Activity report on postprocessing and evaluation of data model in pilot area Vogtland –W-Bohemia

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1. Executive summary in English language

This report describes the steps of harmonization, data transformation and quality check performed for the 3D structural model of the pilot area Vogtland W-Bohemia. Changes in the model representation were necessary, since the geological dataset available described the base of sedimentary lenses, since the standardized output had to describe the tops of the units. Changes in the data structure were necessary, since the model was produced with two software packages (Move and Gocad) in order to combine the two parts of the model in one consistent output file. Quality control of the model was performed by checking for horizon crossings, for sudden changes in the unit thickness and for holes in the model. The final 3D model is used on the GeoPlasma-CE web portal for the generation of virtual borehole profiles. A check of the resulting borehole profiles also enabled us to find errors in the 3D model, which were corrected for the final version of the model.

2. Executive summary in national language

Dieser Bericht beschreibt die Arbeitsschritte der Datenharmonisierung, -transformation und der Qualitätskontrolle, welche am 3D Modell des Pilotgebietes Vogtland W-Böhmen ausgeführt wurden. Die Modellrepräsentation einiger modellierter Einheiten musste geändert werden, da die geologischen Datensätze die Basen der Einheiten beschrieben, während für den standardisierten Output die Tops der Einheiten dargestellt werden mussten. Änderungen in der Datenstruktur waren nötig, da das Modell mit zwei Software-Paketen (Gocad und Move) erstellt wurde und dann in einem gemeinsamen Ausgabe-Modell-File organisiert werden musste. Qualitätskontrolle der Modellierungsergebnisse umfasste Tests, ob sich Horizonte kreuzen, ob sich Mächtigkeiten von modellierten Einheiten plötzlich ändern und ob Löcher im Modell auftreten. Das finale 3D Modell wird im Web-Portal von GeoPLASMA-CE zur Darstellung von virtuellen Bohrlöchern verwendet. Eine Kontrolle der Bohrprofile zeigte ebenfalls Fehler im 3D Modell auf, welche korrigiert wurden.

3. Introduction

3.1. Aim and scope of this report

This report describes the postprocessing steps performed on model of the pilot area Vogtland W-Bohemia, which have been created within the frame of Activity A.T3.3. These reports summarize activities on postprocessing and evaluation of 3D model of the pilot areas. It identifies strong and problematic points of preparation of the model.

This report describes the following postprocessing steps:

General postprocessing steps:

- Harmonization of attributes,
- Transformation of the reference system and parameter units to GeoPLASMA-CE standards.

Geological 3D modelling:

- Change the model representation (e.g. 3D/2D, unit tops),
- Change data structure (e.g. grids, triangulated surface),
- Quality control, validation and error estimation,
- Visualisation of modelling results and derivation of secondary maps.

4. General postprocessing steps

4.1. Harmonisation of attributes linked to modelling

The output OP01 “Tops of geological units” was produced for the pilot area Vogtland W-Bohemia. Harmonization of the geological data resulted in a standard geological column comprising 47 lithostratigraphic units. During data assemblage and reinterpretation it gradually appeared that not all of the planned units could be distinguished unambiguously throughout the entire modelled region, mainly due to scarcity / bad quality of archive data. For this reason, not all of the planned units are used in the 3D geological model. At the same time, not all of the units used are present in both parts of the joint 3D model. The southern part of geological model that was constructed by Czech Geological Survey consists of 22 lithostratigraphic units, the northern part that was modelled by the Saxon Geological Survey consists of 24 units.

The input data were given in Krovak S-JTSK, Bessel Gauss-Krueger Zone 4 and ETRS1989 UTM 33 projections. All input data were transformed into ETRS1989 UTM 33, which is the GeoPLASMA-Ce standard coordinate system.

5. Geological modelling

5.1. Overview of applied prodcuts

The output OP1 is a set of triangulated surfaces describing the tops of the geological units in the pilot area. The triangulated surfaces were produced with the software Gocad-Skua on the

German side and with the software Midland Valley Move on the Czech side. Both data sets were transformed into Gocad ASCII format and the surfaces were connected along the border, which means that overlaps and holes were corrected in order to obtain one continuous model surface for each unit top.

5.2. Changes of the model representation

The Quarternary units in the model consisted mainly of lenses, which had to be represented by their model base. In order to obtain the top of the next unit, the digital elevation model and the base of the hanging unit had to be merged. The crystalline units could be directly modelled as tops, such that no transformation of the model representation was necessary.

5.3. Changes of the data structure

In order to combine the Czech and the German parts of the 3D model, the data structure of Move was transformed into Gocad ASCII, which could be directly combined with the German model. The transformation was performed using an export function of Move.

5.4. Quality control, validation and errror estimation

The accuracy of the data sets was estimated to be 1 m for the well data. All deviations larger than this were handled as modelling errors. The model quality was checked by thickness plots, which were not allowed to show sudden changes. If a thickness change occurred around a single data point, it was handled as an artefact and the whole surface was corrected such that it respects the datum without thickness change in its surrounding. Additionally, the surface were checked for crossings between neighbouring horizons. If a horizon crossing is feasible, it represents an unconformity. In this case, one horizon was cut by the other and terminated at the unconformity. If two conformable horizons crossed, the crossing was removed by apply range thickness constraints, which specify a minimum thickness of the unit.

5.5. Visualisation of modelling results and derivation of secondary maps

The 3D model is presented on the GeoPLASMA-CE web portal, where it is displayed as full 3D model and is used in the location query for the generation of virtual borehole profiles. A quality check of the virtual borehole profiles allowed to find several error in the 3D model, which were corrected in the final version of the presented model.

6. Conclusions and outlook

Since the 3D model of the pilot area Vogtland W-Bohemia is very complex, the quality check was especially necessary and time-consuming. Errors were identified in a qualitative way by feasibility checks. A future quality check and improvement of the model is possible if new geological data like new drillings or mappings will be generated in the pilot area.

Activity report on postprocessing and evaluation of data model in pilot area Cheb-Vogtland

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Content

1. Executive summary in English language

The experiences gathered during model construction and data pre- / post- processing and related methodical rules set for the Geoplasma model construction were generally very good and led to significant improvement and generalization of 3D geological modelling approach at the Czech Geological Survey. Nevertheless several decisions and rules defined for Geoplasma model construction were inappropriate by our opinion and should be carefully considered in similar projects in future. In particular, extent of the pilot area was to large compared to detail needed for consideration of individual target users (i.e. often owners of houses, small factories e.t.c.). Further, modelling of Quarternary units with the planned detail was very time-consuming and generally imprecise on this model scale. Modelling of tops of geological bodies is non-intuitive and not natural, we suggest to model bottoms rather than tops in future projects. The Czech Geological Survey is recently developing its own web-viewer. In future, after overcoming recent technical and licensing issues, the 3D geological model of this pilot area is supposed to be presented in this viewer.

2. Executive summary in national language

Zkušenosti získané při konstrukci modelu a pre- / post- processingu dat, a související metodická pravidla stanovená pro konstrukci modelu v projektu Geoplasma byly obecně velmi dobré a vedly k významnému zlepšení a zobecnění metodických postupů 3D geologického modelování na České geologické službě. Přesto bylo podle našeho názoru několik rozhodnutí a pravidel definovaných pro konstrukci modelu nevhodných a tato by měla být v podobných projektech v budoucnu pečlivě zvážena. Konkrétně byl rozsah pilotní oblasti příliš velký ve srovnání s podrobností potřebnou pro jednotlivé cílové uživatele výstupů projektu (tj. často majitelů domů, malé továrny atd.). Dále, modelování kvartérních jednotek v naplánovaném detailu bylo v tomto měřítku modelu velmi časově náročné a obecně nepřesné. Modelování svrchních hranic geologických těles není intuitivní a není přirozené, v budoucích projektech doporučujeme spíše modelovat báze než vršky. Česká geologická služba v poslední době vyvíjí vlastní webový prohlížeč. V budoucnu, po překonání stávajících technických a licenčních problémů, by měl být v tomto prohlížeči uveden také 3D geologický model této pilotní oblasti.

3. Introduction

3.1. Aim and scope of this report

This report describes the postprocessing steps performed on model of the pilot area (Cheb-Vogtland), which have been created within the frame of Activity A.T3.3. These reports summarize activities on postprocessing and evaluation of 3D model of the pilot areas. It identify strong and problematic points of preparation of the model.

This report describes the following postprocessing steps:

General postprocessing steps

- Harmonization of attributes
- Transformation of the reference system and parameter units to GeoPLASMA-CE standards

Geological 3D modelling

- Change the model representation (e.g. 3D/2D, unit tops)
- Change data structure (e.g. grids, triangulated surface)
- Quality control, validation and error estimation
- Visualisation of modelling results and derivation of secondary maps

Numerical modelling

- Quality control, Validation and error estimation
- Changes of the file structure (e.g. ESRI database, shapefile)
- Visualisation of modelling results and derivation of secondary maps (e.g. calculation of mean temperature)

4. General postprocessing steps

4.1. Harmonisation of attributes linked to modelling

The dataset supplied together with the resulting 3D geological model involved hydrogeological data from boreholes and petrophysical data from rock samples. Both these datasets were imported from MS Excel and ArcMap GIS software into the unified and standardized MS Access database designed for the purposes of the Geoplasma project. The database was then checked for possible mistakes by crosschecking the database values with the original values in measurements results from laboratories etc.

4.2. Transformation of the reference system and parameter units to GeoPlasma standards

The Czech data were often originally available in the very inconvenient Czech national coordinate system S-JTSK. In these cases, all the data needed for model construction or import to database were projected into the joint coordinate system UTM 33N agreed for this PA by the Geoplasma team. Laboratory measurements were originally produced in standard SI units and according to the Geoplasma standards.

5. Geological modelling

5.1. Overview of applied prodcuts

The data preprocessing and postprocessing involved use of the following Software: ESRI ArcMap GIS, MS Excel, MS Access, Surfer. For the 3D model construction of the Cheb-Vogtland pilot area the MOVE software was used. In particular, extensive data preparation and some steps of modelling that involved grid calculations were performed in ArcMap GIS because MOVE does not offer extensive tools needed for the grid operations. Tops of the modelled units were directly created using MOVE software. All geological surfaces are represented by triangulated irregular networks (TIN's).

5.2. Changes of the model representation

To prepare the 3D model for the Vogtland area the SKUA-GOCAD software was applied. Some initial versions of modelled top surfaces were prepared with a use of the Surfer software. Linear interpolation was used for modelling of the Cheb area in the MOVE SW that is most suitable for surface construction of irregularly distributed spatial data. In Gocad a regression plane through the data is calculated and splitted into triangles. The data points are applied as interpolation constraints, the interpolation method is DSI. The two national 3D models were then joined in the SKUA GOCAD SW. For that reason, the Czech 3D model was exported in the GOCAD export format, where names and colours of the MOVE objects are preserved during the export and import into SKUA GOCAD. No other specific preparation steps had to be applied before model joining.

5.3. Changes of the data structure

The TINs of the approved 3D geological model were first exported from MOVE SW in DXF file format. The DXF files were subsequently imported into ArcMap GIS as so-called Multipatch type of objects, using internal import tool of the ArcMap SW. The multipatch –type TINs were then transformed into grids using the standardized master grid as defined in the previous Geoplasma guidelines. The resulting grids were then exported in a common 2D grid file format.

5.4. Quality control, validation and errror estimation

As data density and quality changes significantly across this pilot area, the Quality of resulting 3D geological model and its error estimation cannot be estimated in a relatively simple semiquantitative way, but rather detailed qualitative description of the issu must ge given as follows.

3D geological models are often created from ambiguous and uncertain data which are subject to error propagation during data acquisition and interpretation. Further the data are often scarce and heterogeneous, so that the modeller depends on model-based interpretation, e.g. by assuming a certain tectonic regime or deformation style. Apart from the small scale models of the resource industries, these uncertainties are often neither evaluated nor shown to the users and stakeholders because there is currently no standardized approach to quantify the uncertainties for such complex and large – scale cases. According to results of this project, the quantification of uncertainty would require compilation of different sources of uncertainty, classification of the different types of uncertainty formulated and data sets for the different types of uncertainty provided. Subsequently these data sets would have to be used to test existing and develop new visualization methods from computer graphics. None of such approaches was published so far for comparable geological 3D models.

In case of this pilot area, the modelling uncertainties are caused by data errors (boreholes, maps and cross-sections), lack of data, and the methodology of modelling. The highest credibility was assigned to the boreholes data and the geological map.

Uncertainties and errors of methodology of modelling:

These errors are derived from the interpolation method used. Linear interpolation was used for modelling in the MOVE SW that is most suitable for surface construction of irregularly distributed spatial data. At small thicknesses of modelled units, the meshes locally crossed each other on a scale of 1-2 m. This problem appeared mainly with Quaternary units, but it also occurred elsewhere, where the dip of the units was very small combined with limited thickness of adjacent units. In these cases, it was decided that the boundary of the underlying model unit was locally shifted by 2 or 3 m downwards manually, to correct this purely artificial inconsistency.

Uncertainties and errors of map:

The geological map used for model construction was created by compiling and simplifying archive geological maps of various scales. Each model unit combines multiple lithological or stratigraphical units displayed in the original geological maps. . These maps have been created by various geologists who have different opinions on the geological genesis of the area of interest. The verification of lithological boundaries or fault networks by geological mapping has never taken place thoroughly.

The extent of individual quaternary bodies in the original geological maps seems to be very often imprecise to misleading. The boundaries of the quaternary bodies were strongly corrected using the DTM 4G. Accuracy of these bodies corresponds to the precision of the DTM 4G (grid unit 5×5 m) and the experience of the quaternary geologist. Significant terrain verification could not take place with regard to the project schedule.

The inaccuracies of the model unit boundaries are also related to the inaccuracy of the fault network. The used fault network was created as a compilation of all available tectonic interpretations and maps. Again, each author had different opinion on the fault network and therefore, the map fault networks do not match with each other. The dip or sense of movement has not been established at many faults.

Uncertainties and errors of cross-sections:

The published cross-sections used to create the 3D model are of variable quality that is hard to asses. Uncertainties comprise number and location of faults, as well as determination of the depth of model units.

Uncertainties and errors of borehole data:

Borehole data contain these three principal types of errors:

1. Determination of the model unit boundaries – particularly in sedimentary sequences this feature represents the most important source of errors, due to often lower quality of borehole description combined with complex (sedimentary) succession. Borehole profiles were reclassified according to the created model legend. Unfortunately, some boundaries of model units in borehole profiles are poorly determined or missing. To recognize model units mainly in Tertiary sediments is often difficult.
2. Position of borehole – errors appears relatively scarcely, often of a scale of several meters. The borehole is located in the model unit on the geological map, but in its profile the model unit is missing. There is also a problem with altitude localization. Some boreholes are located a few meters under the terrain (the error is somewhere over 10 meters).
3. Lack of inclinometry – the uncertainty then generally increases with depth. None of the boreholes has inclinometry. Therefore, the boreholes, showed as vertical in the model, pass through faults into another tectonic block and thus into another model unit.

5.5. Visualisation of modelling results and derivation of secondary maps

The PA 3D geological model is visualized solely on the Geoplasma web portal. Despite the Czech Geological Survey is recently developing its own web-viewer with use of the ESRI Arc GSI Pro web functionalities, the viewer cannot process such large areas as this PA covers so far, resp. it cannot handle so huge number of vertexes of the model meshes, as the 3D model is composed of mainly due to areal extent of the PA.

The TINs of the approved 3D geological model were first exported from MOVE SW in DXF file format. The DXF files were subsequently imported into ArcMap GIS as so-called Multipatch type of objects, using internal import tool of the ArcMap SW. The multipatch –type TINs were then transformed into grids using the standardized master grid as defined in the previous Geoplasma guidelines. The resulting grids were then exported in a common 2D grid file format and serve mainly for geothermal potential calculations and for virtual borehole construction. The web-services available for this pilot area include General information, Potential maps - Borehole heat exchangers, Conflict maps, Field measurements and Local contacts for those users, who may need more detailed informations (Professionals, Research institute, Planning and consultation institutes, Authority and Thermal response test). In case of this pilot area, also a 3D model is available through a link to giga-infosystems web interface.

6. Numerical modelling

Numerical modelling was neither planned nor realized in this pilot area.

7. Conclusions and outlook

The experiences gathered during model construction and data pre- / post- processing and related methodical rules set for the Geoplasma model construction led to significant improvement and generalization of 3D geological modelling approach at the Czech Geological Survey. Nevertheless several decisions and rules defined for Geoplasma model construction were inappropriate by our opinion and should be carefully considered in similar projects in future:

- Extent of the pilot area was to large compared to detail needed for consideration of individual target users (i.e. often owners of houses, small factories e.t.c.) Particularly simplifications of lithological units and fault network needed for handling of such large model with presently available hardware equipment may lead to either exaggerated simplification or regular mistakes on a scale of some e.g. 50m deep geothermal borehole planning.
- Modelling of Quarternary units with the planned detail was very time-consuming and generally imprecise on this model scale. The time costs are moreover in contradiction with very low effect of Quarternary sediments on heat extraction potential, due to mainly limited thickness of the Quarternary sediments (not only) in this PA compared to the common depth of geothermal boreholes.
- Modelling of tops of geological bodies is non-intuitive and not natural. In reality, most geological bodies are characterized by well-defined and topologically relatively simple bottom (erosional surface, etc.), but their top boundaries are often affected by several processes and thus neighbouring with several rock units. This causes significant technical problems during model construction and also topological misfits during further model handling. Thus, we suggest to model bottoms rather than tops in future projects.
- The Czech Geological Survey is recently developing its own web-viewer with use of the ESRI Arc GSI Pro web functionalities. In future, after overcoming recent technical and licensing issues, the 3D geological model of this pilot area is supposed to be presented in this viewer.