GeoBlocks: Quantification of Uncertainties in Geological Models

Friedrich Carl (LIH) Chair of Engineering Geology and Hydrogeology, RWTH Aachen University
Jian Yang (CG3) Computational Geoscience, Geothermics and Reservoir Geophysics, RWTH Aachen
Carlos Colombo (CG3) Computational Geoscience, Geothermics and Reservoir Geophysics, RWTH Aachen
Dr. Marlise Colling Cassel (GIA) Chair of Geology and Paleontology and Geological Institute, RWTH Aachen University
Dr. Peter Achtziger-Zupančič (IEG), Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG, Aachen
Prof. Peter Kukla, PhD (GIA), Chair of Geology and Paleontology and Geological Institute, RWTH Aachen University
Dr. Frithjof Bense (BGR), Federal Institute for Geosciences and Natural Resources
Prof. Florian Wellmann, PhD (CG3) Computational Geoscience, Geothermics and Reservoir Geophysics, RWTH Aachen

LIH Department of Engineering Geology and Hydrogeology | RWTH AACHEN UNIVERSITY | RWTH AACHEN UNIVERSITY | EMR Energy & Mineral Resources Group | RWTH AACHEN UNIVERSITY | BGR | BGE BUNDESGESELLSCHAFT FÜR ENDLAGERUNG

Short reminder: Context of GeoBlocks project

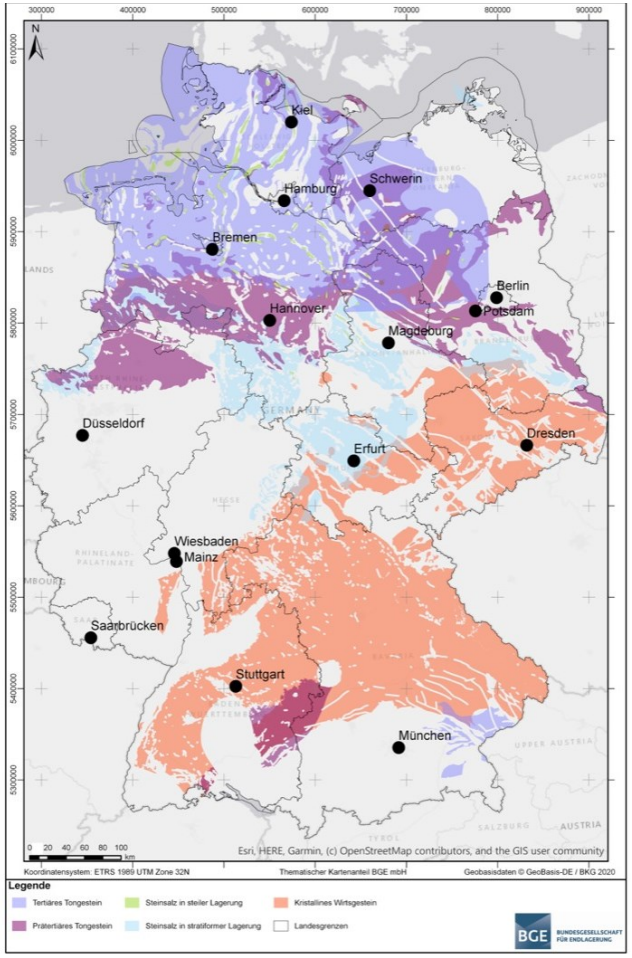
- In site selection geological modelling is performed for suitability assessment of areas
- However, data gathered over decades & partly by private companies → data quality & quantity vary
- Input data possess uncertainties (propagated and potentially increased)
- Uncertainties difficult to quantify & compare
- GeoBlocks was initiated with main objective:

Create open-source workflow for geological modelling that includes

(1) quantification & visualization of uncertainties

(2) optimization of sampling procedures

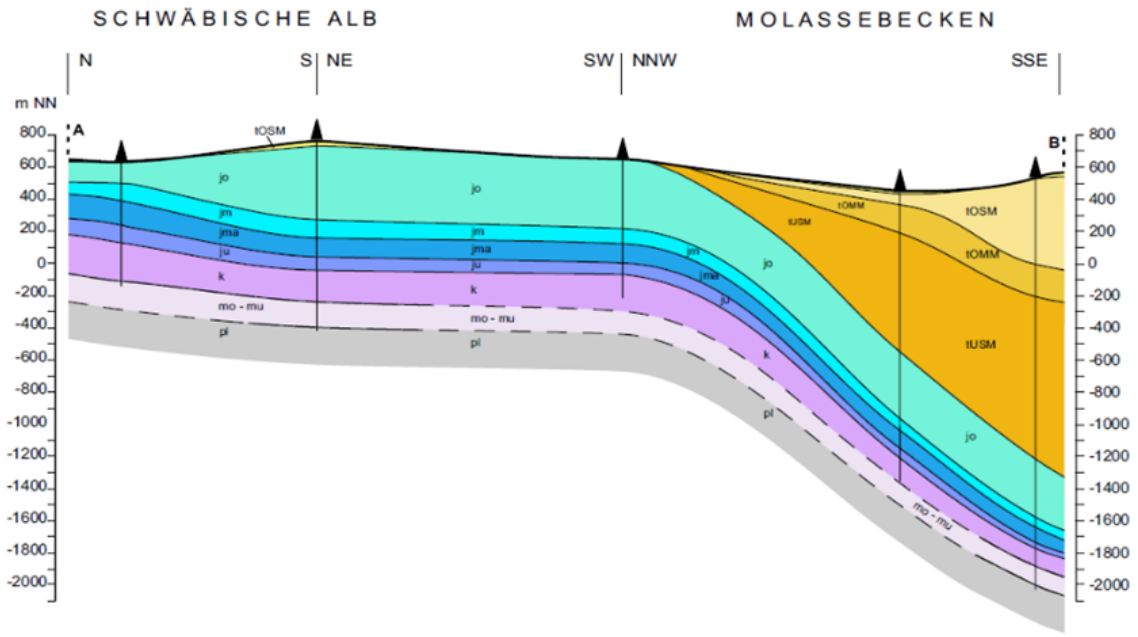
Sub areas after StandAG



https://www.bge.de

Reminder: geological complexity & how we address it

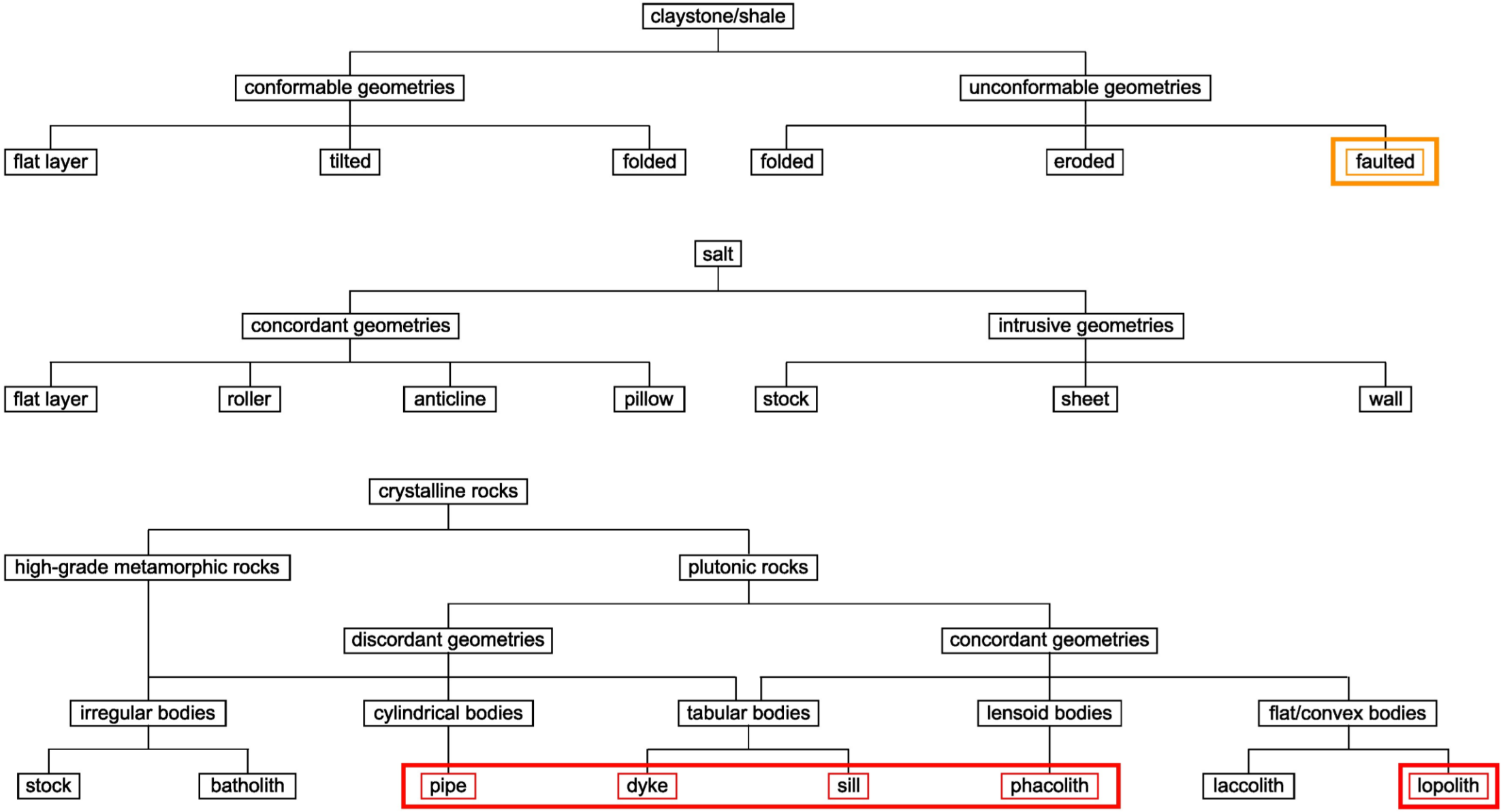
- Workflow for geomodelling has to be compatible for varying geological-tectonic settings and input data sets
- Results of workflow shall be comparable
- Potential host rocks show large range of subsurface geometries
- Systematization into geometrical end members



Section through the Swabian Alb & molasse basin. Hoth, et al. (2007)

Intrusive structures from Saxony. ArcGIS – Erzgebirge 3D

Geological-geometrical systematization



Current focus: categorization & comparison of real structures

- Question: how to describe and compare datasets, geological structures & models quantitatively
- Datasets differ in quality, quantity & spatial distribution and available data types
- Comparison of models can demonstrate the differences of the datasets indirectly

➢ Two approaches:

- Determine „simple“ geometrical/statistical properties for characterization & comparison of structures to illustrate differences of geometries quantitavely
- Use „complex“ approach to compare (implicit) geological models directly

First approach: geometrical/statistical properties for structural characterization

- Most comprehensible parameters to describe a structure geometrically: lateral & vertical dimensions
- Challenges:

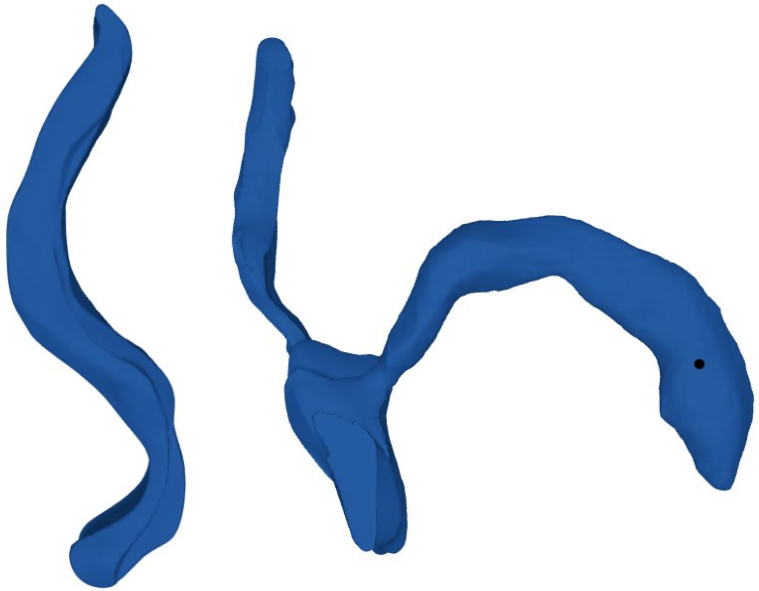
❖ Develop a methodology that can measure the full range of geological complexity

❖ Minimize time effort to measure individual structures → automatize processes

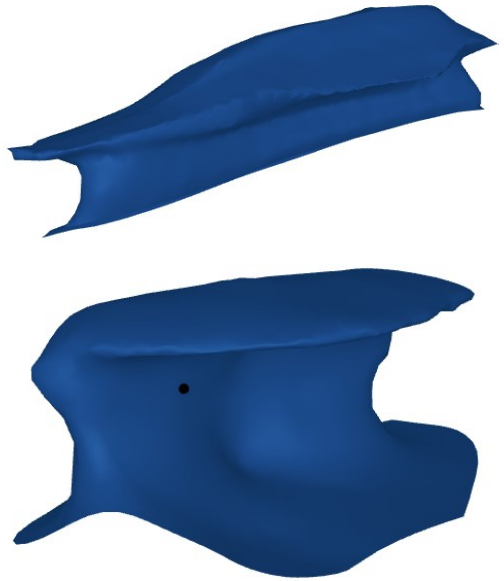
➢ Develop methodology based on salt structures (highest range of geometrical-geological complexity) in Python

- How to measure lateral and vertical extents of irregular geometries?

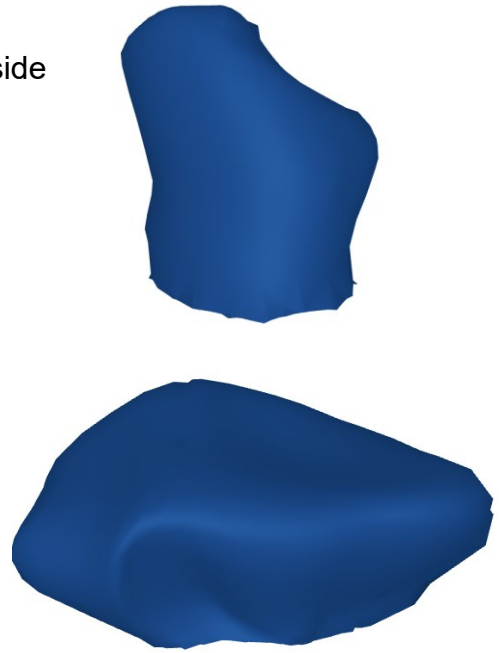
View from above



Oblique view



Views from side

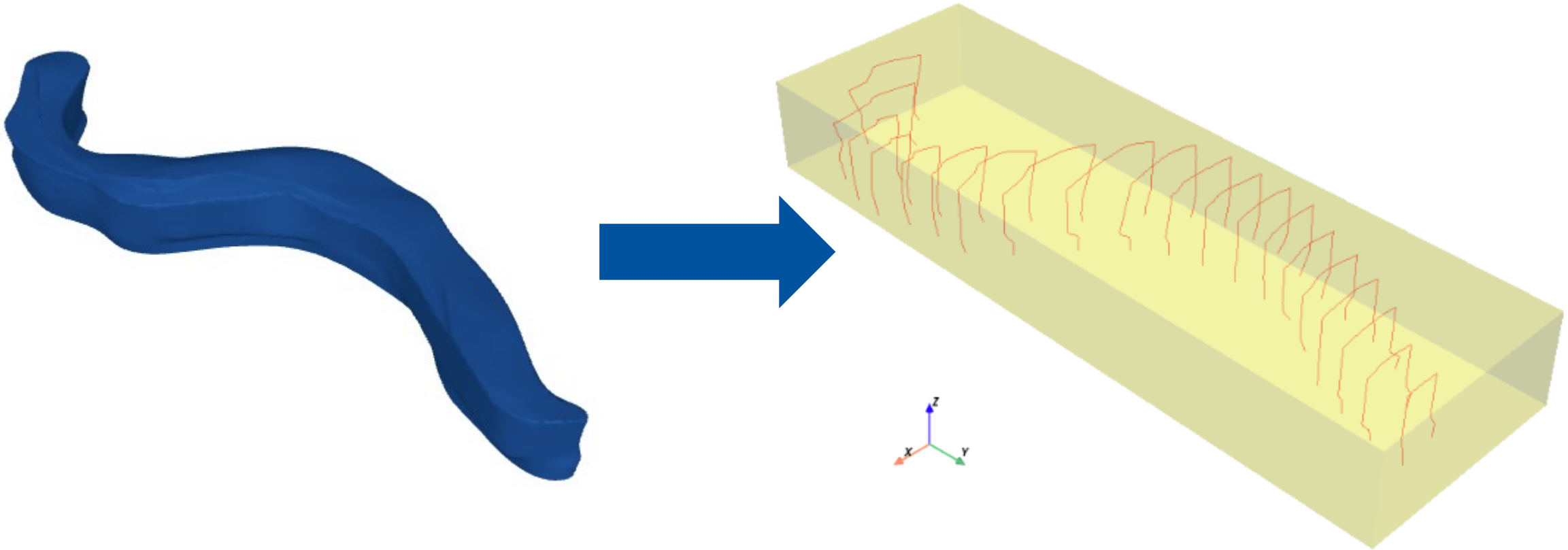


Geological 3D model „Tieferer Untergrund Norddeutsches Becken (TUNB)“.

Procedure

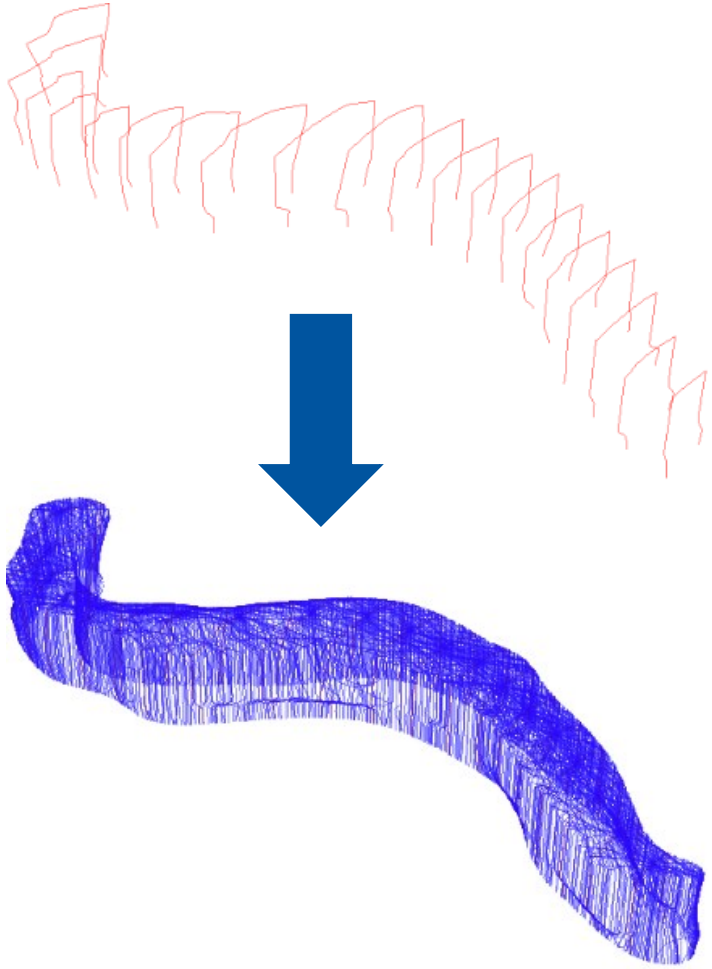
- Determine main axes of the structures and measure a fixed amount of extent-values along the axes
- But how to determine the main axes of a structure at any given point of it?

➢ First step: subdivide structures into 20 intervals parallel to one horizontal axis

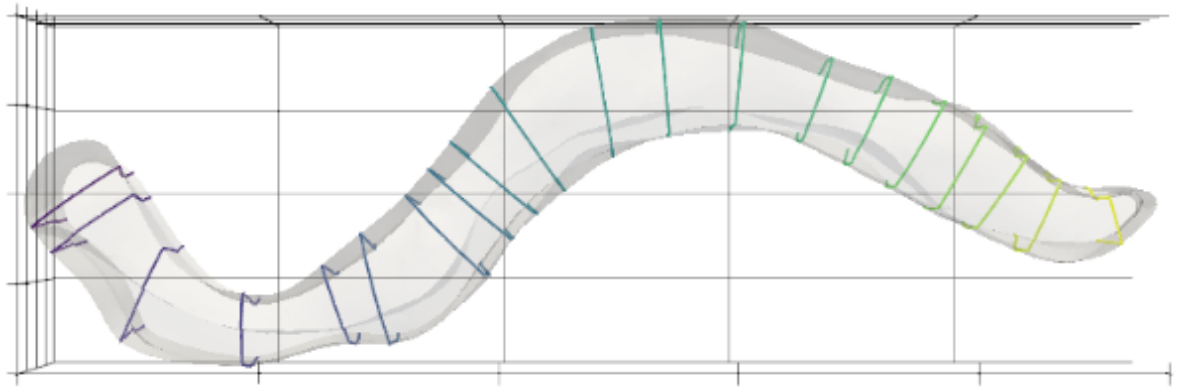


Determine main axes

- Take one interval: calculate area, rotate by 5°, calculate area again…
- Repeat for all intervals



- Find cross sections with smallest area
- Assumption: Area of section is smallest perpendicular to main horizontal axis



Measurement of dimensions

- On these cross sections, measure the lateral & vertical extents (5 measurements each per section)
- Determine the perpendicular cross section (→ perpendicular to the other main axis), repeat procedure
- Repeat method for all parallel intervals of structure

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Enter center index (0 to n-1):  1
Enter rotation step (0 to 19) for center 1:  11
Area: 18799103.5924716
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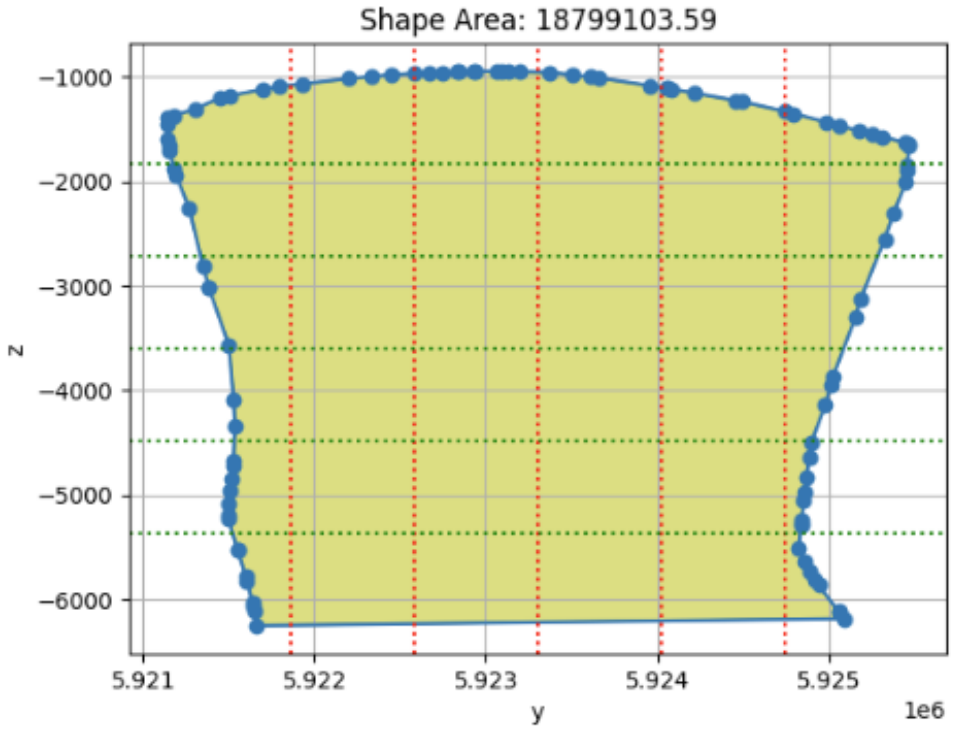
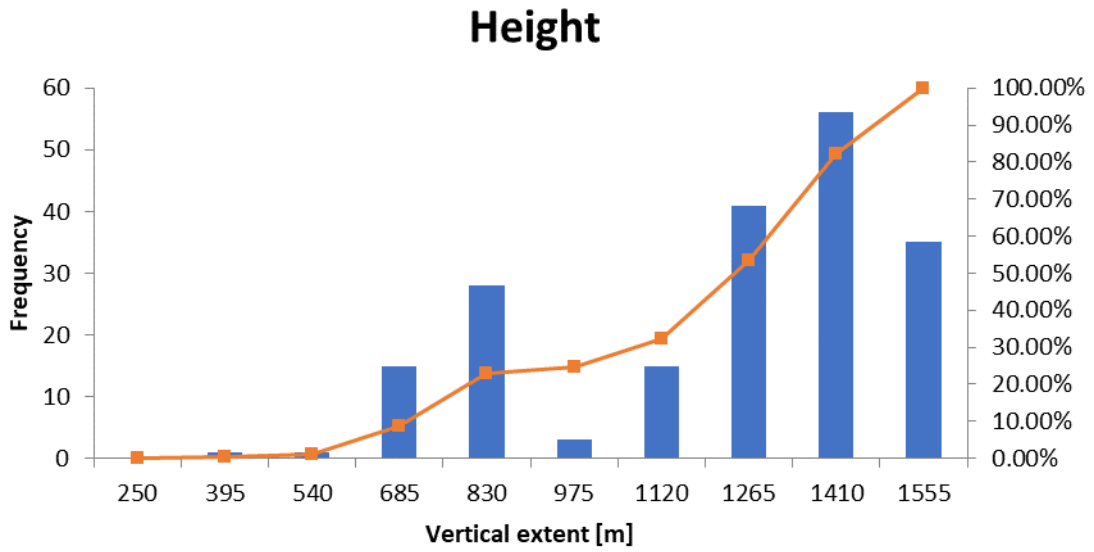
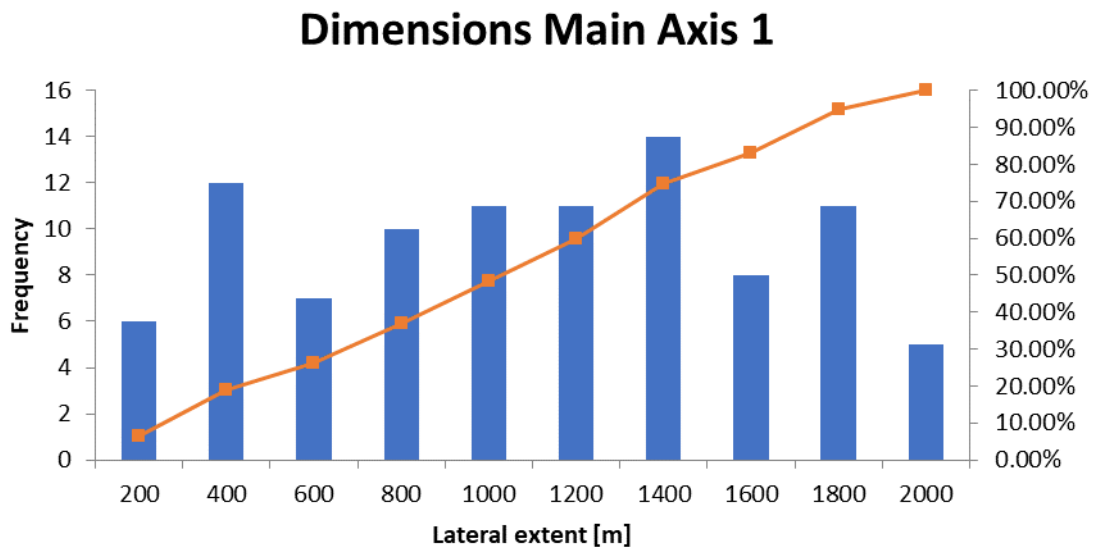


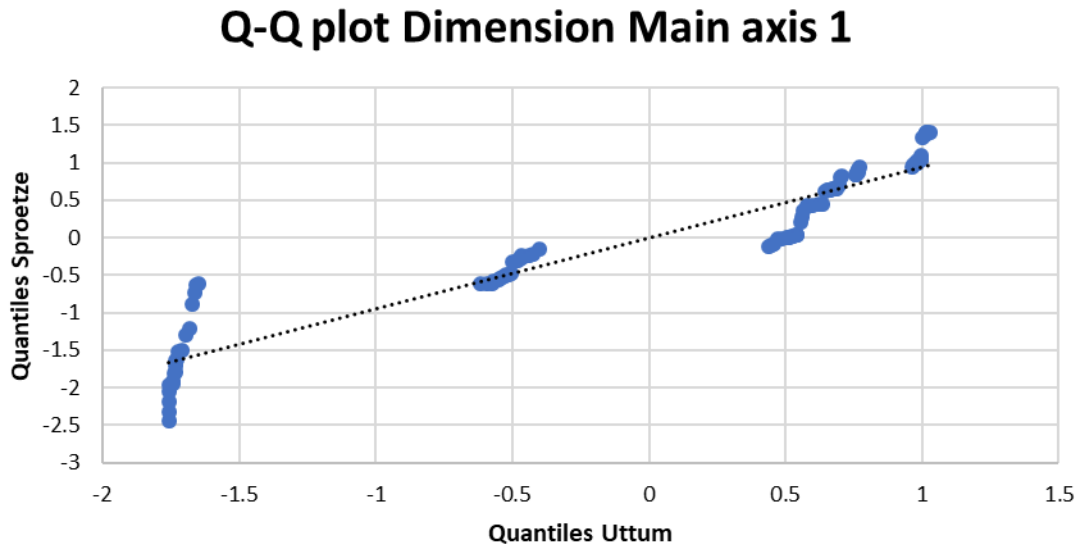

```
Y-Range at specified Z-values:
z = -5366.7696533203125: y-range = 5921521.944544264 to 5924833.791310529
z = -5366.7696533203125: y-length = 3311.846766265109
z = -4482.341552734375: y-range = 5921531.708146488 to 5924901.792392643
z = -4482.341552734375: y-length = 3370.0842461548746
z = -3597.9134521484375: y-range = 5921502.074324375 to 5925086.762664661
z = -3597.9134521484375: y-length = 3584.688340285793
z = -2713.4853515625: y-range = 5921335.582090009 to 5925286.22883519
z = -2713.4853515625: y-length = 3950.646745180711
z = -1829.0572509765625: y-range = 5921171.020550306 to 5925457.57577494
z = -1829.0572509765625: y-length = 4286.555224633776

Z-Range at specified Y-values:
y = 5921858.816260087: z-range = -6247.420603422624 to -1078.4663415053308
y = 5921858.816260087: z-length = 5168.954261917293
y = 5922580.907337911: z-range = -6233.505626612707 to -966.7437789871087
y = 5922580.907337911: z-length = 5266.7618476255975
y = 5923302.998415736: z-range = -6219.59064980279 to -953.0294673146151
y = 5923302.998415736: z-length = 5266.561182488174
y = 5924025.08949356: z-range = -6205.675672992874 to -1098.9032369205106
y = 5924025.08949356: z-length = 5106.772436072363
y = 5924747.180571384: z-range = -6191.760696182957 to -1329.8460916892418
y = 5924747.180571384: z-length = 4861.914604493715
dimensions saved to 'C:\Users\carl\Desktop\Structural dimensions\'
```

Evaluation

- Keep it simple:
  - ➢ Arithmetic mean, variance, standard deviation, skewness
  - ➢ Histograms and CDF´s
  - ➢ Q-Q plots
  - ➢ Cluster analysis (yet to carry out)



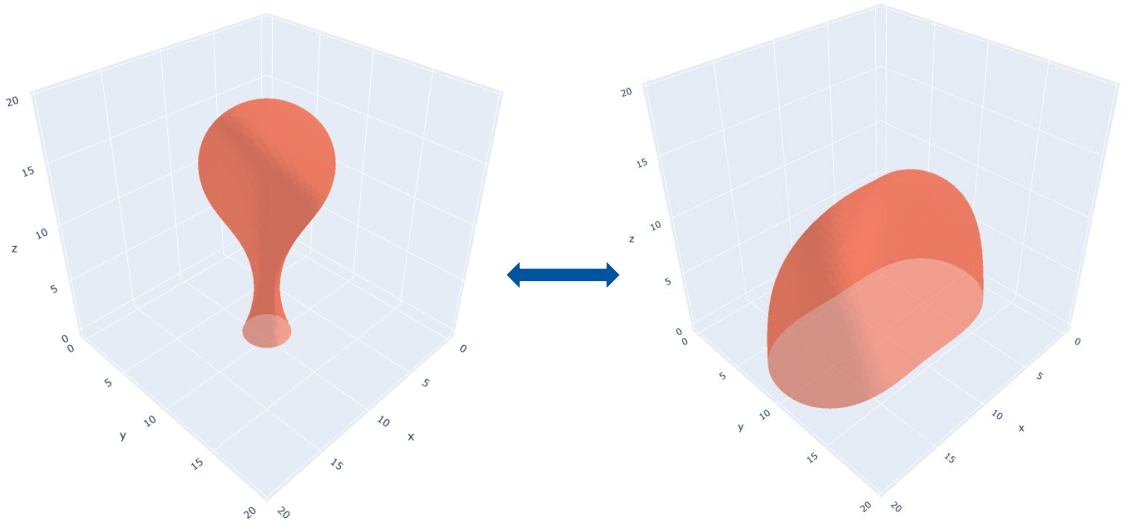




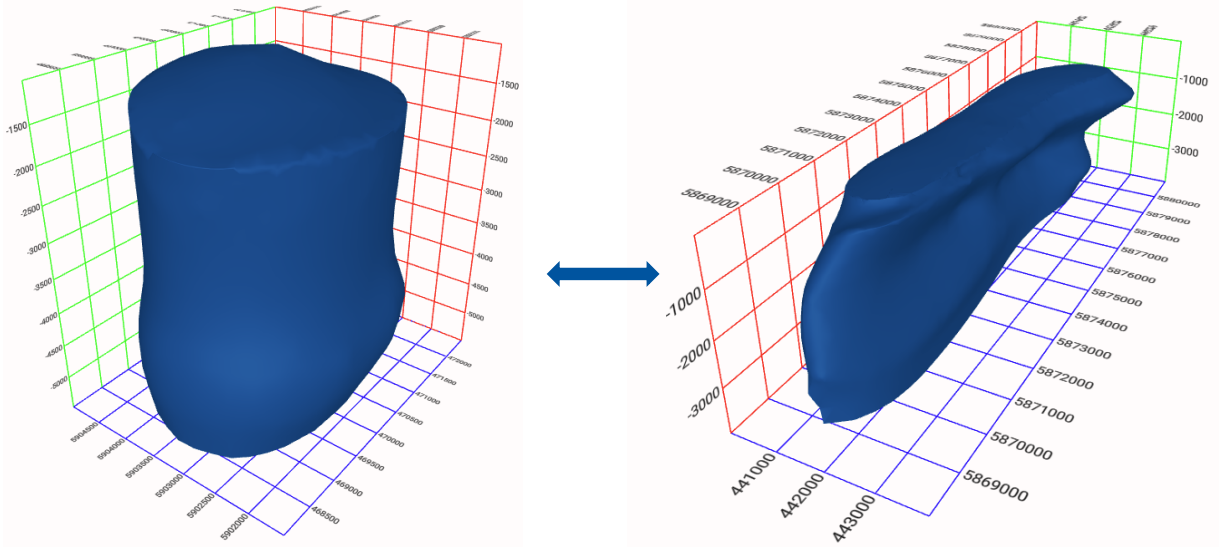
Next up:
2nd approach to compare different models: Direct comparison of implicit models

- Follow-up of cluster analysis: look at clusters of evaluated real models and respective standard geometries (GeoBlocks, 2023)
- Determine Hausdorff distance between standard geometries
- Determine Hausdorff distance between real models that show cluster centroid closest to the one of respective standard geometry class
- Expected result: Large Hausdorff distance between standard geometries and between real models

Hausdorff distance?



Hausdorff distance?



Thanks for your attention!