7th 3D geological modelling meeting in Warsaw 2025 – Minutes of breakout session on **Uncertainty of 3D geological models**

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Evaluation of uncertainties

To evaluate uncertainties, two types of models must be distinguished :

1. **Implicit models** where the uncertainties have already been quantified more times in the past, using variability of X0 to X00 individual model realizations of a single locality that were created based on reliable variations of the input data. As an example can serve papers of F. Wellman or also other authors like e.g. G. Courrioux et al. (2015).
2. For **explicit models** the uncertainty evaluation must be treated significantly differently, because most usually only one model is manually created at each locality, based on (almost) all available input data. For such a case, probably only a paper of F. Staněk et al. (2025) reports and attempt to quantify the model uncertainty.

Despite very different calculation approaches, both of these two model groups share in general these three sources of uncertainties :

1. **input data** uncertainty, while the uncertainties of individual input data (often archival) are usually not available
2. uncertainty related to **methods** of model construction - mostly geostatistical methods for implicit models and manual methods for explicit models,
3. uncertainty of **general geological concept** or conceptualization that was followed during model construction.

Probably the most useful way of quantifying uncertainty is calculation for **each voxel of the whole discretized modelled volume** of rock environment. Each voxel may either contain single scalar value of some bulk uncertainty, or several values of different types of uncertainties. Whatever the evaluation of uncertainties is used, it must always consider distance to the input geoscientific data (to boreholes, geophysical profiles etc.).

For each model it is important to stress out that the quantified uncertainty values will always represent only **relative, subjective and artificial** values. They do not have real geological meaning, but rather serve for better orientation of stakeholders and further model users. It may never well capture uncertainty e.g. at the depth where input geoscientific data are entirely missing.

To reduce the model uncertainty already in the modelling preparatory phase, it is thus important to limit the model extent to the extent of reliable existing input data as much as possible, but of course respecting also further use of the model where the stakeholders may want larger extent than which is well grounded by input data.

Also, a conservative approach to modelling should be applied – conservative with respect to the expected further model usage.

Responsibility of modellers and related legal issues

The present conference revealed trend to focus modelling activities of (European) geological surveys more towards specific various needs of stakeholders, including active further usage of the geological models by non-geological experts. Such more applied modelling topics need to handle the model uncertainties also from the point of view of responsibility and related legal issues.

For this reason, the models should be accompanied by a written report that contains a **chapter related to uncertainty and validation** of the model. Such chapter should contain description of model uncertainties and also a **disclaimer** that warns each user that the model doesn't express correct and detailed reality but rather scientific interpretation that stems just from currently available data sources and current state of knowledge. It then implies limited responsibility of the model authors.

This brings also a question of legal issues when the model would be later used e.g. at some construction site. If for example such constructions would collapse due to assumptions based on wrong geological model, or if private properties like land or houses would attain decreased pricing due to bad subsurface conditions or underground mine excavations revealed in a geological model, or if ground water production of wells would be much worse than proposed according to the geological model, then the responsibility of model authors should be treated a bit similarly to geological maps, because in such cases the model can be understood as a 3D geological map.

For these purposes, an approved general workflow of the model construction and QA / QC forms or approaches should be formulated.

It should be also kept in mind that majority of model users do not read thoroughly the accompanying reports, so that a grid of quantified uncertainty values should be in future supplied and visualized as a common part of 3D geological models.

Presentation of uncertainties

There remained no time to discuss this important topic during the breakout session.

Generally, the uncertainty can be **visualized** and / or incorporated as **non-graphic attribute(s)** of modelled objects / voxels.