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Borehole Markup Language (BoreholeML, BML)

99th OGC Technical Committee – 3D Geoscience borehole ad-hoc meeting

Dublin, Ireland

<Rainer Häner> - <GFZ>

22 June 2016

Agenda

BML	A short introduction
Further Development	Reducing the complexity, focusing on the essentials, properly deriving from and adapting existing standards, …
BML in the EPOS context	Establishing interoperability for a System-of-Systems
The big (w)hole	Mapping to SWE, Implementation-Examples

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Status-Quo: Borehole data in Germany

Geological Survey Organisations (GSO) are responsible for the storage of all borehole data in databases („national law for deposits“ – Lagerstättengesetz)

Encoding standards of borehole data

- **= SEP1**
- **= SEP2**
- **= SEP3 (most advanced)**
- **= other data formats (DABO, UHYDRO, BIS-BY, BDH-HE)**

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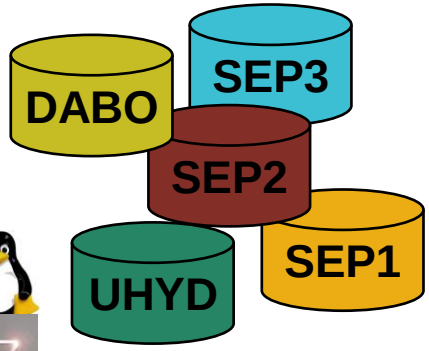
14 Geological Survey Organisations

1. Different levels of quality (incl. historical data errors)
2. Specific format extensions in each GSO
3. Specific usage of the same format (SEP3)



=>

1. Lack if interoperability between systems
2. Restricted exchange of borehole data
3. Expensive data transformations in cross domain projects
   e.g. Geothermal Energy, Carbon Capture & Storage
4. Economic losses: Engineering offices across Germany can‘t handle different input formats without data preparation

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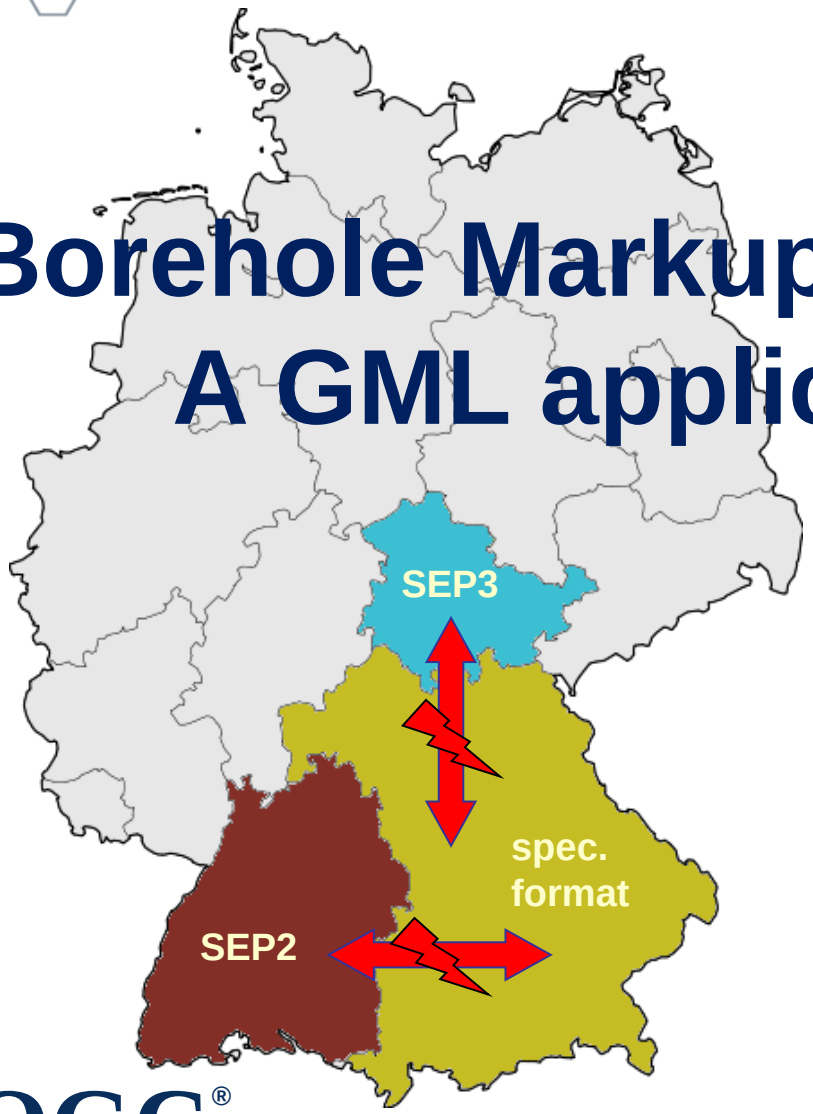
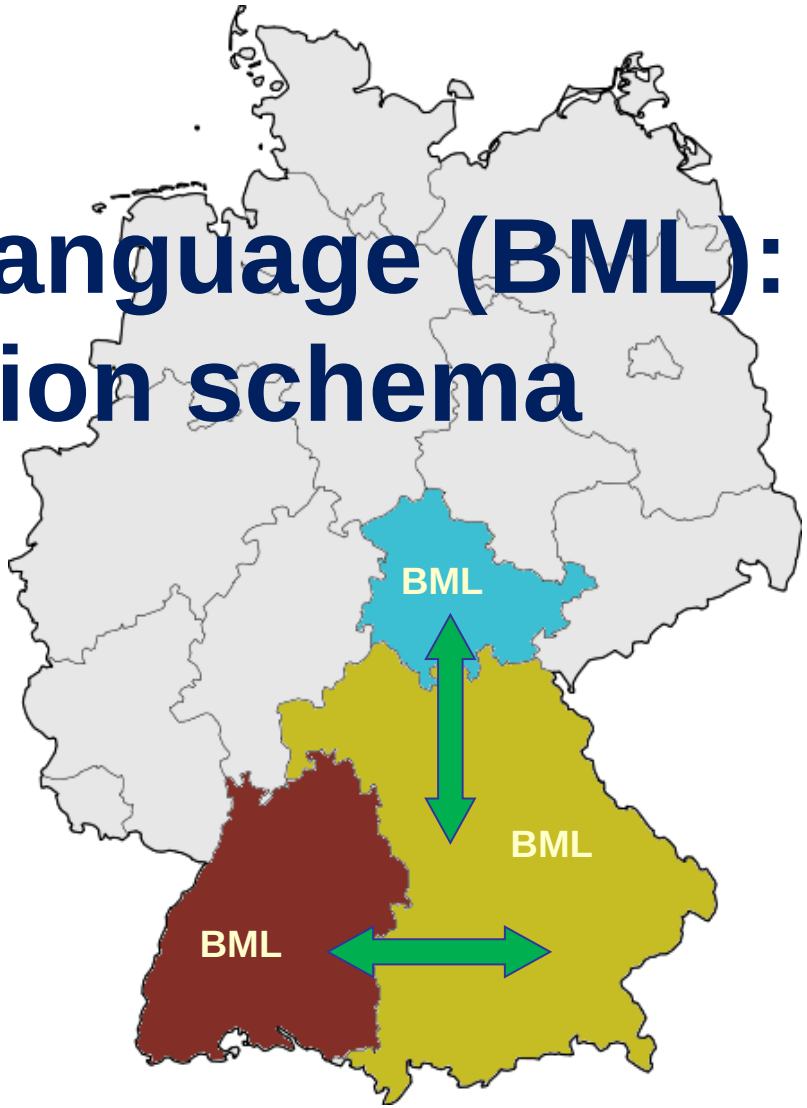
Common Vocabularies & a Standardised Exchange Format

Borehole Markup Language (BML): A GML application schema





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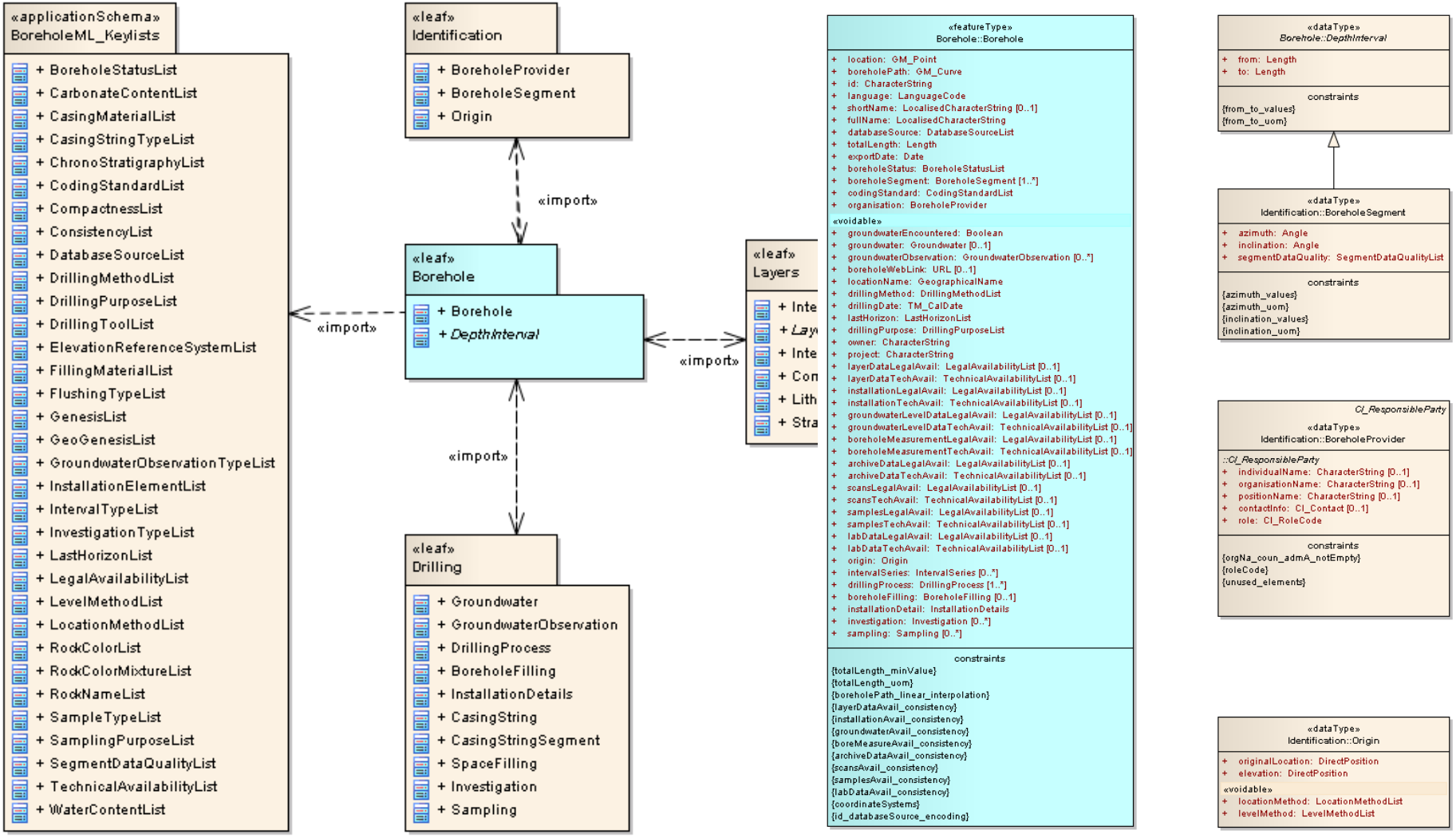
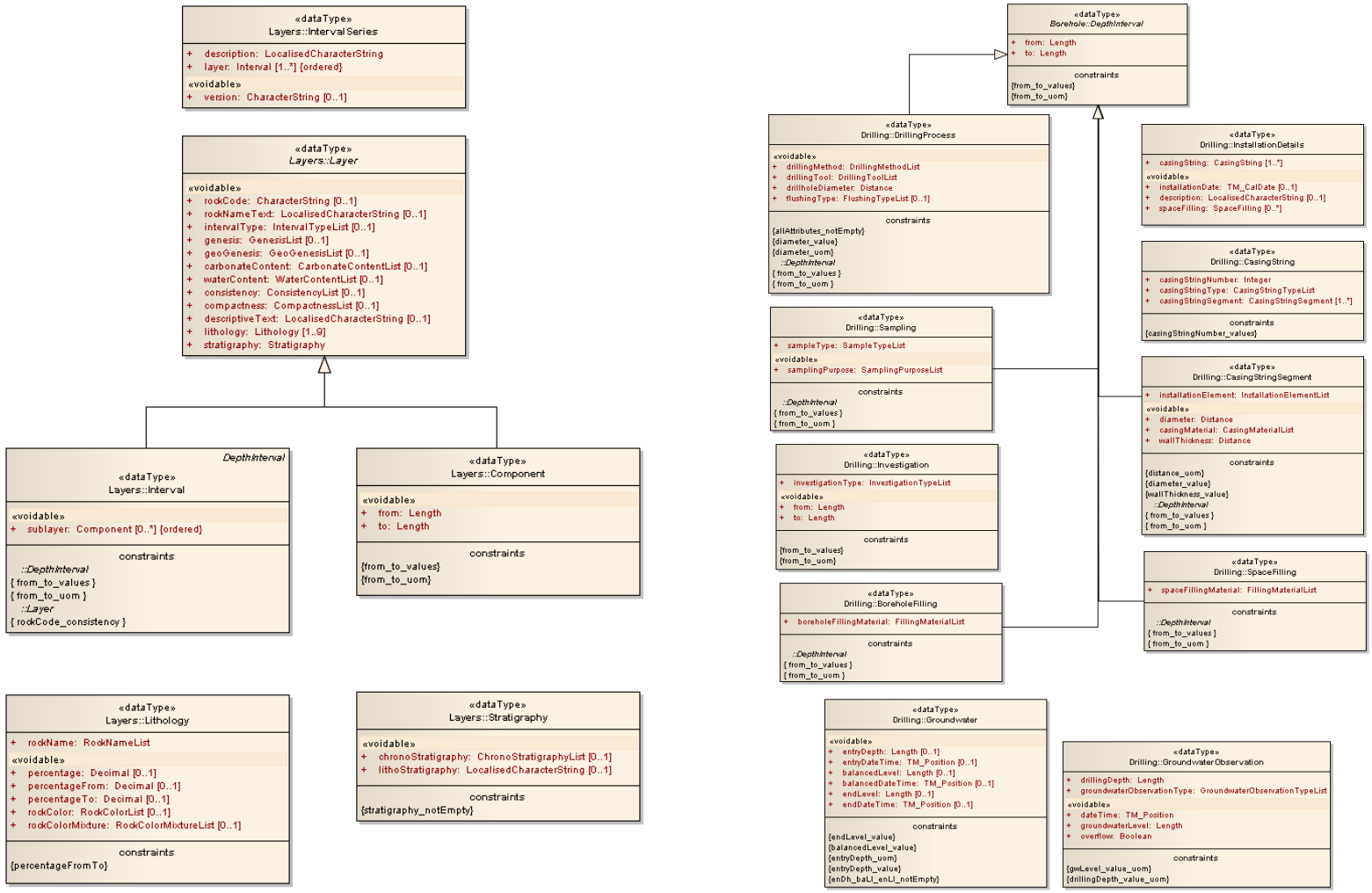
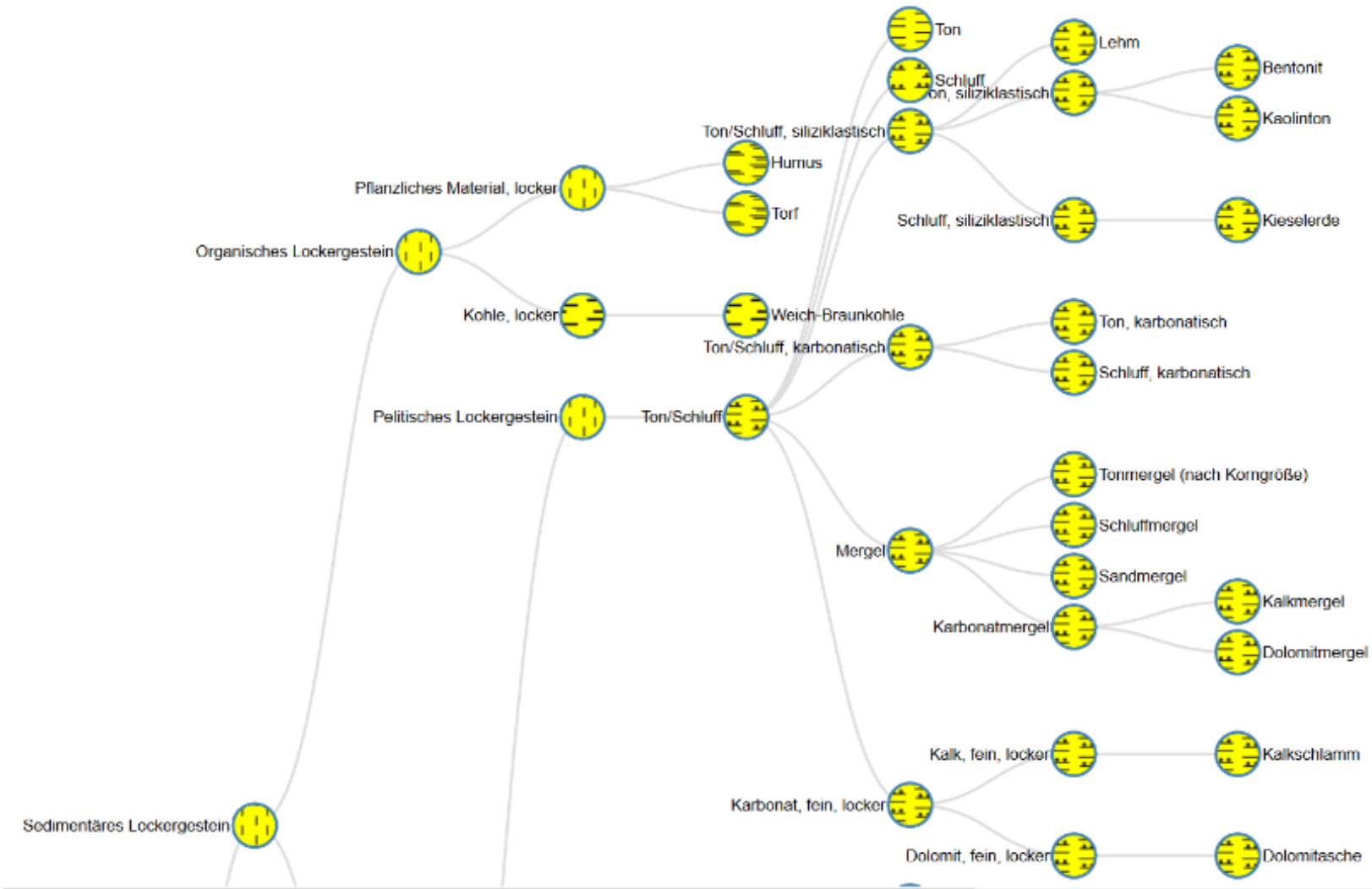
BML: Code-Lists, Packages & Header



Encoding: Layer & Drilling



Code-List: Petrography



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FURTHER DEVELOPMENT

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YAML? Yes and No!

- Yes
- GML Application Profile with specific Syntax
- No clear separation of Data, Syntax and Metadata (Version 3.0.1)
- Re-Inventing the wheel (like many others: …)

- No
- Focus on Dictionaries and Vocabularies (Semantics)
- Legacy Format since 2000
- Volatile, 1 : 1 Mapping to SWE possible with no restrictions

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BML 3.0.1 => BML 4.0 => SWE

- BML 4.0
- Reduction of elements by
  - Use of existing encodings
    - e.g. Availability
  - Use of Dictionaries
    - e.g. groundwaterEncountered
- Application of galdos best practices
- Composite Pattern
- Harmonisation
  - Naming
  - Using context e.g. spaceFillingMaterial ⇔ material
- Application of geological Terms to
  - Syntax and/or
  - Code-Lists

- SWE: SensorML & O&M
- 1 : 1 Mapping with inherent application of
  - principles applied to v4.0
  - GML & ISO 19xxx
- Controlled Vocabularies
- Clear Separation of
  - Data
  - Metadata
  - Semantics
- GML, CSV, JSON, X3D, SVG

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GML Property & Composite Pattern

- property, e.g. installationDetails
  - Class, e.g. SpaceFilling
    - implementation or property, e.g. series of intervals, types, code lists, references, and description

Terms: Litho Stratigraphy

- ***Supergroup***
  - ***Group***
    - ***Subgroup***
      - ***Formation***
        - **Member**
          - **Layer**

```
<bml:interval>
    <bml:Member>
        <bml:range><swe:uom/></bml:range>
        <bml:Layer>
            <bml:range><swe:uom/></bml:range>
            <bml:lithology>
                <bml:rockName/>
            </bml:lithology>
            <bml:stratigraphy/>
        </bml:Layer>
    </bml:Member>
</bml:interval>
```

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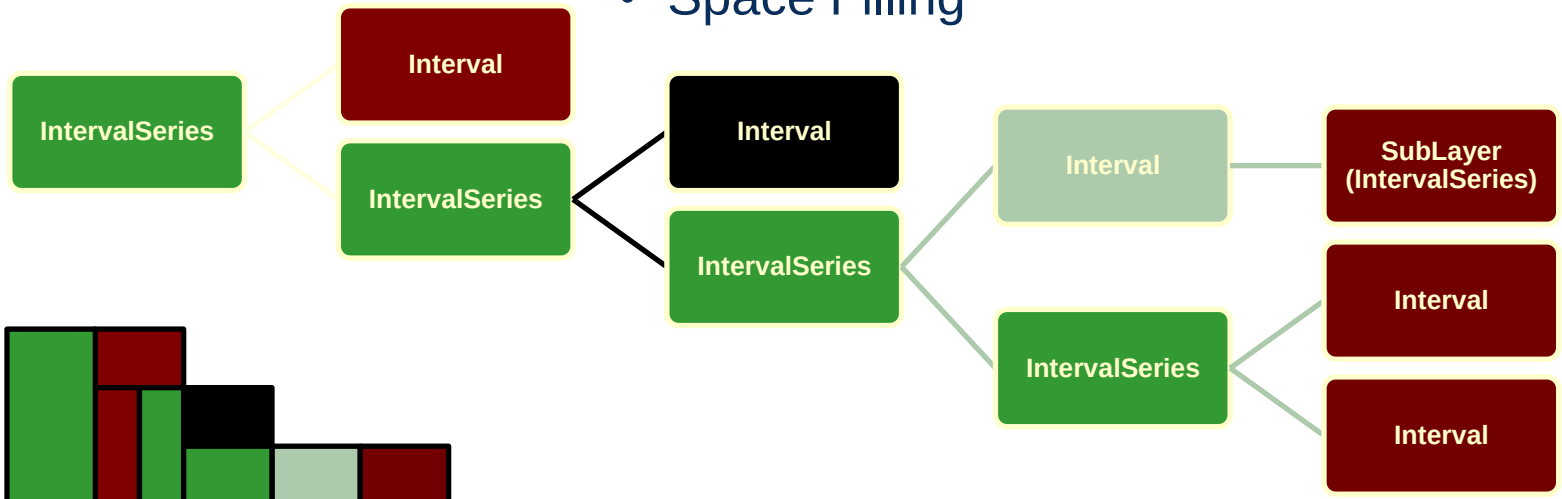
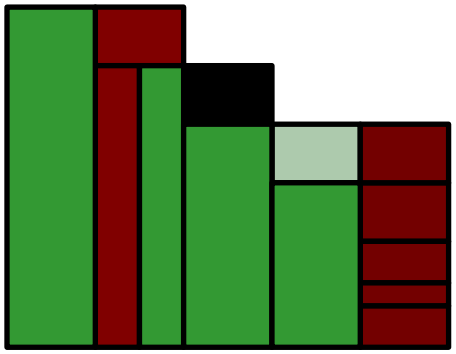
Common Model for Depth & Depth-Interval Derivations

- Observations aka Layers
- Borehole Segment
- Groundwater
- Groundwater Observation
- Interval Series
- Sampling

- Installation Details aka Drilling
- Borehole Filling
- Casing String
- Drilling Process
- Investigation
- Space Filling





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Interval Series

- 3.0.1: intervalSeries (1..n)
- IntervalSeries
  - layer (1..n)
    - Interval
      - lithology
        - » Lithology
      - stratigraphy
        - » Stratigraphy
          - » chronoStratigraphy
          - » lithoStratigraphy
      - sublayer (1..n)
        - » Component

- 4.0: depthIntervalSeries (1)
- (Litho)Stratigraphy (1..n)
  - interval aka layer (1..n)
    - Layer aka Interval (Class)
      - lithology (a property)
        - » Lithology (Class)
      - stratigraphy
        - » ---
        - » ChronoStratigraphy (Class)
        - » LithoStratigraphy (Class)
      - sublayer aka sublayer (1 .. n)
        - » Component

Layer, Formation, Chrono/LithoStratigraphy, etc. are Classes! Implementation of an interval

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Casing String & Space Filling

- BML 3.0.1
- installationDetail (1)
  - InstallationDetail**s**
    - casingString (1..n)
      - CasingString
        - » casingStringNumber
        - » casingStringType
        - » casingStringSegment (1..n)
          - » CasingStringSegment
    - spaceFilling (1..n)
      - SpaceFilling
        - » spaceFillingMaterial

- BML 4.0
- installationDetail**s** (1)
  - ----
    - CasingString (1..n)
      - ----
        - » number (1)
        - » type (1)
        - » interval aka segment (1..n)
          - » ----
    - SpaceFilling (1)
      - interval aka spaceFilling (1..n)
        - » material (1)

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Establish a domain-specific controlled vocabulary on the basis of common protocols and encodings

BOREHOLE-MANAGEMENT IS ONLY ONE SMALL PART IN THE CONTEXT OF EPOS

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EPOS, A SYSTEM-OF-SYSTEMS

Borehole-Management
Subsurface-Management
3D Basin-Modelling
Early Warning
Observatories

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INTEROPERABILITY?

GML, BML, WITSML, GeoSciML, …

CSV, GOCAD, …

JSON

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Modelling areas susceptible to earthquake induced landslides

- Static (Models and Measurements)
  - 3D Model of Surface Process Dynamics (e.g. Soil-Erosion, proprietary GOCAD)
  - 3D Vector-Field of Land Displacements
  - 3D Model of Earthquake Distribution (e.g. Magnitude, QuakeML)
  - 2D/3D Model of geological environment (proprietary GOCAD)
  - Digital Terrain Model (e.g. Slope, DEM)
  - Climate Measurements (e.g. Trends, dwGML)
  - Borehole Measurements (e.g. Geological Layers, BML)
  - Facility Management (e.g. Buildings, CityGML)
- Dynamic (Monitoring)
  - Borehole Observations (e.g. Groundwater-Level)
  - GPS based Observations
  - Earthquake Observations
  - Weather Observations (e.g. Rain)

Use Cases: Assessing levels of risk & Prediction of possible damages

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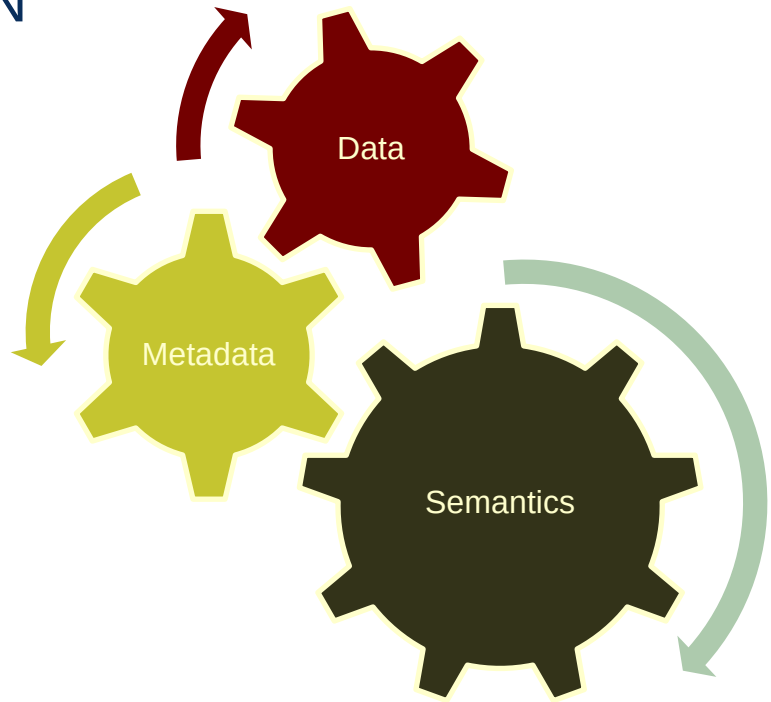
Separation of …

- Structure (Syntax)
  - XML
  - JSON
  - CSV



- Data
  - JSON, CSV
  - O&M, GML
  - X3D, SVG
- Metadata
  - ISO 19139, ISO 19xxx
  - SensorML
- Semantics
  - RDF, RDF-Schema, OWL
  - GML, SWE

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Establish interoperability for 1..n domains with one and only one encoding

THE BIG (W)HOLE

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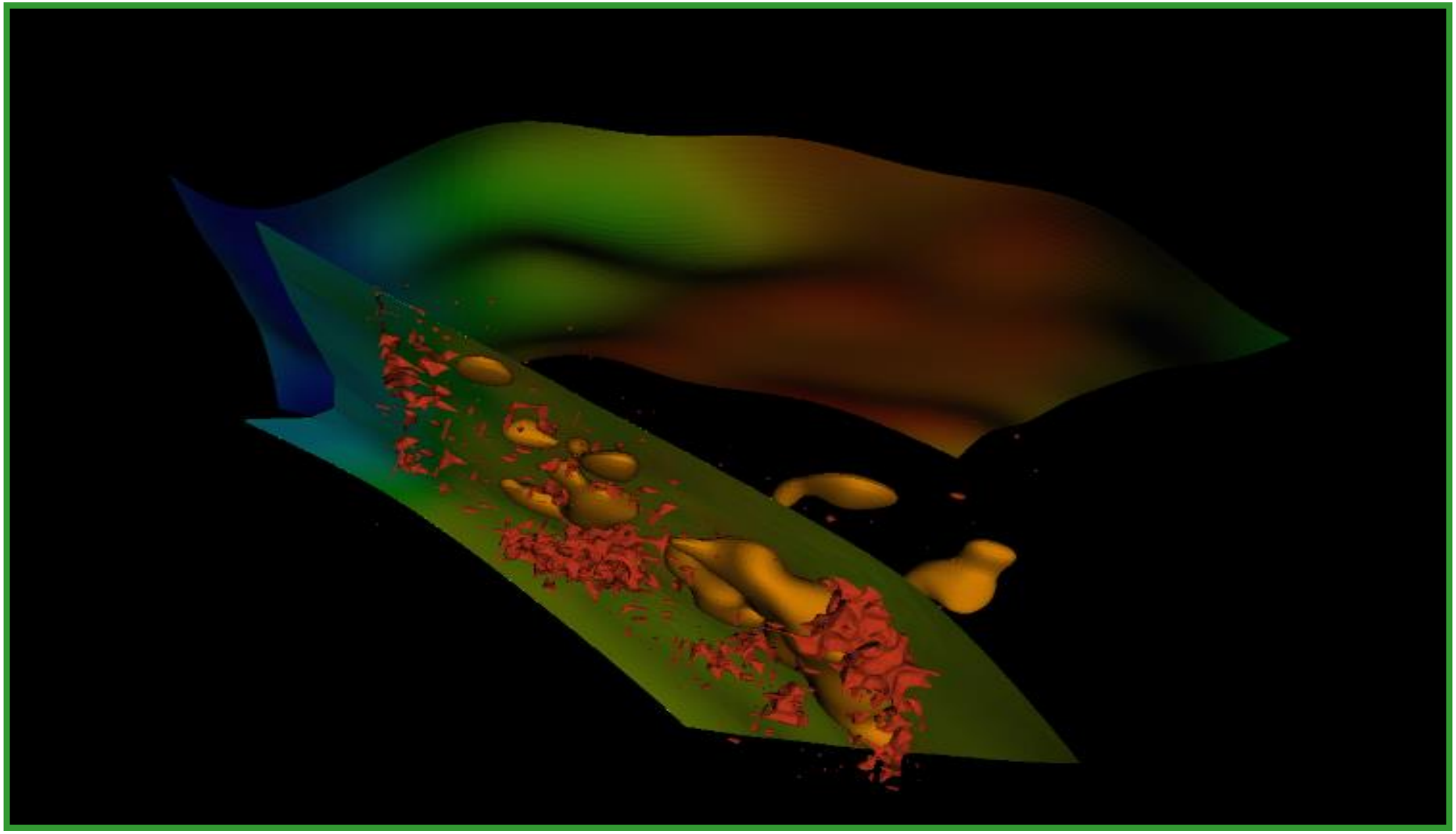
3D-Model: Gravity Field, Slab, EQ, Vp (X3D)

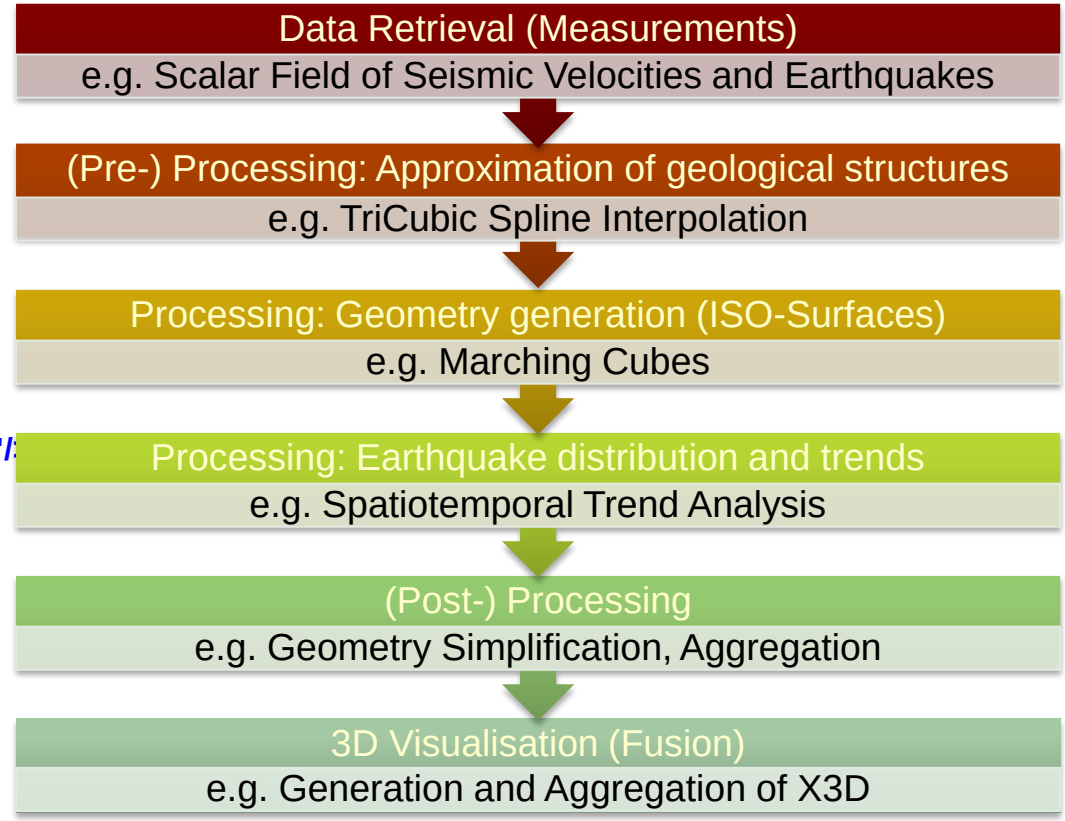


Modelling a Sensor (aka Process)

Approximation of a Contour-Plot from a Scalar Field of Seismic Velocities

SensorML

```
<?xml version="1.0" encoding="UTF-8"?>
<sml:SimpleProcess gml:id="Krige" xmlns:sml="http://opengis.net/sensorml"
xmlns:xlink="http://w3.org/1999/xlink">
    <sml:identification>
        <sml:IdentifierList>
            <sml:identifier>
                <sml:Term>
                    <sml:label>Processing Method</sml:label>
                    <sml:value>Kriging</sml:value>
                </sml:Term>
            </sml:identifier>
        </sml:IdentifierList>
    </sml:identification>
    <sml:inputs>
        <sml:InputList>
            <sml:input name="Vp-Field“/>
        </sml:InputList>
    </sml:inputs>
    <sml:outputs>
        <sml:OutputList>
            <sml:output name="Contour-Plot"/
        </sml:OutputList>
    </sml:outputs>
    <sml:parameters>
        <sml:ParameterList>
            <sml:parameter name=“nugget"/>
        </sml:ParameterList>
    </sml:parameters>
</sml:SimpleProcess>
```



Observation of a Scalar Field

```
<?xml version="1.0" encoding="UTF-8"?>
<om:OM_Observation gml:id=„Vp_Andes“
    <om:phenomenonTime/> <om:resultTime/>
    <om:procedure xlink:href="urn.ipoc.kriging"/>
    <om:observedProperty xlink:href="urn.ipoc.vp"/>
    <om:featureOfInterest xlink:href="urn.slab.andes"/>
    <om:result xlink:href="http://IPOC/Vp/SF.csv">
        <!-- Scalar Field (Data), CSV encoding -->
        <swe:DataStream>
            <swe:encoding><swe:TextEncoding
                    tokenSeparator=",„
                    blockSeparator="&#;„
                    decimalSeparator="."/>
            </swe:encoding>
            <!-- longitude,latitude,scalar value -->
            <swe:values>
                1, 1, 42
                1, 2, 42
                1, 3, 42
            </swe:values>
        </swe:DataStream>
    </om:result>
</om:OM_Observation>
```

O&M

```
<?xml version="1.0" encoding="UTF-8"?>
<swe:DataArray
    <swe:elementCount/>
    <swe:elementType unit_name="ScalarField">
        <swe:DataRecord id="SF_CSV_Definition">
            <swe:field unit_name="longitude">
                <swe:Quantity>
                    <swe:uom xlink:href="m"/>
                </swe:Quantity>
            </swe:field>
            <swe:field unit_name="latitude">
                <swe:Quantity>
                    <swe:uom xlink:href="m"/>
                </swe:Quantity>
            </swe:field>
            <swe:field unit_name="value">
                <swe:Quantity>
                    <swe:uom xlink:href=„Vp"/>
                </swe:Quantity>
            </swe:field>
        </swe:DataRecord>
    </swe:elementType>
</swe:DataArray>
```

Data Definition, “Header”

SWE Common

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Observation of a Vp Cross-Section

```xml
<?xml version="1.0" encoding="UTF-8"?>
<om:OM_Observation gml:id="Cross_Section_Subductionzone_Andes "
xmlns:gml="http://www.opengis.net/gml/3.2" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:swe="http://www.opengis.net/swe/2.0" xmlns:om="http://www.opengis.net/om/2.0">
    <om:phenomenonTime/>
    <om:resultTime/>
    <om:procedure xlink:href="urn.gfz_potsdam.numerical_model.kriging"/>
    <om:observedProperty xlink:href="urn.gfz_potsdam.structure.subduction.structure"/>
    <om:featureOfInterest>
        <gml:MultiCurveCoverage gml:id="Vp_66W_23S">
            <gml:domainSet/>
            <gml:rangeSet>
                <gml:ValueArray gml:id="ScalarField_Vp_66W_23S"/>
            </gml:rangeSet>
        </gml:MultiCurveCoverage>
    </om:featureOfInterest>
    <om:result xlink:href="http://gfz_potsdam.de/IPOC/seismic_velocity/isolines.svg">
        <!-- Approximated Geological Structure (Contour-Lines) -->
        <svg style="fill-opacity:1;" xmlns="http://www.w3.org/2000/svg">
            <defs id="genericDefs"/>
            <g style="fill:blue; stroke:blue;">
                <path d="M105.1296 56.2529 L110.2591 56.1232 L115.3887 56.1044 Z"/>
                <path d="M105.1296 56.32 L110.2591 56.1839 L115.3887 56.1642 Z"/>
            </g>
        </svg>
    </om:result>
</om:OM_Observation>
```

O&M

Contours have been “observed”

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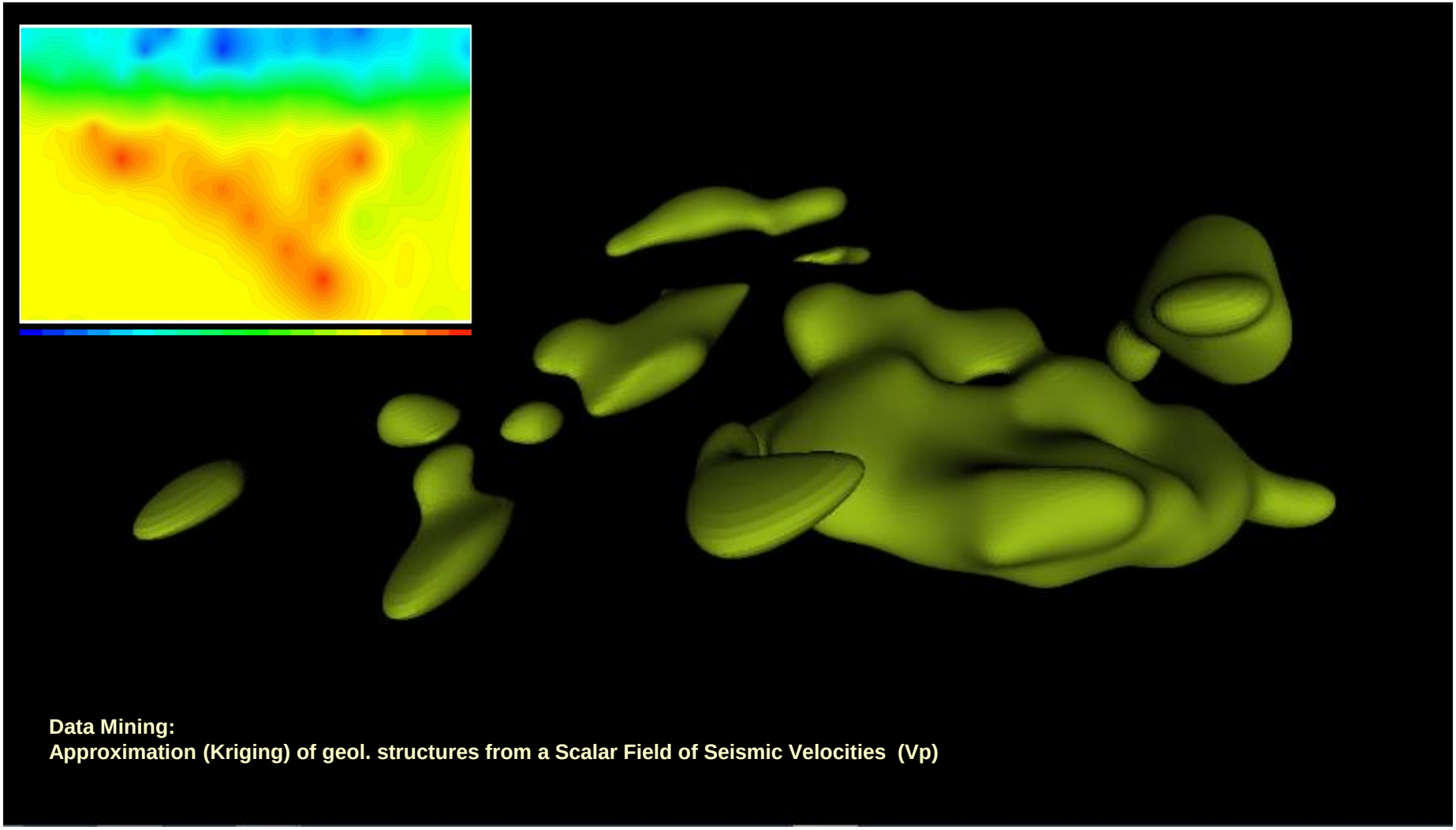
3D-Model: Vp 8.8 Bodies (X3D)



Code-List: ChronoStratigraphy

```
<?xml version="1.0" encoding="UTF-8"?>
<swe:DataArray id="Cenozoic_Systems" xmlns:swe="http://www.opengis.net/swe/2.0"
xmlns:xlink="http://www.w3.org/1999/xlink">
    <swe:values>
        <swe:field unit_name="systems">
            <swe:TimeRange>
                <swe:value>0.0    2.58</swe:value>
            </swe:TimeRange>
            <swe:Text><swe:value>Quaternary</swe:value></swe:Text>
        </swe:field>
        <swe:field unit_name="Quaternary Series">
            <swe:DataArray id="Quaternary_Series" definition="series">
                <swe:values>
                    <swe:DataRecord id="Q2">
                        <swe:field unit_name="timerange">
                            <swe:TimeRange>
                                <swe:value>0.0    0.0117</swe:value>
                            </swe:TimeRange>
                        </swe:field>
                        <swe:field unit_name="unit_name">
                            <swe:Text><swe:value>Holocene</swe:value></swe:Text>
                        </swe:field>
                    </swe:DataRecord>
                </swe:values>
            </swe:DataArray>
        </swe:field>
    </swe:values>
</swe:DataArray>
```

SWE Common

Measurement of Geological Layers

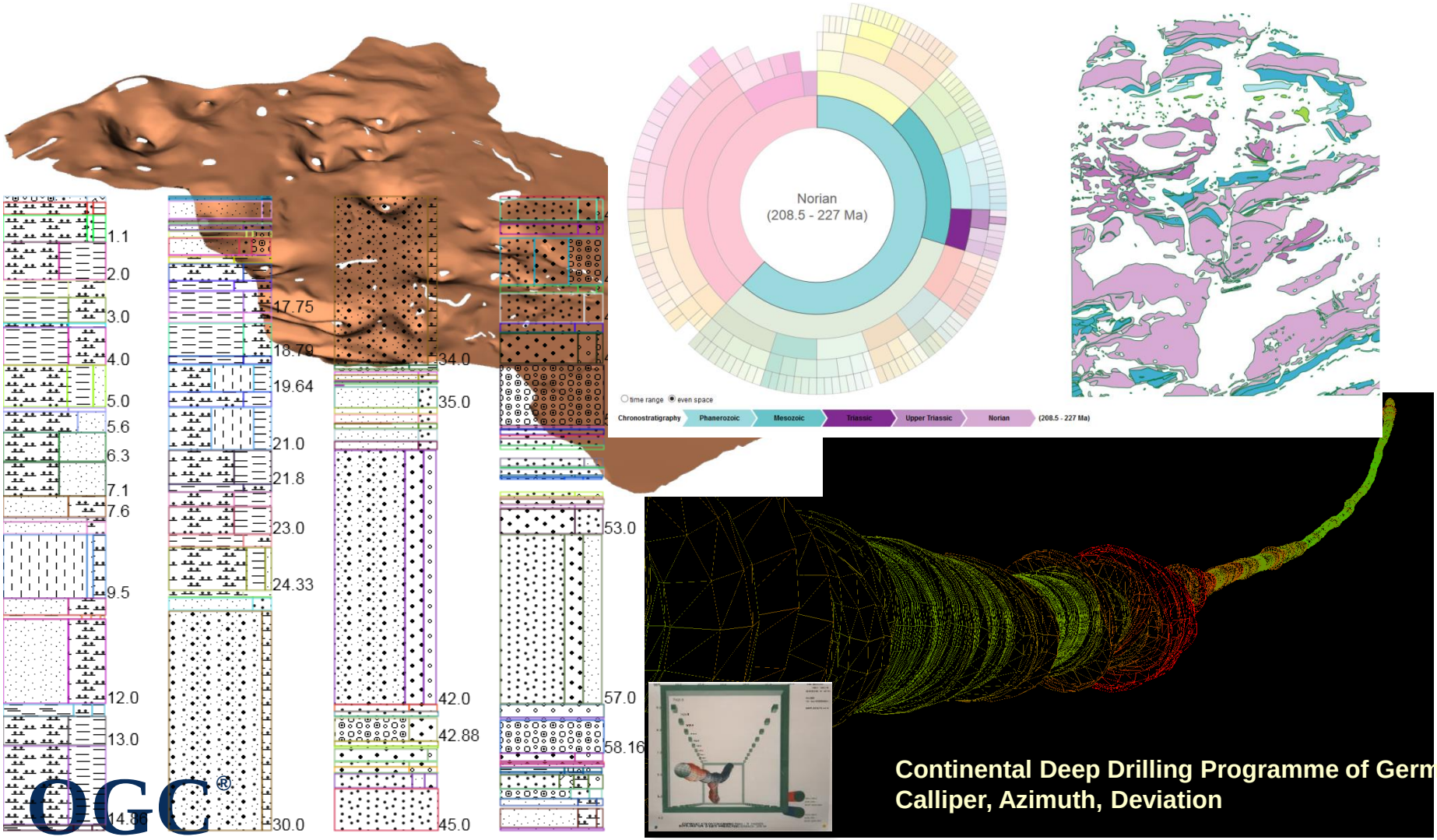
```
<bml:intervalSeries>    <bml:IntervalSeries>        <bml:layer>
        <bml:Interval>
            <bml:from uom="m">0.0</bml:from><bml:to uom="m">2.5</bml:to>
            <bml:rockCode>G</bml:rockCode> <bml:rockNameText>Granit</bml:rockNameText>
            <bml:lithology>
                <bml:Lithology>
                    <bml:rockName codeSpace=codelists/rnl">KMat</bml:rockName>
                    <bml:percentage>100.0</bml:percentage>
                </bml:Lithology>
            </bml:lithology>
            <bml:stratigraphy>
                <bml:Stratigraphy>
                    <bml:chronoStratigraphy codeSpace="codelists/ChronoList.xml">D</bml:chronoStratigraphy>
                    <bml:lithoStratigraphy>Devony</bml:lithoStratigraphy>
                </bml:Stratigraphy>
            </bml:stratigraphy>
            <bml:sublayer xsi:nil="true">            <bml:Component/>            </bml:sublayer>
        </bml:Interval>
    </bml:layer>
```

BML 3.0.1

```
<svg xmlns="http://www.w3.org/2000/svg" width="100%" height="100%">
    <defs>
        <pattern id="urn.petro.solid_rock" style="opaque" stroke=„red">
            <image width="35px" height=“14px“ xlink:href=“http://infogeo.de/img/litho/solid_rock.png"/>
        </pattern>
    </defs>
</svg>
```

SVG

3D-Model, Map, Stratigraphy(X3D, SVG, JSON)



Thank you for your attention …

… and for no more MLs

Rainer Häner

Centre for GeoInformation Technology Helmholtz Centre (CeGIT),

GFZ German Research Centre for Geosciences Potsdam

E-Mail: rainer.haener@gfz-potsdam.de

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Installations … of SWE

GITEWS (German Indonesian Tsunami Early Warning System)

- http://www.gitews.org/
- productive operation
- seismology, CGPS, simulation, buoys, ocean bottom units, tide gauges
- focuses on processing sensors (Seismic System, CGPS and Simulation)

DEWS (Distant Early Warning System)

- http://www.dews-online.org/
- wide area network of systems and resources
- prototypical implementation of a system of systems
- information logistics and dissemination

CAWa (Central Asia Water, a Regional Research Network)

- http://www.cawa-project.net/portal/cms/CAWa
- scientific data basis for the development of sustainable water management strategies in Central Asia
- monitoring, analysis, modelling, planning and prediction

TRIDEC (Collaborative, Complex and Critical Decision-Support in Evolving Crises)

- http://tridec.gfz-potsdam.de/
- putting focus on knowledge management, choreography and service orchestration
- emphasising adaptivity, evolution and collaboration
- two completely different scenarios (proof of concept)
  - natural crisis management (tsunami warning in North-eastern Atlantic and Mediterranean region)
  - industrial subsurface development (planning and operation of drilling projects)