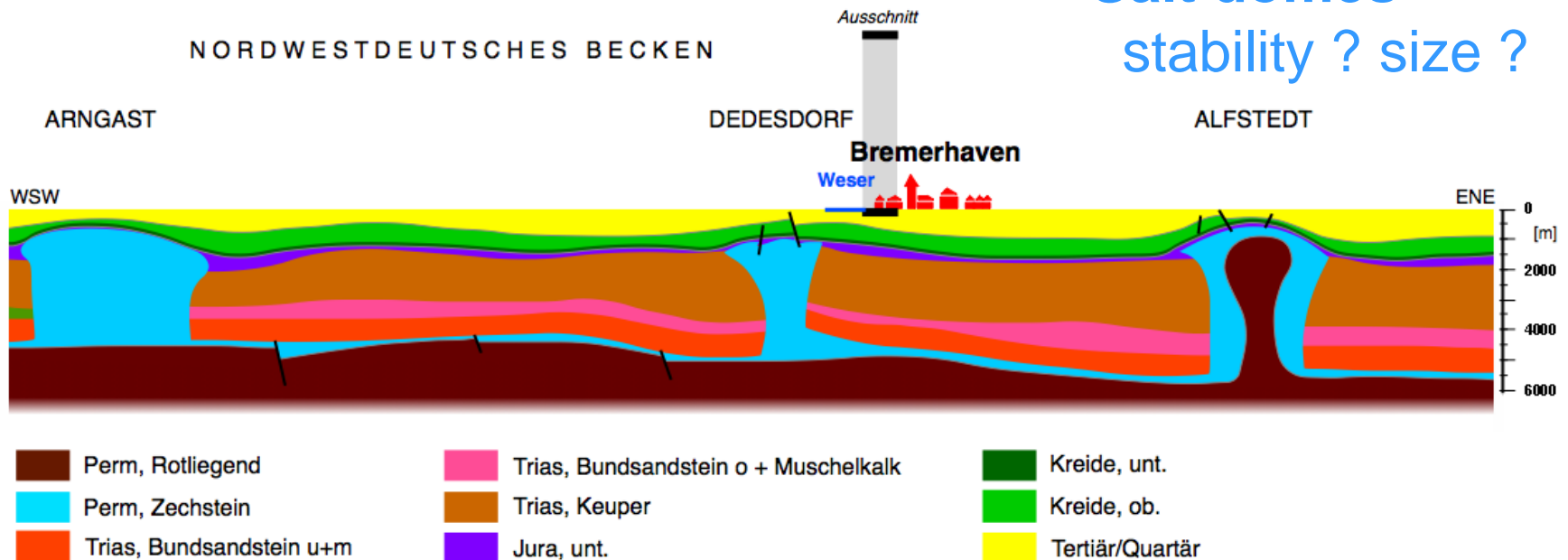


# Review of Site Search 1989--92

Search for **underground** sites:

Suggestion of using **salt deposits** in Germany  
(1990 inquiry with „Kali und Salz“, now „K+S“)

**Salt domes**  
stability ? size ?

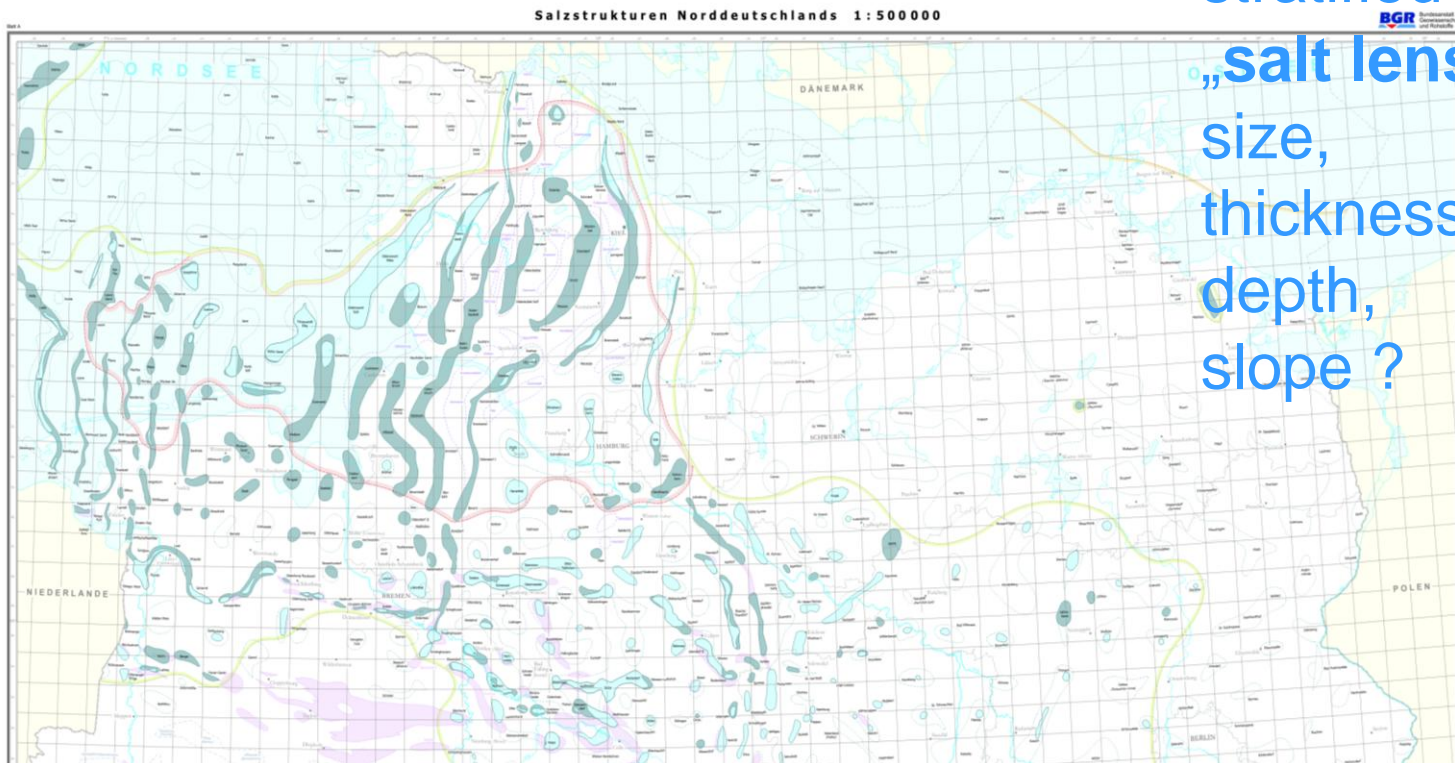




# Review of Site Search 1989--92

Search for **underground** sites:

Future investigations in **salt deposits** in Germany  
(better suited: **salt lenses**)



stratified layers

„salt lenses“

size,  
thickness,  
depth,  
slope ?



# Mining in rock salt

Digging in salts is made by means of continuous mining machines like this one

Arbitrary cave shapes are possible within the rock stability limits (30-50 m depending on salt quality)



Courtesy *Riccardo de Salvo*

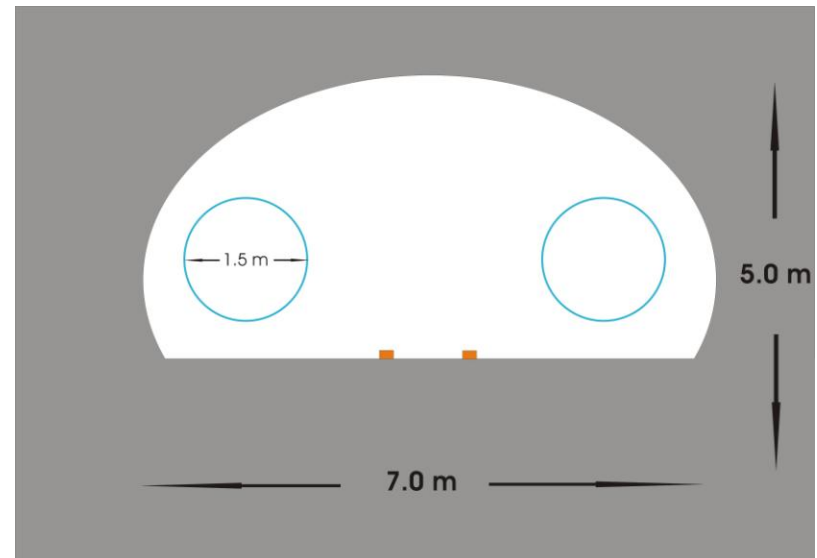
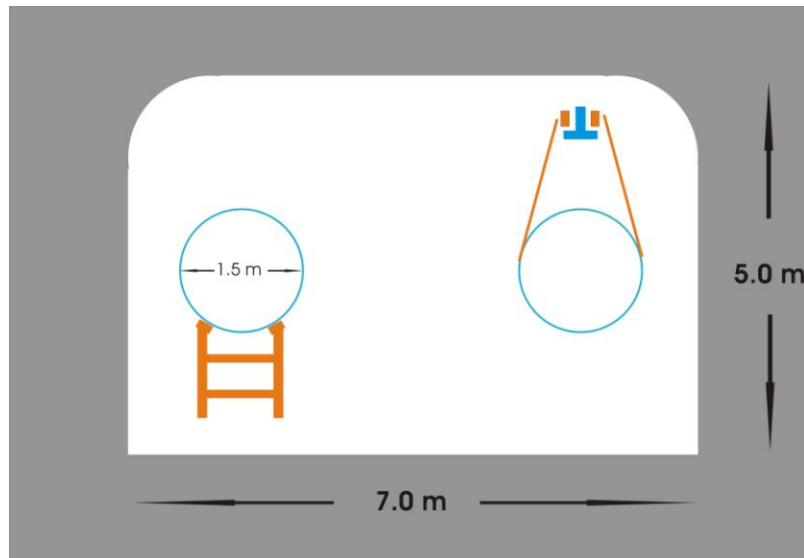
# Accommodation of pipes in tunnel

Transport equipment, pipe segments

Plenty of room in tunnels (**Riccardo**),

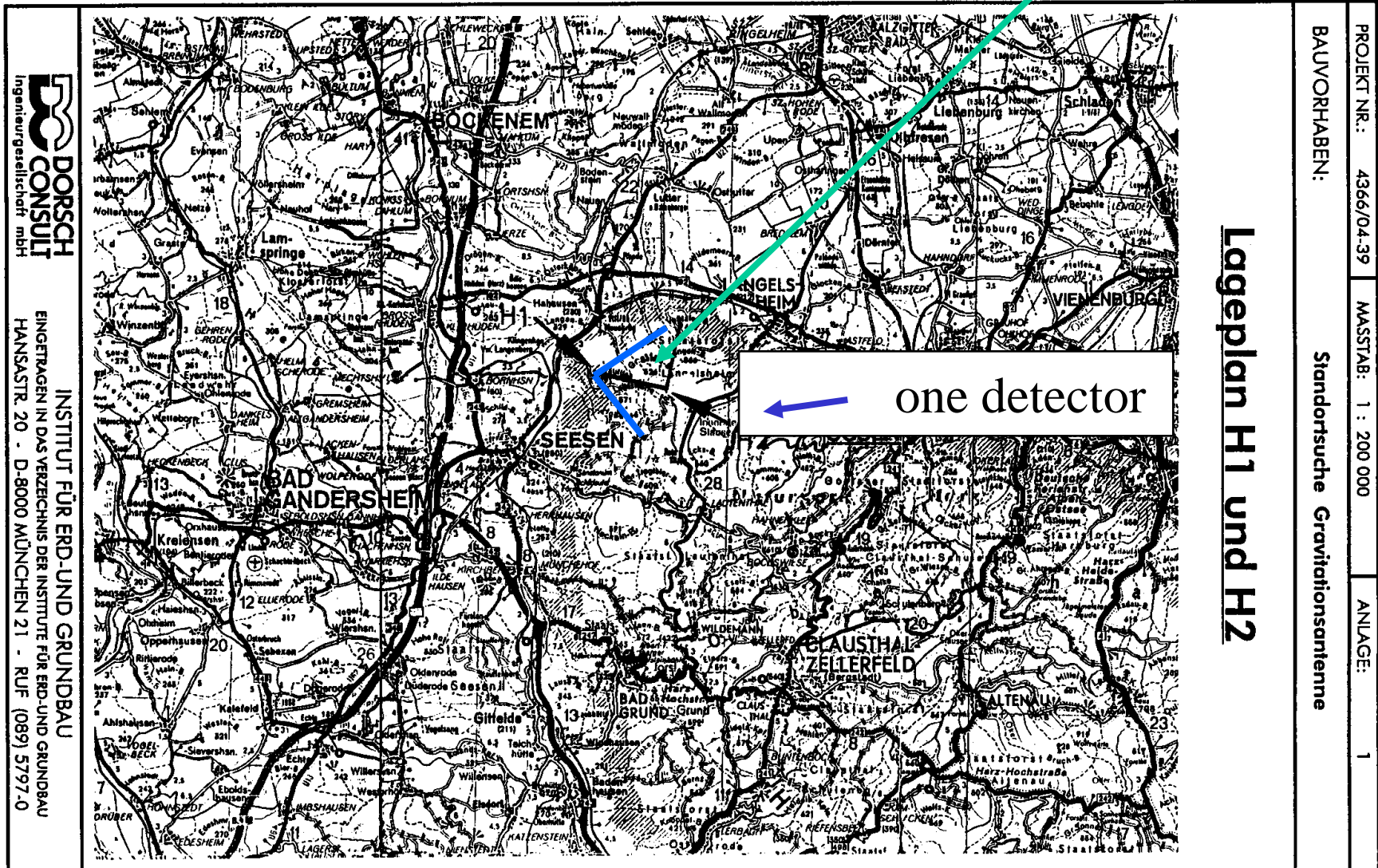
non-circular cross section

transport pipes on rails, on beam (**GEO**)



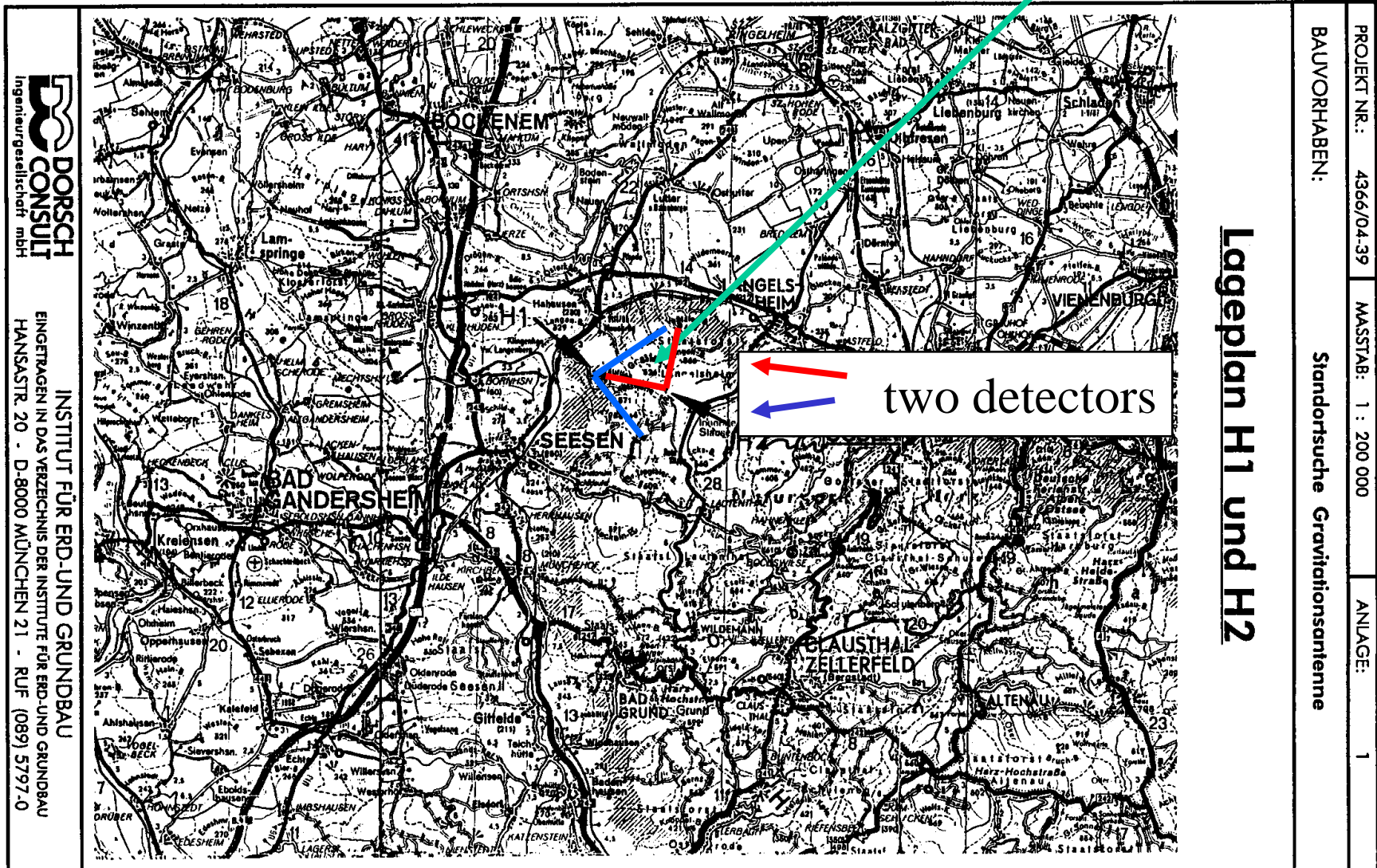
# Review of Site Search 1989--92

Sites near abandoned **ore mines**, Harz Mountain range



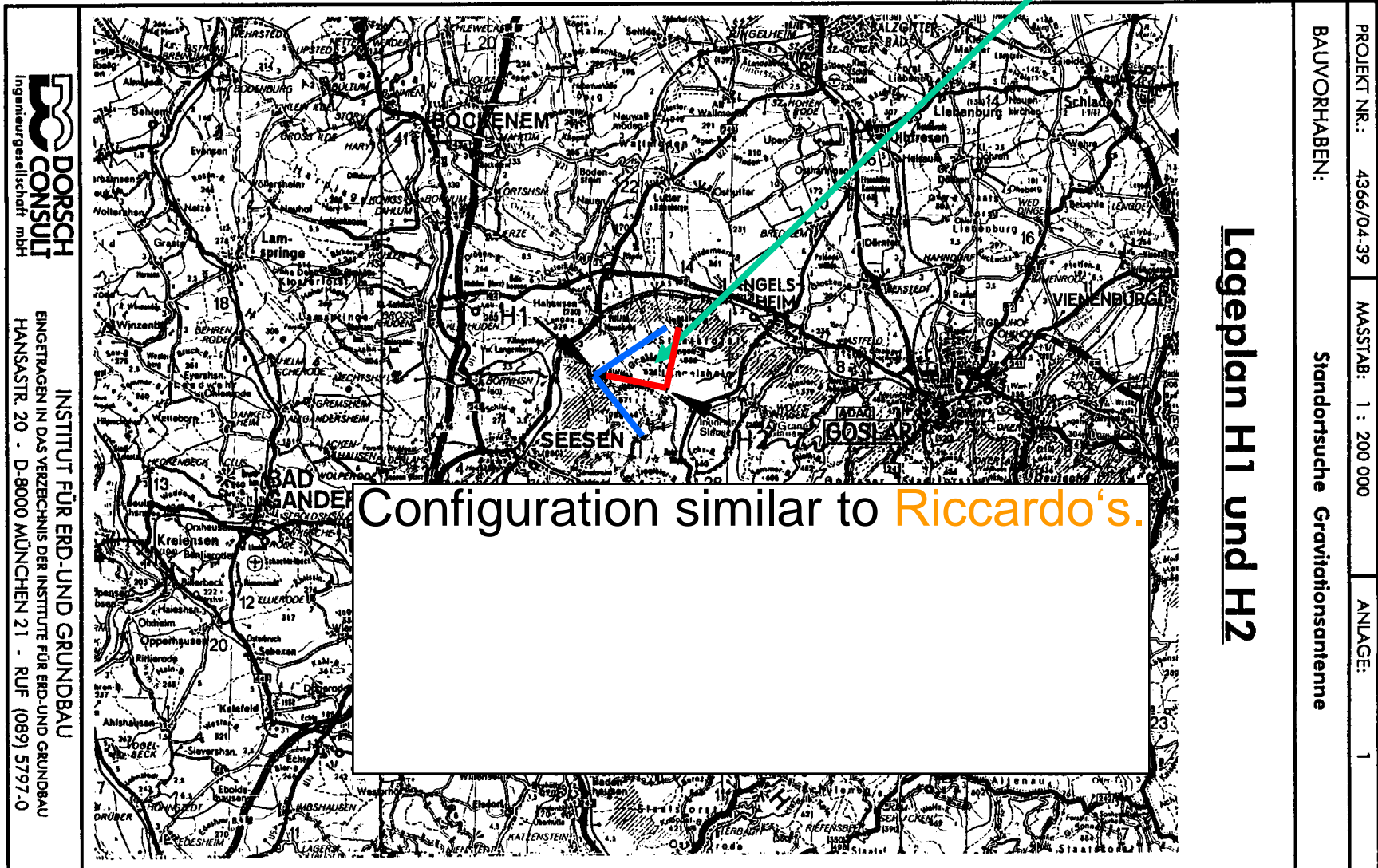
# Review of Site Search 1989--92

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# Review of Site Search 1989--92

Sites near abandoned **ore mines**, Harz Mountain range



PROJEKT NR.: 4366/04-39

MASSTAB: 1 : 200 000

ANLAGE: 1

BAUVORHABEN:

Standortsuche Gravitationsantenne

Lageplan H1 und H2

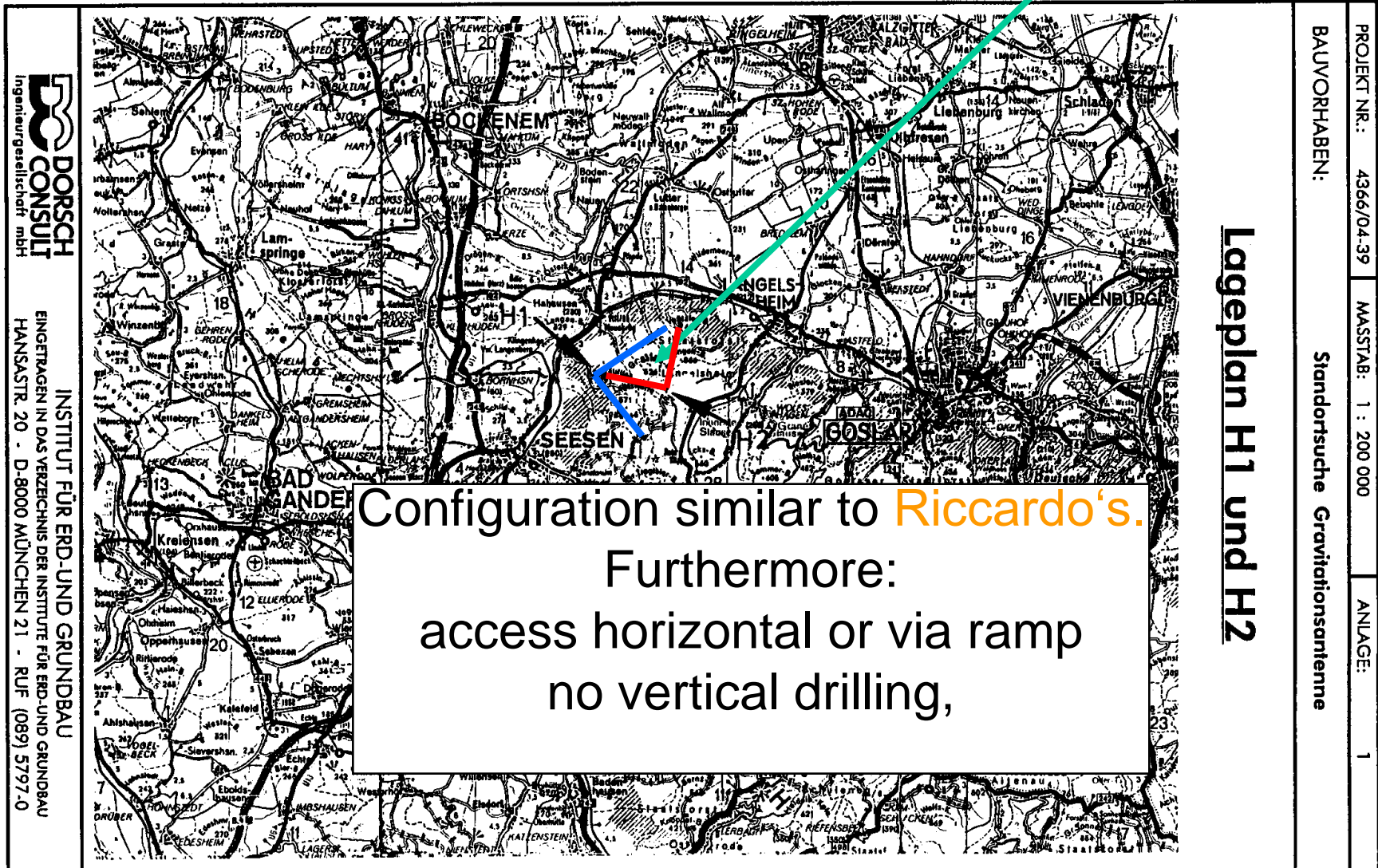
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# Review of Site Search 1989--92

Sites near abandoned **ore mines, Harz Mountain range**



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PROJEKT NR.: 4366/04-39  
BAUVORHABEN: Standortsuche Gravitationsantenne

MASSTAB: 1 : 200 000

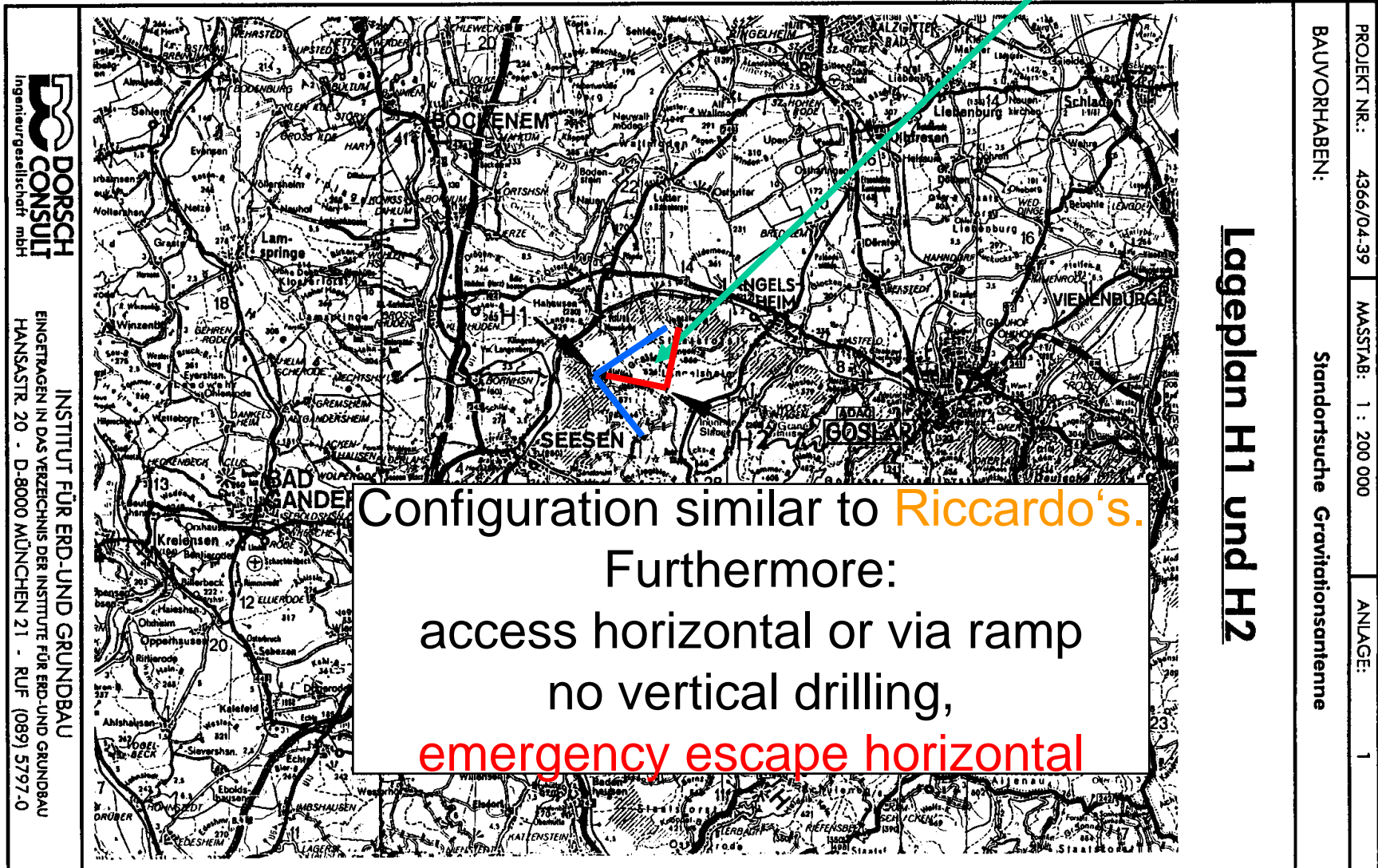
ANLAGE: 1

**Lageplan H1 und H2**



# Review of Site Search 1989--92

Sites near abandoned **ore mines**, Harz Mountain range



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Standortsuche Gravitationsantenne

ANLAGE: 1

**Lageplan H1 und H2**





# Review of Site Search 1989 -- 1992

Search for **3 km sites** was abandoned in 1992  
due to lack of funding for **large** detector

Instead, the **smaller** detector, later **GEO 600**,  
was actively pursued



# Review of Site Search 1989 -- 1992

Search for **3 km sites** was abandoned in 1992  
due to lack of funding for **large** detector

Instead, the **smaller** detector, later **GEO 600**,  
was actively pursued

Became important test bed for developing  
**advanced** techniques, technologies



# Review of Site Search 1989 -- 1992

## Relevance of results, as of today:

The former DDR may provide more ideal areas,  
so **surface sites** might be more readily available

Targeted ET arm lengths now are longer than 3 km,  
thus further reducing the availability of sites.

No **surface site** for 10 km appears in sight

The option of going **underground** makes some of  
the search criteria of 1989 rather obsolete

If cost of **underground** mining (**rock salt**)  
turns out to be very low, the triangular configuration  
loses a little of its main economic advantage



# Cut cost of vacuum tubes

In 1990s, GEO proposed **corrugated pipes**

Investigations at RAL, UK (**R. Bennett**)

Cost of **stainless steel** dominant

1.2 m diameter tubes tested, successful

Such tubes later used for GEO 600



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ET: might save up to **25 million €**



# Investigations RAL

(R. Bennett)

5 m tube tested,  
1.2 m in diameter

used in **GEO 600**



# Cut cost of vacuum tubes

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Investigations at RAL, UK (**R. Bennett**)

Cost of **stainless steel** dominant

1.2 m diameter tubes tested, successful

Such tubes later used for GEO 600

**Safety**: inherent **bellows** feature

will need added **stiffening rings**  
restraining elements



# History of site search and cost reduction

Some of the 1990 issues may be obsolete,  
some may find better solutions,  
but further investigations are required





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Realization of ET is not only matter of  
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# History of site search and cost reduction

Some of the 1990 issues may be obsolete,  
some may find better solutions,  
but further investigations are required

Realization of ET is not only matter of  
technological realizability,

but also of having attractive cost estimates



**thank you**



