Chapter 10: 3D Geological Modelling at the Czech Geological Survey

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Introduction
The Czech Geological Survey (CGS), established in 1919, provides the state geological service for the Czech Republic. Even though the structure of the institution and its name have changed several times, its main mission and related unique social status have remained. CGS has the statutory responsibility to gather, store and interpret geological information so that the state administration can take appropriate decisions about national economic and environmental issues. It provides the results of systematic regional geological mapping and investigation to all interested persons.

The Czech Geological Survey pays increasing attention to building 3D geological models as a part of the research and commercial projects and provides definition of a unified systematic approach to their storage, administration and presentation.

Organizational Structure and Business Model
The Czech Geological Survey is a state contributory organization that belongs to the structure of the Ministry of Environment of the Czech Republic. The organizational structure of the CGS consists of six divisions within the frame of eight local offices: four in Prague and one in each of Brno, Kutná Hora, Jeseník and Lužná u Rakovníka. These divisions include the Directorate, Geochemistry and Central Laboratories Division, Economic Division, Geological Division, Geofond Division and the Division of Informatics.

Overview of 3D Modelling Activities
As the administrator and owner of large geoscientific datasets from the whole territory of the Czech Republic, CGS is involved in numerous applied research projects dealing with various kinds of use of the subsurface rock environment. High-speed railway tunnels, reassessment of mineral resources, assessment of geothermal energy potential, carbon capture and storage (CCS) and, last but not least, location of a deep radioactive waste repository are among priority projects of the national importance.

Resources Allocated to 3D Modelling Activities
There is no dedicated yearly budget allocated to 3D modelling activities within the CGS. Geological models are built within different projects or contracts (ca. 9 FTE) and standardization activities related to the data storage and administration are partly covered by an internal project with limited capacities (ca. 0.7 FTE).

Overview of Regional Geological Setting
A majority of the territory of the Czech Republic is built by crystalline rocks of the Bohemian Massif consolidated during the Variscan Orogeny. The Massif is partly covered by Permian, Carboniferous, Cretaceous and Tertiary sedimentary basins and in the East it is buried below the Carpathian overthrust units since Middle Miocene. The Bohemian Massif is conventionally subdivided into the Saxothuringian domain in the West, the Teplá-Barrandian and Moldanubian domains in the central part of the Massif and the Brunovistulian (Brunia) Neoproterozoic lithospheric plate in the East. Presently it is interpreted as a Gondwana-derived Variscan collisional domain characterized by: 1) relics of a two-stage SE-directed subduction at the Saxothuringian–Teplá-Barrandian boundary; 2) a magmatic arc genetically related to the subduction represented by the Central Bohemian Plutonic Complex in the centre; and 3) the rigid foreland represented by the Brunia plate in the SE. Large Variscan strike-slip zones (e.g. the Elbe Fault Zone) strike NW–SE dismember the NNE trending Variscan structure of the Bohemian Massif.
Data Sources

The input data for creation of a regional structural geological model usually includes: geological map 1:50,000 or 1:25,000, archival purpose-specific geological maps, tectonic data from the rock outcrops, cross sections and maps from the mineral exploration (e.g. extensive uranium surveys), subsurface data in digital and printed form (borehole data, geological profiles, archival or new geophysical data and interpretations). A problematic aspect is often the scarcity of deep borehole data (especially in crystalline parts of the territory of the Czech Republic), or the absence of high-quality geophysical survey.

3D Modelling Approach

The 3D geological models built in the Czech Geological Survey cover a broad spectrum of scales and lithotectonic environments. Concerning scale, they range from meters in the case of outcrop fracturing quantification for Discrete Fracture Network models, to regional scale covering areas of hundreds of square kilometres and up to 1.5 km depth. They depict structurally complex high-grade metamorphic units that exhibit several episodes of pervasive ductile deformation, partial melting and emplacement of magmatic bodies, as well as simple overlying sedimentary formations. Each model includes an initial assessment of model reliability, used especially for purposes of risk/safety analysis. The scarcity, heterogeneity and complexity of available archived and newly acquired geological data often do not allow for any semi-automatic techniques of model construction; the models usually need to be created purely manually.

Models of sedimentary basins are put together based on 2D and 3D seismic surveys, well logs and all other supporting data, such as lithological core samples description and laboratory analysis. First, the well logs are converted from depth to time (TWT) domain and linked with the seismics, then the horizons and faults are mapped using different interpretation techniques and tools.

Clients

The 3D geological models are used either for presentation purposes, or in further research and exploration as a geometrical basis for numerical simulations and other engineering applications. Based on the 3D geological models, e.g. 3D hydraulic and transport numerical simulations are performed to estimate groundwater flow. Additionally, the models are used by engineering companies in CAD-type SW as natural limits for technical design of underground facilities (Figure 1).

Another application is the use of 3D models for the evaluation of geological structures focused on reservoir volumes, permeability, and seal efficiency. The results serve as a basis for further scenario testing of future technological actions and related environmental risks, e.g. subsurface gas or CO₂ storage (Figure 2).

As the models are often created for a specific purpose, their construction comprises numerous meetings with customers and continuous adaptation of the data processing and modelling workflow to fulfil their needs. Even after finishing a particular project or contract, the CGS is eventually engaged in further use of the resulting model(s) as a geological or hydrogeological consulting expert team.

Recent Jurisdictional-Scale Case Study Showcasing Application of 3D Models

Information on this topic is currently not available.

Current Challenges

3D geological models are often created from ambiguous and uncertain data which are subject to error propagation during measurement and interpretation. In addition, they are often

Figure 1. 3D structural geological model of the ZK-3S niche in the underground research facility Bukov operated by SURAO. The model with dimensions of about 10 x 10 x 4 m represents compilation of a laserscan and photogrammetric model. The lithology and structures in the nearby boreholes are plotted into this model, individual brittle structures on the walls of the niche (cracks in blue, faults in orange) were created manually, along with schematic main lithological boundaries (green). Based on all these data, position of 10 horizontal wells (purple color) was proposed for in-situ interaction experiments with bentonite and heaters.
scarce and heterogeneous, so that the modeller has to rely on a model-based interpretation, e.g. by assuming a certain tectonic regime or deformation style. Currently, the challenge is to evaluate the uncertainties mentioned above and provide them to the model users and stakeholders in an easily understandable and precise form. More challenges are related to dynamic simulations of the processes which happened in the past, e.g. oil, gas or water production, and which are going to happen, such as underground gas storage. The key words are: the volumes or amounts of produced or stored fluids, the velocity of the fluid movement, and the associated risk.

CGS is currently working on the development of a customized web viewer (based on Esri API for Javascript) for a satisfying visualization of models without the need to install any plugins. This viewer should be publically available in 2019 and should be interlinked with an interactive map overview of the modelling activities of the CGS (described by proper metadata according to the ISO 19115 standard).

A continuous challenge is to set the topic of the creation of the 3D geoscientific information system as one of the priorities of our institution and have a dedicated team with capacities to work on it systematically.

Lessons Learned

First steps have been done in developing a 3D modelling system in our geological survey organization. The selection of the modelling software has been done based on a careful analysis of available solutions for the future needs, e.g. their presentation possibilities, modelling workflow, and flexibility in import and export of various data sets. New 3D models require some important changes in existing database structures and applications. New ways of financing of such supporting activities need to be sought, especially in cases where particular regions or smaller areas are not strictly involved in certain projects or contracts but, at the same time, they are important on the national scale.

Next Steps

The long-term CGS mission is to create a 3D geoscientific information system that would include a spatial database for the central storage, administration and use of 3D data and models (GEOCR3D), methodology for a standardized creation of the 3D models from existing or newly acquired data, quality assurance processes, and sharing of the modelling results. In the short term, we would like to advance with the standardized metadata description of the models, making the models accessible via a web viewer, and customization of the applications to retrieve relevant input data from the CGS central databases.

Reference