A conceptual model for 3d geological model data and testing capabilities in spatial databases

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A conceptual model for storage of 3D Geological Models

Our goal is to…

1. Define a conceptual model from which we can define the structure of a database for the storage of digital 3D geological models.

2. We will do this by identifying what a 3D geological model consists of, such as geological boundaries, volumes, units formation, relations, etc..

3. These are collection of spatial geological elements with certain properties, and in their entireity are considered a representation of the real world.
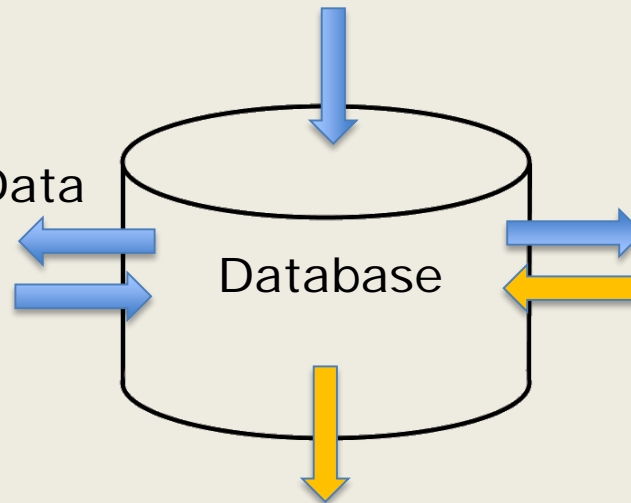
2

Database Roles

1: Gather Geological Data
(Field maps, Borelogs, Seismic, Geochemical samples, SkyTEM, . .)

2: Interpret Geological Data
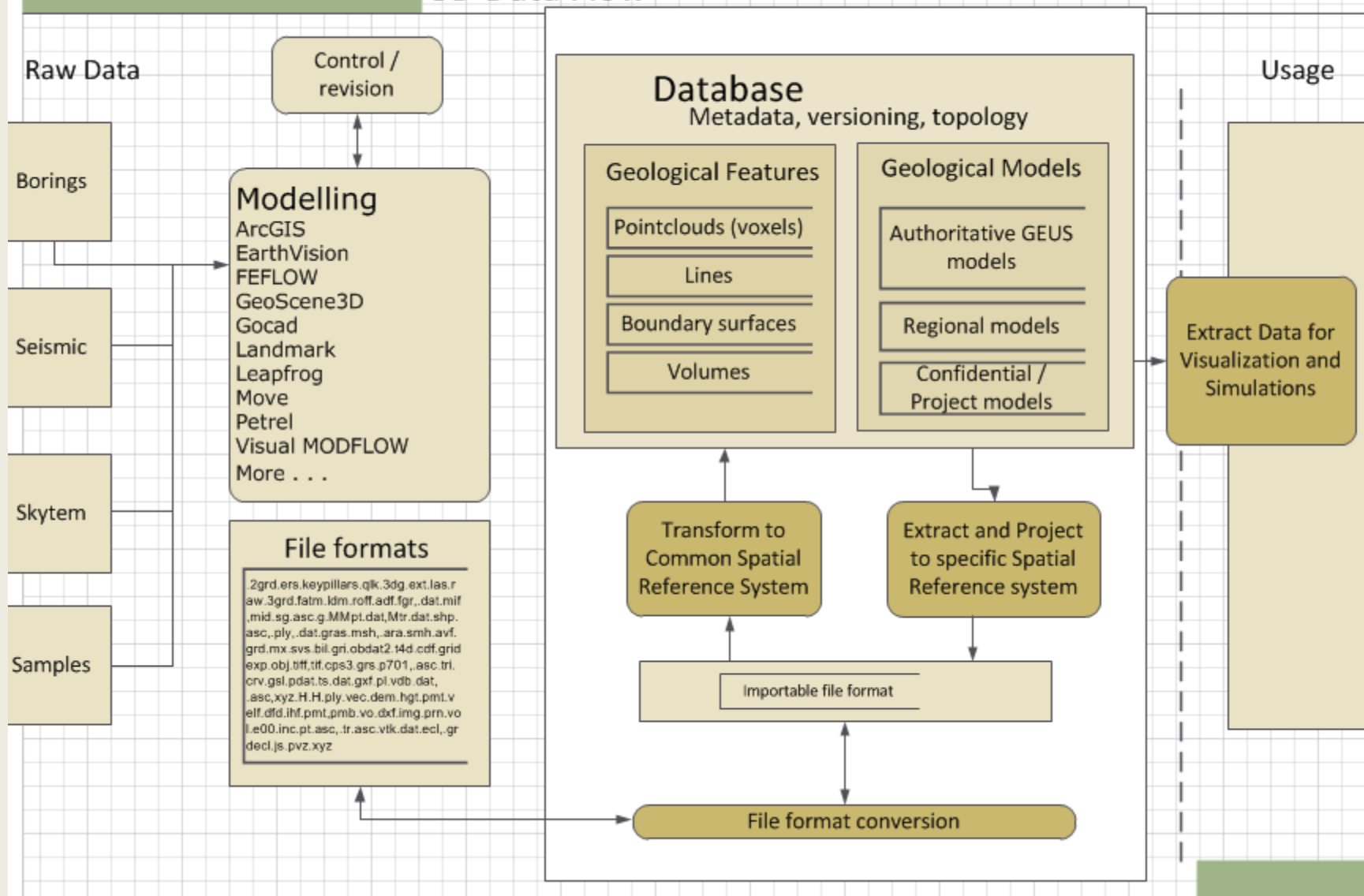- Digitize
- Analyze
- Process

Database

3: Model Geology
- Categorize
- Draw frontiers
- Generalize
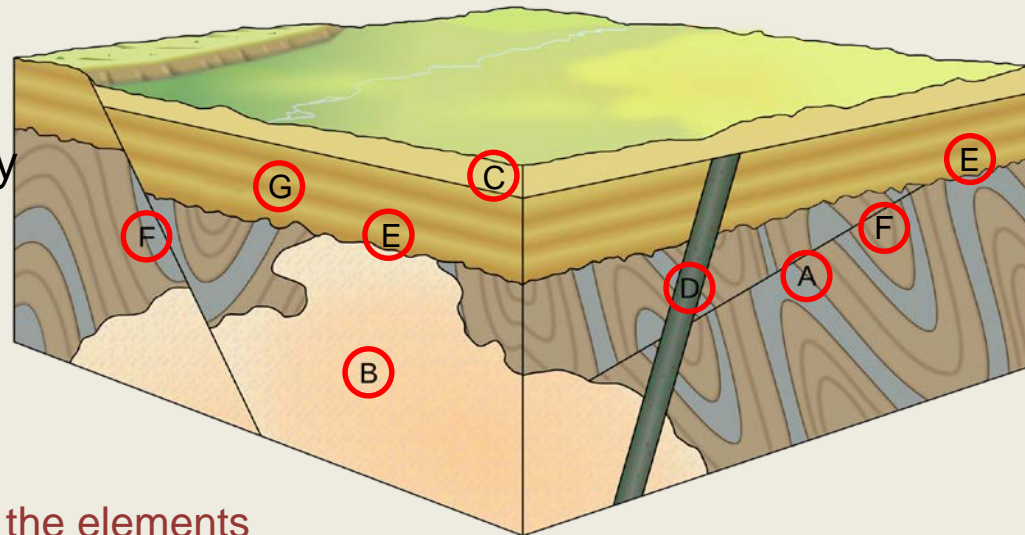- check topology

4: Use of Geological Models
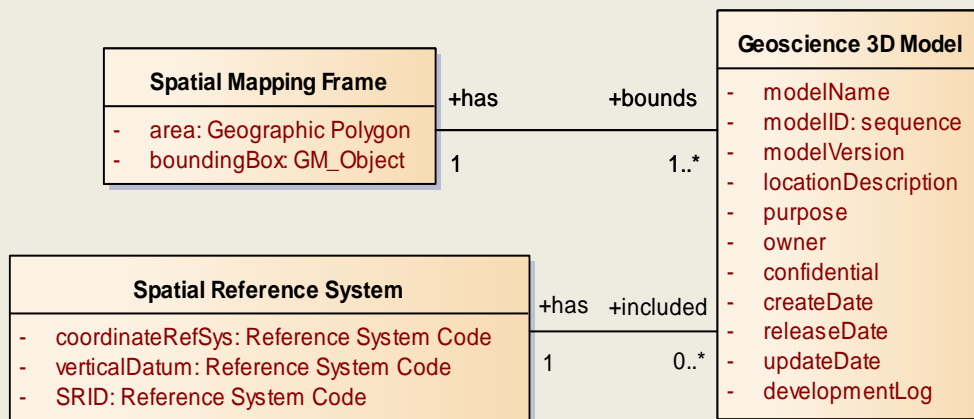(Visualize, Simulate, Decision support, . .)

Elements of a 3D geological model

A. Deformed layer boundarie
B. Batolith bodie (closed volume)
C. Stratigraphical conform boundary
D. Dike intrusion
E. Unconform erosional boundary
F. Fault
G. Stratified unit (facies)

Defined porperties and relations between the elements
 – Type of deformation, lithology, erosion and stratigraphy.
 – Age and depositional environment.
 – Boundary relationships between boundaries and closed volumes.
 – Metadata (who interpreted it, quality, uncertainties, …).
 – Etc.

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Step 1: A geoscientific 3D model

Spatial Mapping Frame
- area: Geographic Polygon
- boundingBox: GM_Object

+has   +bounds

1   1..*

Geoscience 3D Model
- modelName
- modelID: sequence
- modelVersion
- locationDescription
- purpose
- owner
- confidential
- createDate
- releaseDate
- updateDate
- developmentLog

Spatial Reference System
- coordinateRefSys: Reference System Code
- verticalDatum: Reference System Code
- SRID: Reference System Code

+has   +included

1   0..*

Overall model properties

- Model name
- Model ID
- Model version
- Purpose of the model
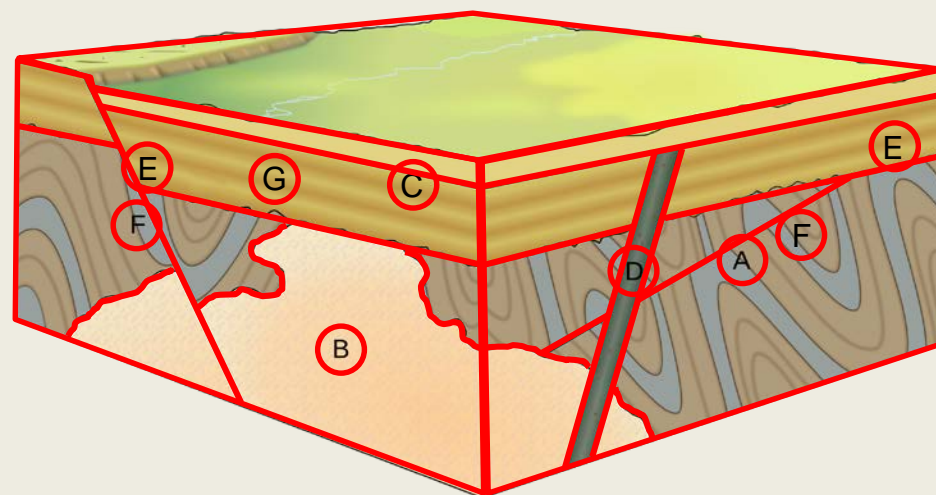- Location description
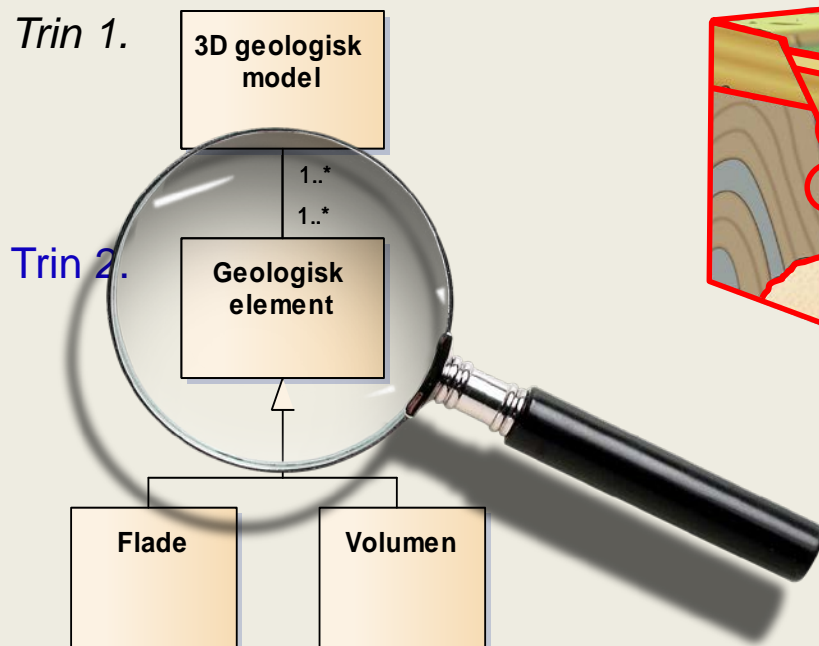- Owner
- Confidentiality
- Dates

- A model is defined from the spatial extension which describes the boundary of the model in three dimensions and the purpose and method of modelling.

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Geological model

Hydrogeological model
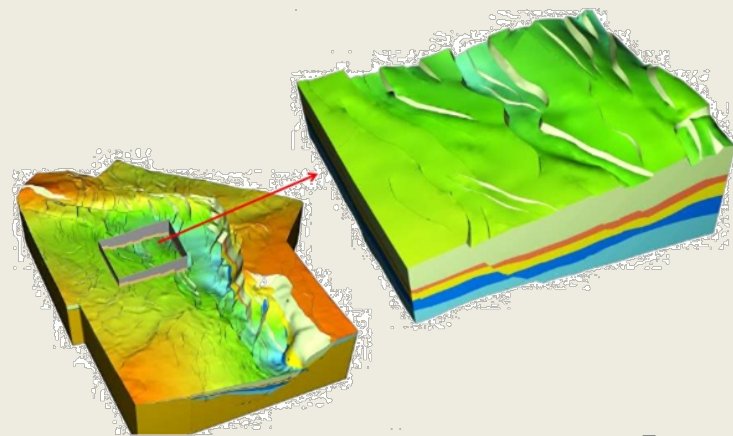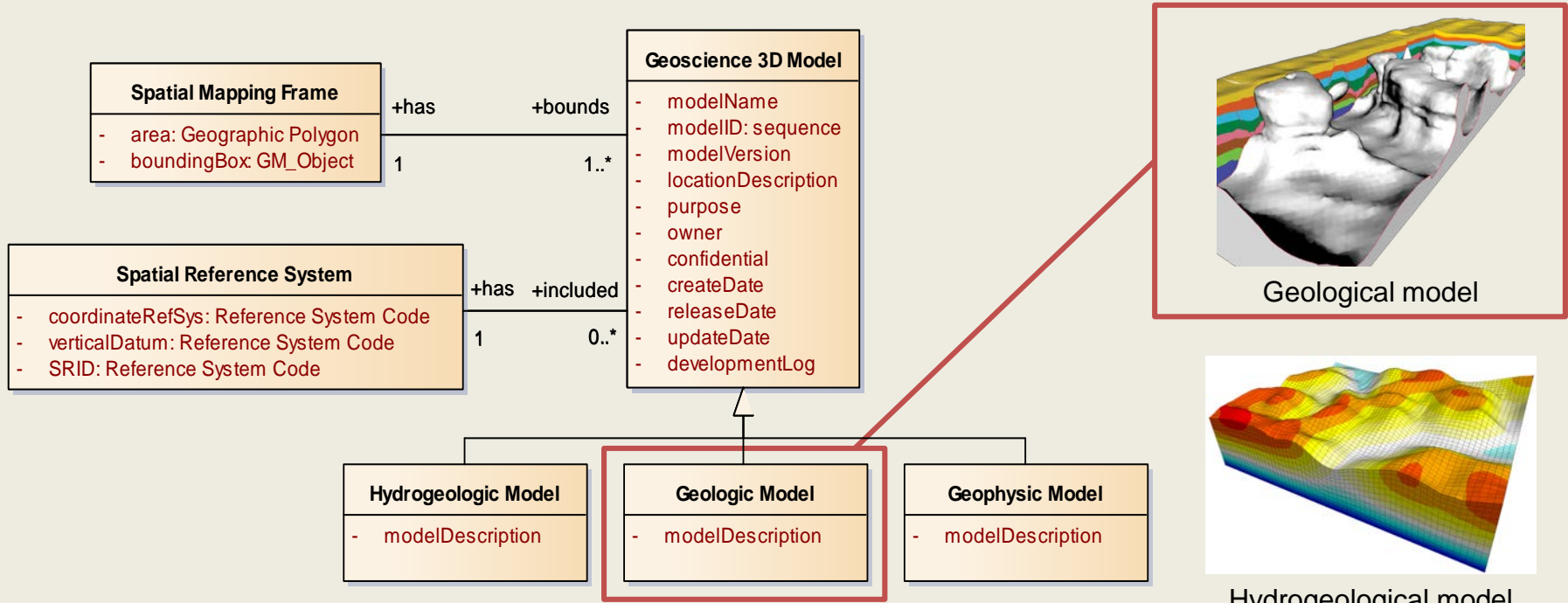
- A geoscientific 3D model is a digital model with a specific scientific purpose representing one out of these domains: Geology, Hydrogelolgy of geophysics.

- *We have focused on the geological model*

Gephysical model   8

Step 2: Elements in a 3D geological model

Trin 1.

3D geologisk model

1..*

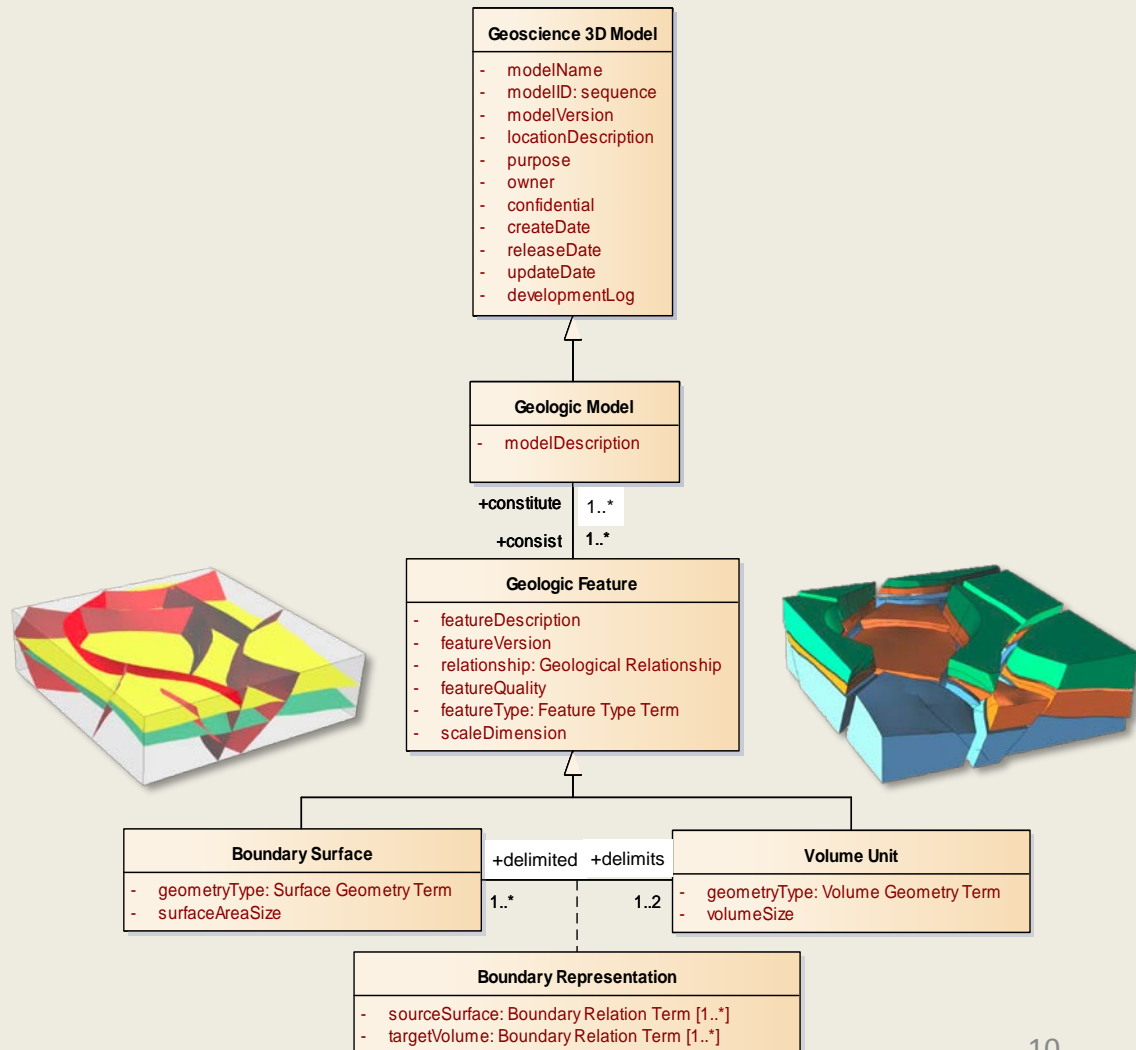1..*

Trin 2.

Geologisk element

Flade

Volumen

A. Deformed layer boundary
B. Batolith bodie (closed volume)
C. Stratigraphical conform boundary
D. Dike intrusion
E. Unconform erosional boundary
F. Fault
G. Stratified unit (facies)

- A 3D geological model may consist of one or more combined 3D spatial geological elements.

- These elements are either interpreted boundaries or (closed) volumes.
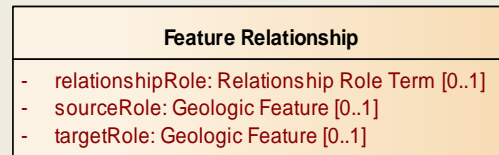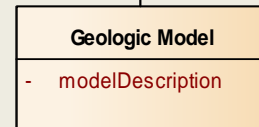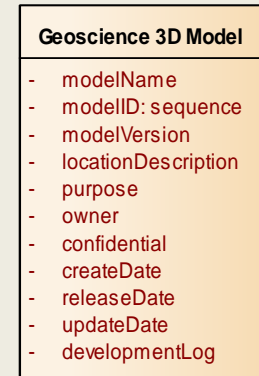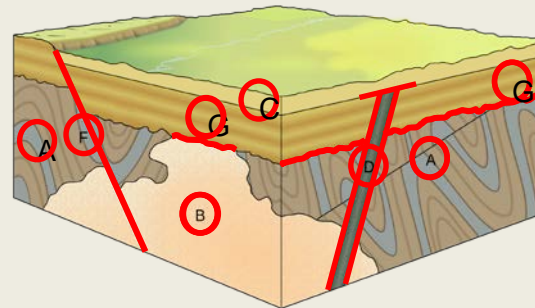
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Step 2: The geological elements in the model

- A 3D geological model may consist of one or several interpreted geological elements.

- These geological elements, which constitute the spatial structure of the model, represent interpreted geological boundaries and closed volumes.

- Each boundary surface represent the boundary between two volumes.

- A volume unit constitutes a closed geological element which is delimited by one or several boundary surfaces.

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Geologic Model
- modelDescription

+constitute 1..*
+consist 1..*

Geologic Feature
- featureDescription
- featureVersion
- relationship: Geological Relationship
- featureQuality
- featureType: Feature Type Term
- scaleDimension

Boundary Surface
- geometryType: Surface Geometry Term
- surfaceAreaSize

+delimited +delimits
1..* 1..2

Volume Unit
- geometryType: Volume Geometry Term
- volumeSize

Boundary Representation
- sourceSurface: Boundary Relation Term [1..*]
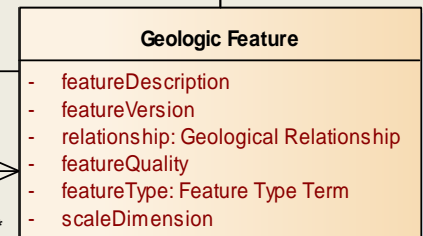- targetVolume: Boundary Relation Term [1..*]

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Step 2: Relationships between the geological elements

Geological elements have topological relations to each other if they touch, cut or overlap.
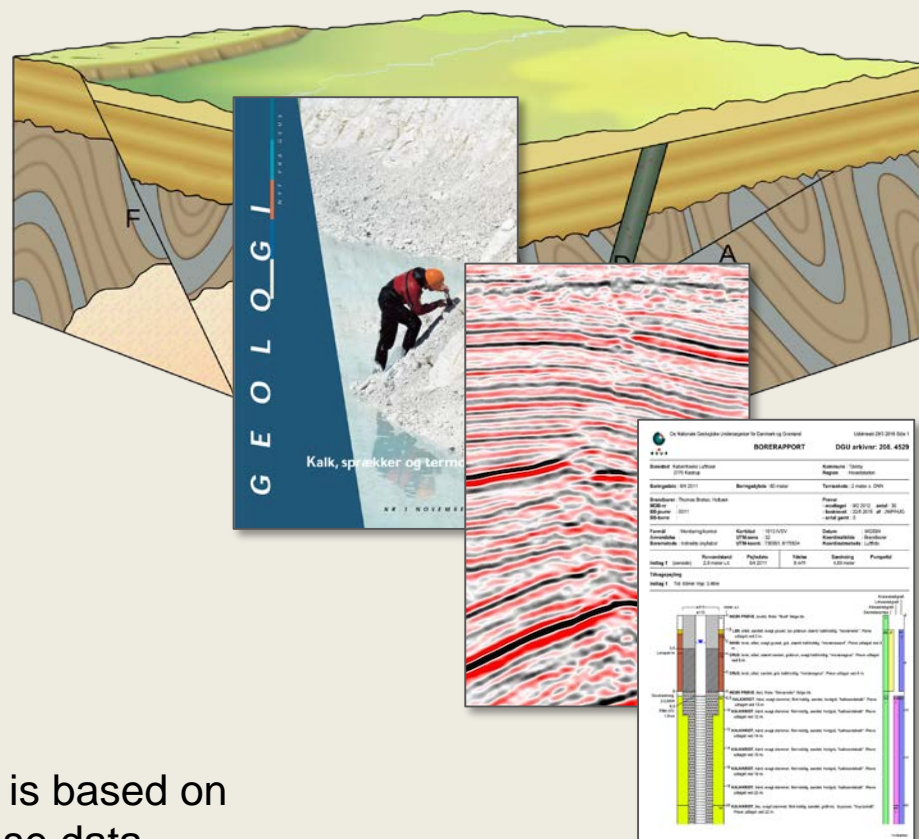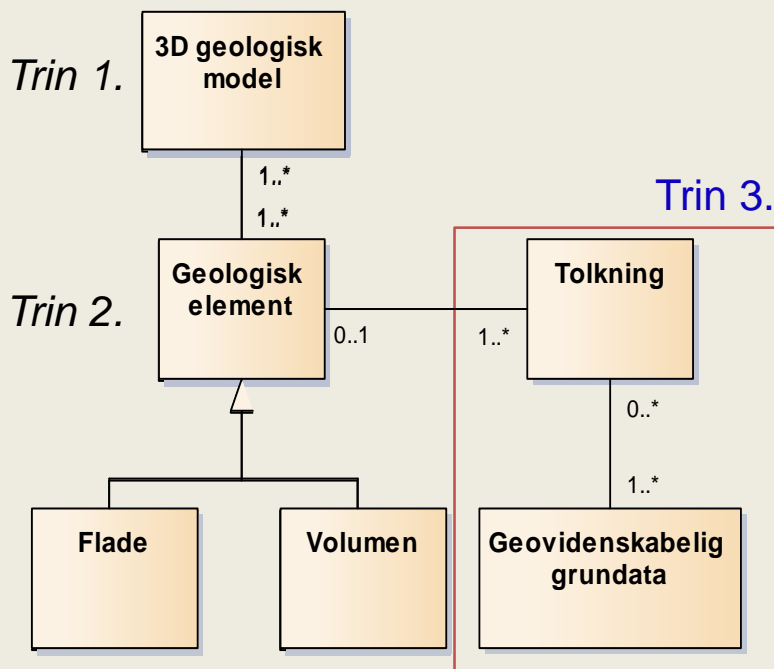
- The Batholith body (B) has a non-conform relation to the stratified volume (G).

- The stratified volume with folds (A), has an unconform relation to the stratified volume (G).

- The dyke (D) has an intrusive relation to the batholith body (B) and to the stratified volumes (A and G), and an unconform relation to the stratified volume (C).

- The fault (F) has a cutting relation to the batholith body (B) and to the stratified volumes (A og G).

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Geologic Model

- modelDescription

+constitute   1..*

+consist   1..*

Feature Relationship

- relationshipRole: Relationship Role Term [0..1]
- sourceRole: Geologic Feature [0..1]
- targetRole: Geologic Feature [0..1]

Geologic Feature

- featureDescription
- featureVersion
- relationship: Geological Relationship
- featureQuality
- featureType: Feature Type Term
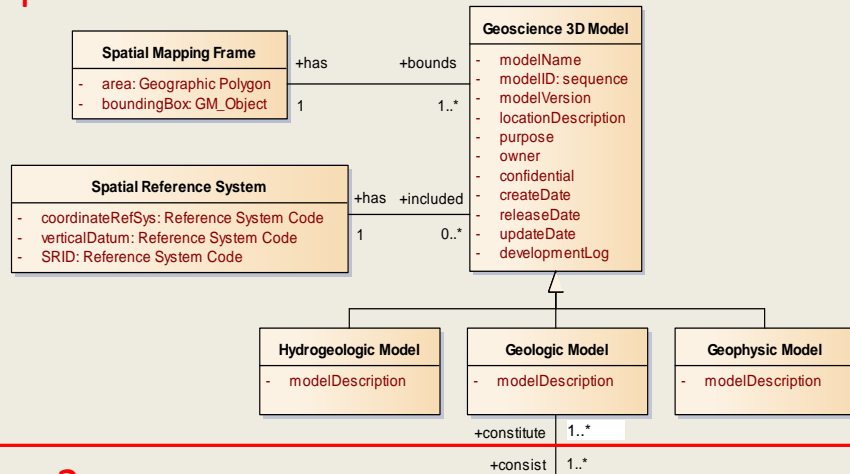- scaleDimension

+relatedFeature 0..*

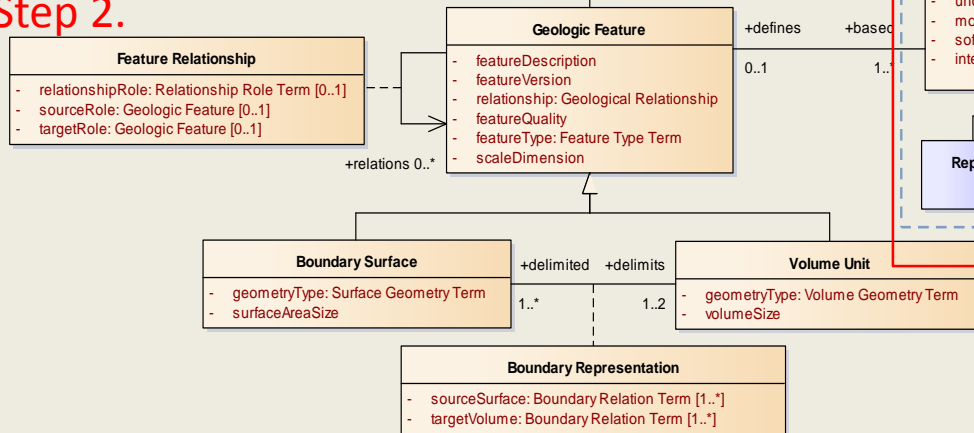# Step 3: Interpretations and interpreted data

- Each geological element in the 3D model is based on interpretations done from geoscientific base data.
- We must account for the quality and uncertainties on the data in the model as well as a reference to the base data.
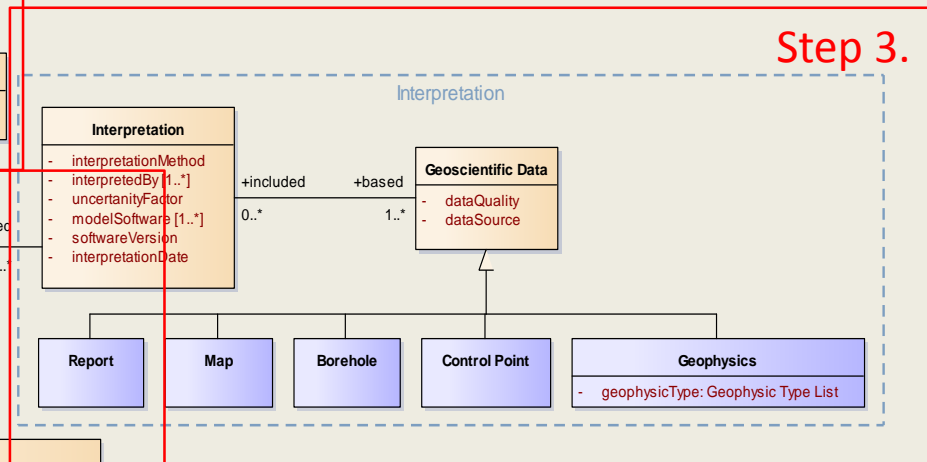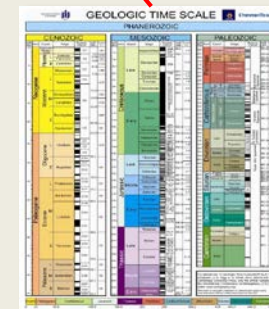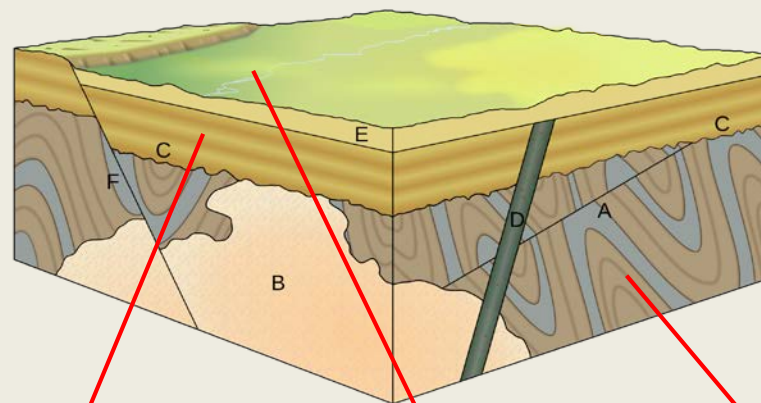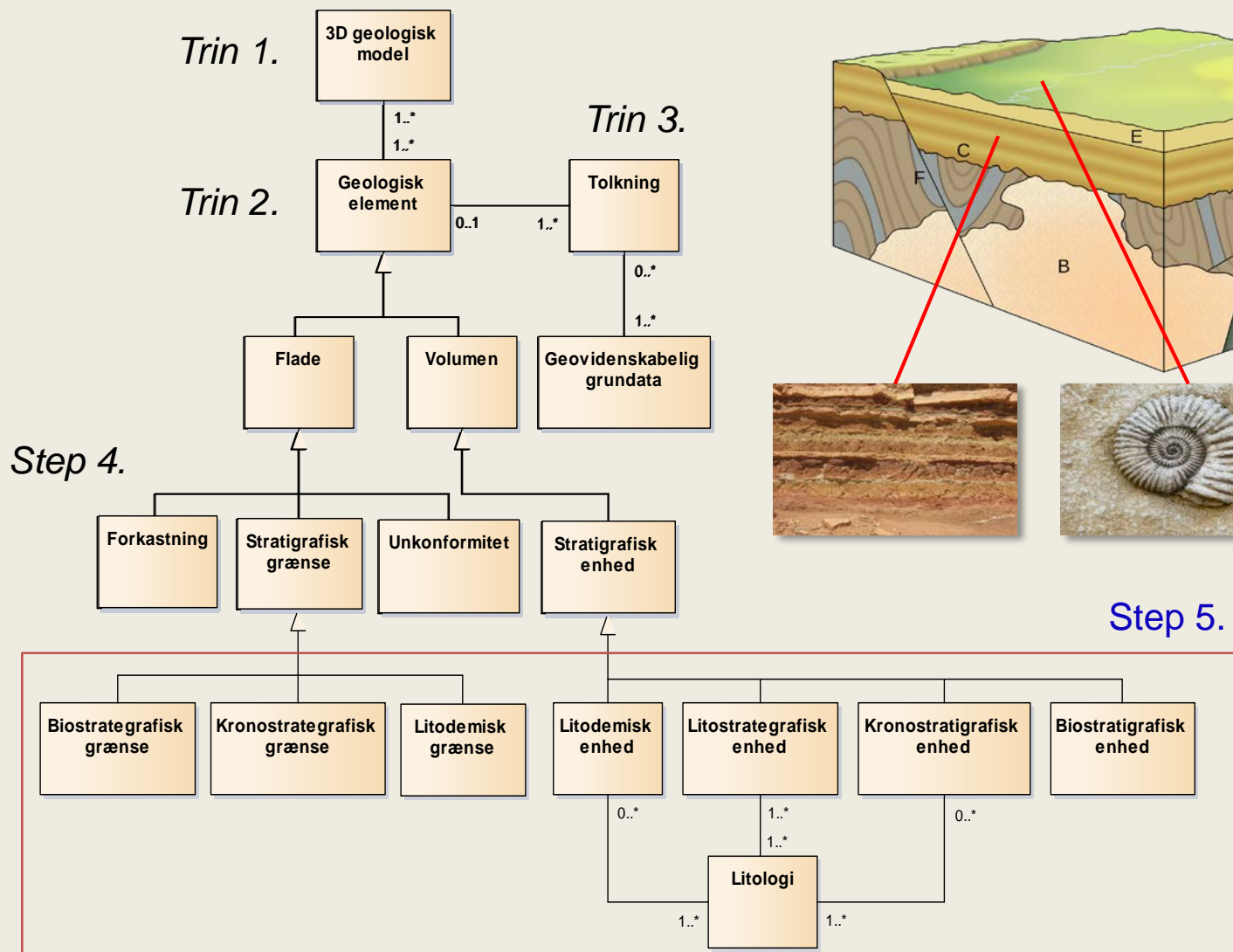
Recap, steps 1, 2 og 3

We have

1. Described the fundamental properties and metadata for the 3D model.

2. Described the basic and fundamental geological elements the 3D model consists of and the relationship between them.

3. Described the interpretations and fundamental data the elements are defined from.

Step 5: Specialisation of stratigraphic categories

Trin 1.

3D geologisk model

1..*
1..*

Trin 2.

Geologisk element

0..1

Flade

Volumen

Trin 3.

Tolkning

1..*

0..*

1..*

Geovidenskabelig grundata

Step 4.

Forkastning

Stratigrafisk grænse

Unkonformitet

Stratigrafisk enhed

Step 5.

Biostrategrafisk grænse

Kronostrategrafisk grænse

Litodemisk grænse

Litodemisk enhed

Litostrategrafisk enhed

Kronostratigrafisk enhed

Biostratigrafisk enhed

0..*

1..*

0..*

1..*

Litologi

1..*   1..*

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Lessons learnt

- Using UML. Challenges:
  - UML itself. We use only "primitive" elements.
  - Geologists are busy people. UML is a "science" in itself. Difficult to learn in ½ hour.
  - Really going through all aspects of the model will take weeks.
  - But we need the input from the scientists
- They ask for a mock-up. That must be one of the next steps.
- But also some spreadsheets with test-data. One column for each class.
- It will be an iterative process…

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Uniform Spatial Reference System

- Common spatial reference system necessary for effective spatial queries.

- Geographic Reference System based on ellipsoid not influenced by shifts in terrainheight and water levels over time.

- Visualizing large areas as curved in an earth model such as Cesium is easier from geographic reference system.

- Modern positioning utilizes GPS, and so ellipsoids anyway.

Database Oracle 11g

- Pros:
  - GEUS official database
  - Commercial support
  - Will exist in foreseeable future
  - All existing data can be referenced
- Cons:
  - Expensive
  - Closed source
  - Documentation overload

PostGres/PostGIS

- Pros
  - Opensource
  - Based on standards
  - No license, commercial support available
  - Well documented
- Cons
  - Dependant on community
  - Risky if key developers leave
  - Must reference data in Oracle

Database Spatial Capabilities Test I

- Purpose
  - Check capabilities in storing and retrieving
  - Test capabilities of spatial queries
    - Pointcloud bounded by volume
    - Lithological boundary sliced by faults
  - Test format conversions workflow
  - Report obstacles
  - Measure performance
 - Choose database model

Test Objects

- 0D: Points, Pointclouds
- 1D: Boreholes, Seismic lines
- 2D: Faults, Salt Diapers
- 3D: Cube, Volume from GoCAD
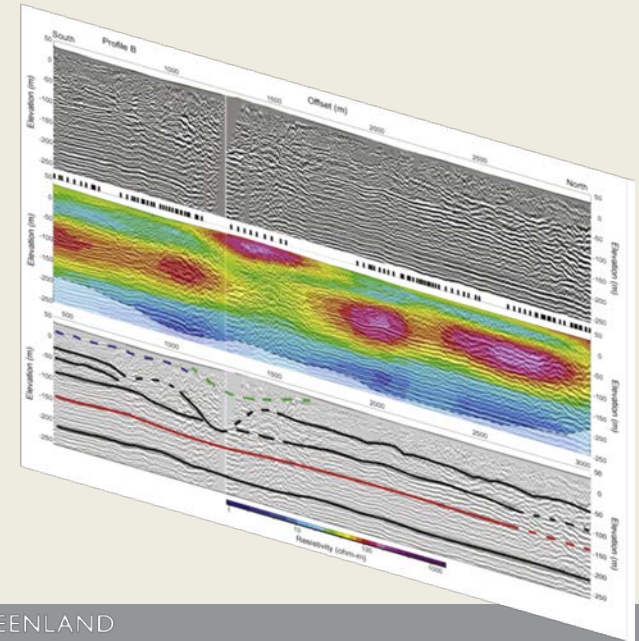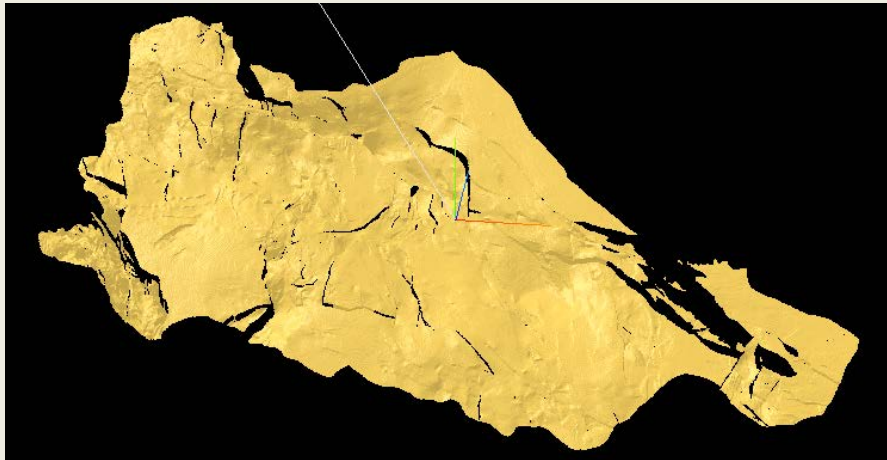
Testing Procedure I

- Obtain data from modeller
- Convert formats
- Store in temporary table
- Project Spatial Reference System
- Store in geometry table
- Query, re-project, convert to fileformat
- Compare original data in model program
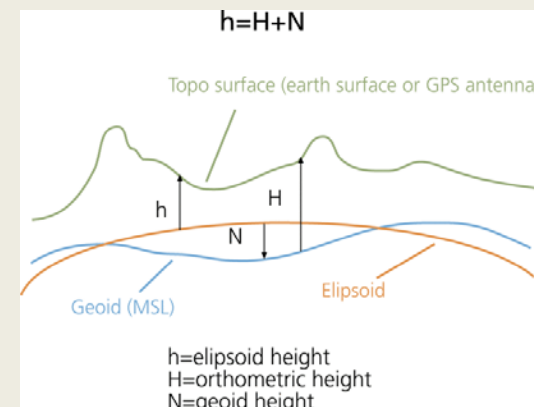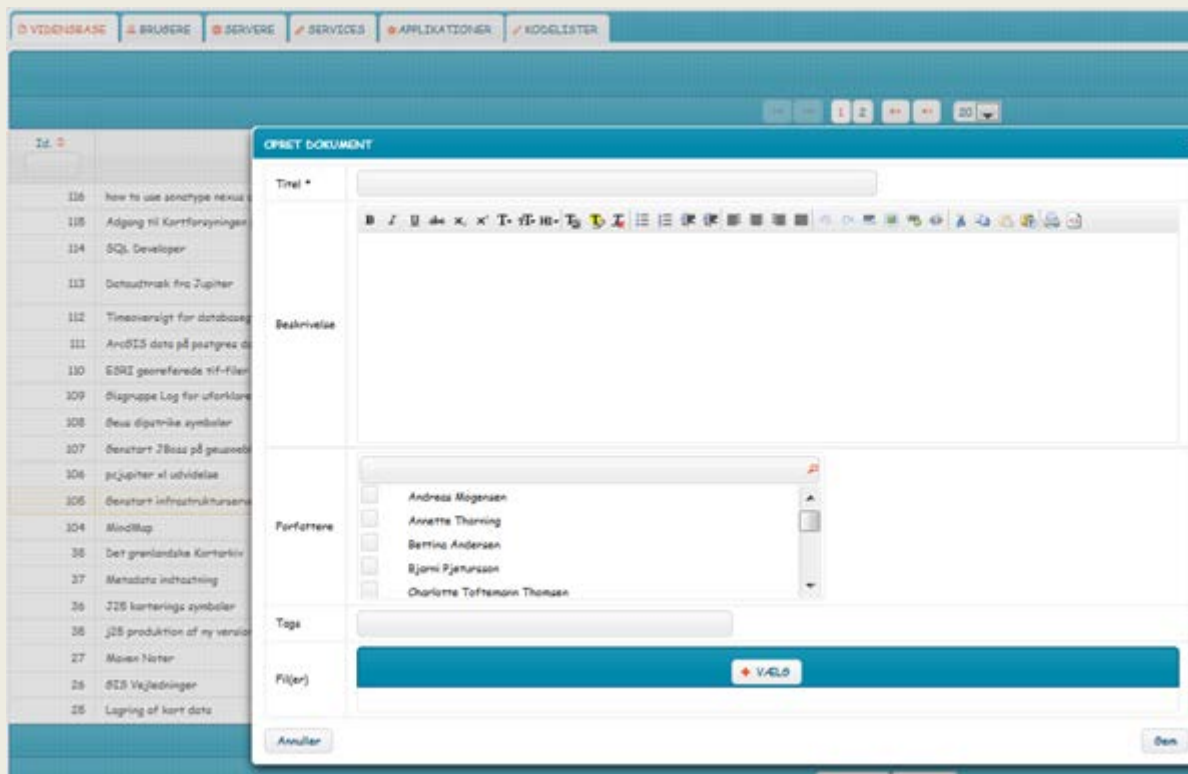
Testing Procedure II

- Simple Queries
  - Partition pointcloud by plane
  - Partition Surface by plane
  - Query solid from 2 layers and bounding rectangle
- Advanced queries
  - Volumes of solid
  - Partition geometries by curved surface
  - Intersecting volume
  - Union volume

Results

- Not finished yet
- Seems that Oracle and PostGIS are not that different

Next Steps

- Make Mockup of User Interface, for modellers to test storage an retrieval.

Questions ?