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New frontiers and challenges in geomodelling

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Contents

Integration of geoinformation systems into geological exploration works on the example of Kokpatas ore field

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The accelerated development of metal production in recent years determines the relevance of preparing a long-term mineral resource base of ore minerals in Uzbekistan. Active increase in the rate of development of metallogenic potential and mining and metallurgical industry of the republic entails an urgent need to increase the growth of predicted gold resources. First of all, this is needed in the areas with existing and emerging mining enterprises. Therefore, the study of new territories based on the analysis of primary and resultant data of previous geological studies has a great prospect. At present, digitalization of geological, geophysical, geochemical and various thematic maps is being carried out with the creation of a digital database in ArcGIS software for the territory of the Kokpatas ore field of the Bukantau Mountains. On the basis of the created database of geological, geophysical and geochemical and other information re-interpretation of geoinformation with the use of new remote sensing data in specialized programs Statistica, Oasis montaj, Zond 1-2, Suefer, geomatica PSI, Envi, Erdas, TSG and others is carried out [1]. Systematization and generalization of data accumulated as a result of many years of research conducted in the Bukantau Mountains was carried out in the ArcGIS software environment. All the material collected over an extensive period of research digitized into a digital format, provide a basis for decision-making and contribute to the development of measures to fulfill the geological task. Creating thematic GIS-layers, while performing cosmogeological works, geological maps were compared with the cosmogeological scheme, where the composition, age and boundaries of the structural and demarcated complexes were specified. By comparing the cosmogeological scheme with thematic layers of minerals and geochemistry, the ore-concentrating role of remotely identified SDK and structural elements was clarified. The position of structures within the studied areas was clarified by analyzing geophysical data. GIS enabled the integration of huge amounts of data and the creation of new links between data stored in heterogeneous databases.

The automation and digitalization of exploration processes, including the creation of digital databases and the use of geographic information systems (GIS), allow for the integration of heterogeneous data and more accurate analysis. This, in turn, contributes not only to improving the accuracy of forecasting hidden deposits and identifying new deposits, but also to optimizing fieldwork costs, which significantly increases economic efficiency.

References:

[1] https://www.esri-cis.com/ru-ru/industries/mining/overview

Testing tTEM capabilities for geological mapping in Estonia

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This poster presents the testing of the geophysical method tTEM (towed Transient ElectroMagnetic measurement) under Estonian conditions. The tTEM method is a novel and rapid geophysical technique that allows for high-precision mapping of hydrogeological layers and mineral resources. The studies were conducted in two different areas: Pärnu and Kunda.

In the Pärnu study area, the objective was to gather detailed information about the clay layers present in the overburden, which play a crucial role in protecting groundwater from contamination. The detailed information collected about the clays significantly improves the accuracy of groundwater protection maps. The tTEM method mapped the thickness and distribution of clay layers, which vary from zero to 25 meters.

The Kunda study area involved mapping a buried valley and a potential tectonic fault. The study revealed that it is possible to distinguish different geological layers and groundwater layers in the Kunda area, including the Ordovician and Cambrian groundwater complexes. The tTEM data refined the boundaries of the buried valley and the nature of its infill sediments.

Overall, the testing of the tTEM method demonstrated that it is an effective and rapid method for conducting geological and hydrogeological studies, providing detailed and accurate information about the subsurface and bedrock. These results partially reflect known information but also highlight new and important details that enhance our understanding of Estonia's geological layers and groundwater protection.

Optimal methods of three-dimensional calculation of reserves of gold ore deposits Bulutkan by different cut-off grades

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Gold ore deposits Bulutkan is located in Bukantau ore region of Uzbekistan. The area is composed of metaterrigenous and siliceous-carbonate deposits of the middle subsuite of the Kokpatas suite, conventionally dated to the Upper Riphean. The ore body of the occurrence is represented by metasomatically measured quartzite, siliceous-carbonate and carbonaceous-siliceous rocks.

To calculate the reserves of the Bulutkan gold deposit, the stock materials, including sections and geological maps, are tied to the georeferencing in the Micromine programs. Then digitized with primary graphic materials. The database of the Bulutkan site is represented by 32 wells with a depth of 20 to 76 m. The length of the sampling intervals varies from 0.4 to 4.0 m.

The reserves are calculated based on the cutoff gold content of 0.5 g / t. For the cut-off gold grade of 0.5 g/t, the following conditions were applied (minimum industrial gold grade in the calculation block is 3.3 g/t, minimum gold grade in the edge intersection for outlining the ore body in the plane is 3.0 g/t). For the cut-off gold grade of 0.5 g/t, the minimum industrial gold grade in the calculation block is 3.3 g/t, the minimum gold grade in the edge intersection is 2.5 g/t, the minimum thickness of the ore bodies is 1.0 m; the maximum thickness of the layers of substandard ores or waste rock is 3.0 m.

The reserves were calculated using a block model using the Micromine software package using the inverse distance method due to the small number of intersections. The interpretation and contouring of ore bodies was carried out along sections with reference to ore intervals along the sides. In total, 4 ore bodies were allocated, as in the calculation of reserves by the BM method. The contours of the ore bodies were linked into wireframe models. A histogram was constructed to determine the nature of the distribution of gold grades. Taking into account the main statistical parameters of the distribution (median, variance and mean), it can be concluded that the distribution of the studied population belongs to the lognormal law, that the sample is represented by one population, and no clearly expressed hurricane population is observed in the area of erratic distribution. However, given the sufficiently high variation coefficient, it can be assumed that the involvement of samples in the interpolation of grades without limitation can lead to a biased estimate of the mean.

Spatial maps of a potential salt pillow in the Złotów area

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The Central Polish Anticlinorium is a regional structural unit that was formed as a result of the Late Cretaceous inversion of the Permian-Mesozoic Polish Trough (Krzywiec et al., 2024). Within this area, salt pillows composed of Upper Permian evaporites occur locally. In the Szczecinek-Złotów area, the integrated archival seismic and borehole data was used to reinterpret and verify previously identified salt structures. The obtained results allowed to reveal area with increased thickness of evaporites, indicating the possibility of the occurrence of a previously unrecognized salt pillow. Some of prospecting areas were subjected to detailed analyses. Three-dimensional structural maps were developed in order to estimate spatial extent and morphology of salt structures located in the study area. Their more detailed analysis was possible thanks to advanced algorithms applied in Schlumberger's Petrel software, which was used to create previously mentioned structural maps. The potentially newly discovered salt pillow occurs at an approximate depth of 2,900 m to 3,700 m. Thanks to advanced structural mapping, it is possible to better understand the structure of salt pillows, which is important for future projects related to, among others, the exploration of new salt structures and assessment of the geothermal potential of the studied region.

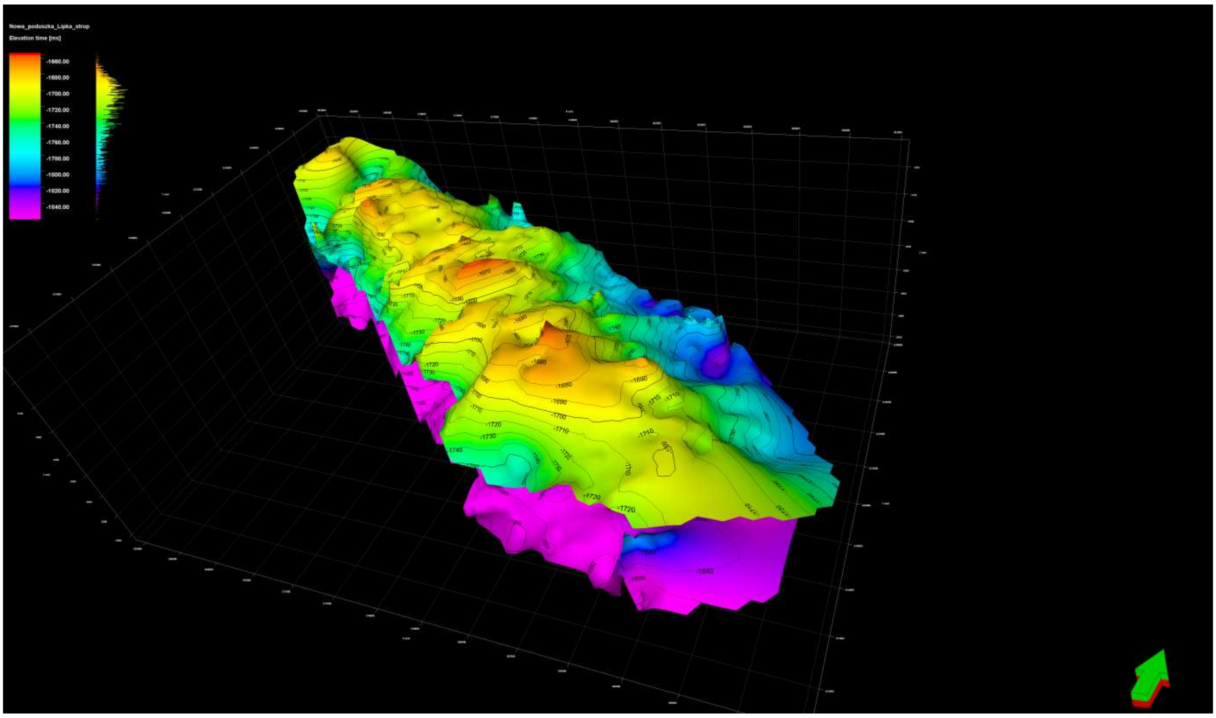

Figure 1. Spatial maps of a potential salt pillow in the Złotów area.

References:

Krzywiec, P., Adamuszek, M., Filbà, L., Rowan, M. G., & Ferrer, O. (2024). Salt-pillow formation during inversion of evaporite-filled half graben–Insights from seismic data interpretation and integrated analogue-numerical modelling. Journal of Structural Geology, 184, 105148.

Survey-Client Collaboration – Ripples in a Pond

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Over 250 m of Quaternary-aged sediments deposited during successive glaciations cover bedrock across much of southern Ontario, Canada. These sediments form vital aquifers and groundwater recharge areas, and are important sources of aggregates, but are at risk from the competing demands of the housing, infrastructure and industry required by an expanding population. Conservation Authorities work with the Province and local municipalities to deliver the Source Water Protection Program under Ontario’s Clean Water Act (2006). As part of the program, each municipality has developed local numerical groundwater flow models to map quality-based Wellhead Protection Areas for their municipal water supply wells, and in areas under moderate to significant water quantity stress, have assessed the long-term sustainability of their municipal supplies through detailed groundwater flow models. Typically, the services of consulting hydrogeologists are required to complete the work and these practitioners use Ontario Geological Survey (OGS) three-dimensional (3D) hydrostratigraphic models to streamline their workflow.

A recent OGS drilling program exemplifies the development of meaningful collaboration. An older OGS 3D model was extended to cover the numerical flow model domain of a city dependent on groundwater by a post-doctoral student whose research was partially funded by a local consulting company. The project informed the selection of several targets for drilling continuously cored holes in preparation for a new, and more extensive, public access OGS model. Consultants working on a separate project for the city recommended converting one of the cored holes into a nested monitoring well. Further north, municipal planners, and their consultants, requested OGS assistance in preparation for defining new municipal wellhead protection areas where future growth is anticipated. This provided the impetus to design a drilling program extending across a glacial interlobate zone and develop the Quaternary stratigraphic framework in an area not previously studied. Several cored boreholes have been converted to monitoring wells, and one will be included in the provincial monitoring network maintained by a sister ministry. Negotiating access agreements with a municipality along the planned transect led to the installation of an additional well, and the opportunity to provide, and release publicly, detailed logs for core obtained during a concurrent drilling program. Word of the collaborative spirit spread, and the OGS has been given a gamma logger by a retired hydrogeologist to aid future work.

To be or not to be findable – results of the first stage of the GSEU 3D geomodels inventory

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Research aimed at securing natural resources and protecting the environment often requires basic information on the geological composition of the subsurface, typically represented through geological maps and 3D geomodels. Access to these data sources is essential, yet the current methods of discovering and retrieving such information, particularly 3D geomodels, are inefficient. Standard web browsers, paper publications, and library catalogues (often unavailable online) are the main tools for searching, making access to up-to-date data challenging.

To address this, WP6 of the GSEU project (HORIZON-CL5-2021-D3-02) is working to create a sustainable system for cataloguing geological maps and 3D geomodels. This initiative aims to build an inventory that makes geological data FAIR (Findable, Accessible, Interoperable, and Reusable), facilitating search and cross-border harmonization.

The GSEU 3D geomodels inventory was developed in two stages. Stage 1 focused on collecting basic data to define and describe the datasets, which was achieved through online questionnaires sent to participating Geological Survey Organisations (GSOs). Stage 2 will complete the attribute set and resolve any data errors.

Twenty-four countries participated in Stage 1, revealing that five countries do not possess 3D geomodels. A total of 237 geomodels were inventoried, but only one was produced through international cooperation. The data also included information on the number of models per country, their scope, language, purpose, subject types, metadata availability, file format, and software used.

A key finding was that 68% of the 3D geomodels are not accessible online. This lack of online availability will be further explored with GSOs to understand whether it is due to technical, formal, or other issues. The overall goal of this inventory is to improve the search and accessibility of 3D geomodels across Europe.

3D Geological Map of Gothenburg to support Underground Planning

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Information about soil layers and bedrock composition and structure is crucial both in the planning and implementation of major infrastructure projects. However, valuable geological data from completed infrastructure projects are not always consistently preserved. The Geological Survey of Sweden (SGU) strives to collect, store, and provide geological information from external stakeholders in order to improve this situation. This 'recycling' of externally sourced information, when processed and integrated with SGU's own data, enhances the geological input to the planning of future construction and infrastructure initiatives. Most detailed geological data is prepared by consultants and contractors, typically reported only to the project client and used solely for the specific project. If this information were systematically preserved and made broadly accessible, significant economic benefits could be achieved for society.

The Geological Survey of Sweden (SGU) has previously developed a regional 3D bedrock map of Gothenburg municipality (*https://geo3d.pgi.gov.pl/SGU_Goteborg/index.html*) and a report detailing the area's bedrock, soil types, and geological development (*Bergström, et all, 2021*). Recently, SGU has significantly updated the interpretation of soil layers, integrating borehole data from external consultants' boreholes and modelling fracture zones in the bedrock, based on extensive public and confidential infrastructure tunnel projects.

These fracture or weakness zones are often associated with brittle faults in the bedrock. When such zones are unforeseen and encountered during tunnel construction, the associated poor rock conditions can lead to delays and increased costs for rock reinforcement and grouting. The 3D map is intended to enhance early-stage project planning by providing an indication of the quantity and characteristics of weakness zones likely to be encountered, based on previous project experience. Although the 3D map is only a model, it is hoped to help reduce risks and improve economic planning in early project phases.

The modeling is based on subsurface information from various construction projects, including tunnels for roads, railways, and sewage systems, as well as boreholes and geophysical surveys. Each weakness zone is described by multiple parameters, and the reliability of the observations is indicated by a confidence level. High-confidence zones are linked to multiple observations, objects, or references. These zones also include information on dip, estimated thickness, and strike direction, enabling visualization of the zone's orientation. The established modelling process involves a GIS database; Groundhog software by BGS along with 3D modelling with AspenTechs SKUA-Gocad and Mira Geoscience software. The resulting model, report and underlying data are all presented and made available on the web with the cooperation of the Polish Geological Institute – National Research Institute (PGI) and their Geo3D visualization system.

References:

Bergström U., Pile O., Curtis P. & Eliasson T., 2021. Göteborgsområdets berggrund, jordarter och geologiska utveckling.
https://resource.sgu.se/dokument/publikation/sgurapport/sgurapport202131rapport/s2131-rapport.pdf

Mapping seabed-sediments in the Dutch North Sea with Artificial Intelligence

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Maps of seabed-sediment composition are valuable geological data for maritime spatial planning. With many human activities affecting the seabed of the North Sea, the demand for detailed and up-to-date seabed-sediment maps is higher than ever before. Over the last few decades, the Geological Survey of the Netherlands has produced several subsurface maps of the Dutch sector of the North Sea. Hand-drawn maps from the 1980s and 1990s were based on relatively few sample locations. Geostatistical methods in the 2000s made it easier to use the information from thousands of sample locations. These methods also enabled the incorporation of secondary information like bathymetry as a deterministic parameter.

The latest update of the seabed-sediment map, developed by TNO and released in 2023, uses Machine Learning (ML) techniques that are able to create high-quality maps based on more data, faster than ever before. A Random Forest algorithm was trained on ~14,500 sample locations to predict sediment classes following the Folk classification scheme. A great advantage of ML is the ability to handle multiple predictor variables. As bathymetric characteristics are an important proxy for seabed-sediment composition, predictor variables include spatial position as well as bathymetry-derived variables such as slope, focal mean and the bathymetric position index. The trained model was used to predict Folk sediment classes for the entire Dutch North Sea at a gridded resolution of 100x100 m.

The ML model realistically reproduces geological features, such as sediment distribution over sandbanks versus swales in higher detail than previous methods allowed. Cross-validation confirmed the map's high accuracy and demonstrated that the model also produces a reliable uncertainty map. By presenting a map of seabed-sediment composition along with prediction likelihood, the map's practical value was significantly enhanced. The current data-driven approach opens up the possibility for regular updates, ensuring the map remains up-to-date by incorporating new data as they become available. The results of the mapping are publicly accessible through https://www.dinoloket.nl/en/subsurface-models/map.

General-purpose 3D geological models in Italy: the new "dimension" of the Geological map of Italy at 1:50,000 scale

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Although geological maps remain the most common way of representing geological knowledge, the growing demand from different stakeholders for up- to-date, high-quality, and policy-relevant subsurface geological information is driving the production of 3D geological models to support decisions on resource assessment and management, infrastructure planning, risk assessment and mitigation.

To address this demand for knowledge, the Servizio Geologico d'Italia has accelerated the systematic production of 3D geological models within the CARG Project (official Geological map of Italy at 1: 50,000 scale). Over the coming years, more than 40 general-purpose 3D geological models will complement the production of traditional geological sheets.

These 3D geological models may cover the entire area (about 570 sq. km) of the corresponding geological sheet of the CARG Project, thus describing the different Italian geological settings, down to hundreds or thousands of meters deep, depending on the availability of input data.

Initially, the upcoming 3D geological models will focus on stratigraphic and structural architecture, enhancing the representation of the geometries and relationships between geological units and faults, thus facilitating communication and collaboration with experts and stakeholders who are not familiar with maps.

The Servizio Geologico d'Italia has established key pillars to reach the goal of adding the third dimension to institutional general-purpose geological data and products:

i) collaboration with private companies to access industrial geological and geophysical data (e.g., seismic lines, curve logs, gravimetric and Airborne ElectroMagnetic data) under confidentiality agreements;

ii) adoption of an INSPIRE Geology-based extended data model, to comply with the mandatory European rules for public sector organisations on data sharing and interoperability and facilitate collaboration with Research Infrastructure initiatives (EPOS, EGDI, GeoSciencesIR);

iii) publication of metadata with DOI persistent identifiers to enhance the findability of geological models and credit the authors;

iv) use of OGC standard download services and implementation of bulk download, under a CC-BY open license to ensure reusability;

v) development of a dedicated 3D web viewer to facilitate communication between geologists, engineers, and decision-makers.

This increased effort in the production of 3D general-purpose geological models aims to provide a solid foundation for applications such as urban geology, hydrostratigraphy, seismogenic faults, contaminated sites, and natural resources, which are also crucial for territorial authorities.

Ultimately, it enhances national subsurface geological knowledge fulfilling the primary institutional mandate of the Servizio Geologico d'Italia to deliver nation-wide, uniform, robust, and publicly accessible geological information.

Modelling anthropogenic disturbance in the Brussels Periphery

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In urban settings, human activity alters the original structure and composition of the shallow subsurface significantly. This transformation is especially noticeable in densely populated and infrastructure-rich areas, where anthropogenic effects can reach depths of over 20 meters. In response, the Flemish government has initiated a new city-scale geological model of the periphery of Brussels dedicated to capturing the detailed characteristics of shallow geology, with a particular emphasis on the heterogeneous nature of anthropogenic disturbance.

The primary objective of modeling the anthropogenic disturbance is to enhance end user awareness of areas where the subsurface might behave differently compared to conventional geological expectations. Historically, models in Flanders have aggregated all anthropogenic material into a singular unit, which has masked the diversity in this unit. The new Brussels periphery model adopts a more refined approach by categorizing the anthropogenic disturbance into distinct classes, thereby yielding deeper insights into the expected nature of the different types of disturbances.

Various methodologies exist for classifying artificial ground (Ford et al., 2010). Our case study demonstrates a pragmatic balance between data relevance, availability and suitability for modelling. Despite the rich supply of both direct and indirect 2D spatial data to map the anthropogenic deposits in Flanders, a critical challenge remains: the dimension of thickness or depth of subsurface structures (tunnels, cellars, parking facilities, etc.) is often absent. This gap necessitates reliance on literature, technical norms and expert judgement to make informed estimations on the thickness of these disturbances.

In our presentation, we will demonstrate how we combined input data from current and historical land use maps, digital elevation models, borehole descriptions and others into a detailed (5x5m) 3D-model of the anthropogenic disturbance. The model consists of the following 8, laterally varying classes:

- Landfills
- Building foundations
- Infrastructure
- Raised terrain
- Water
- Reclaimed water bodies
- Disturbance zone – industrial
- Disturbance zone – residential

In addition, we will discuss how we could enhance the model and which additional data are required to refine the current approach. Ultimately, we believe that improving the representation of the anthropogenic disturbance in geological models will significantly enhance their utility for urban planning, environmental management and the sustainable utilization of the subsurface in urban areas.

References:
Ford, J., Kessler, H., Cooper, A. H., Price, S. J., & Humpag, A. J. (2010). An enhanced classification for artificial ground (Open Report OR/10/036). British Geological Survey.

3D modelling for subsurface policy needs

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The subsurface can play a crucial role in answering capital societal challenges like secure energy demand, climate mitigation, critical raw materials, strategic reserves of drinking water, or long-term solutions for highly radioactive waste.

Since more than twenty years, the Flemish Ministry of Environment manages a subsurface modelling taskforce through which extensive 3D models have been developed, as well as user-friendly tools to make subsurface information available for a broad public. All information is available through an open platform (www.dov.vlaanderen.be).

The models are used also for policy needs. A challenge Flanders is confronted with is the limited useful subsurface space, which urges us to be efficient in subsurface planning. For this, we need adequate 3D visualization in which, apart from geology, permit volumes, zones of high potential, exclusion zones, influence areas etc. can be shown. In this way, sweet spots, potential conflicts of use, overall field development and suboptimal fragmentation of the resources could be intuitively grasped by everyone.

Another challenge relates to the stepwise increase of scattered data from subsurface exploration and exploitation. It is inherent to 3D models that they cannot be frequently updated and that they need to deal with scale and data density issues. At the same time, investors use the subsurface data and models to develop their projects and policy makers need to know the geology well enough to efficiently delimit permit boundaries.

There are also the blind spots, where no previous drilling information is available. Especially in atypical reservoirs depending on local diagenetic processes – which is the case in Flanders for the main targets – the upfront investment risks are high. To lower the geological risks new techniques like AVO anomalies are being explored to complement the scarce reservoir information, in the hope to fill in the blind spots by developing parametrized models for future resource mapping.

Induced seismicity, leakage paths, sealing capacity, … are some of the fault-related hazards that should be understood for a responsible subsurface management. A general 3D fault model is not always adequate nor sufficient for this purpose, because the tectonic style and the assumptions made determine largely the outcome of for example geomechanical modelling. Of course, each project works with detailed and customized models for the specific location and objectives, but from the policy perspective we also need a more regional overview.

Policy makers look forward to novel developments in 3D modelling to tackle the issues mentioned above and to strengthen their subsurface management policy.

How Data Management and Services help to share 3d Models across Systems

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Many institutions do use different software packages with distinct objectives. Amongst the popular packages for 3d modelling are for example Gocad/Skua, Petrel, Move or even more and more open-source packages like GemPy. Besides the 3d modelling packages also GIS are used to provide derived products like maps and more or even to change input data like boreholes or cross sections. To be able to adjust the data appropriately it needs to be intersected and integrated with the final 3d models.

Once all the data and models have been adjusted the models are often visualized in 3d model viewers even in web browsers. This allows for the use of several distinct data sources and combination of the data and maps with the 3d models to obtain an integrated view catering the possibility to answer complex issues.

Most of the 3d models reside in silos inaccessible and hardly interoperable with other software. Hence good data management is the first undeniable must have. After setting up a service oriented architecture (SOA) those 3d models can be used with other software packages easily.

We are going to present how the OGC API 3d Volume Module has already been used for the integration of 3d geological data together with city models without any further transformation. Additionally, the OGC API Features Module supports the use of these models in GIS software like QGIS seamlessly. Of course, both even allow for an easy integration of the models in arbitrary modern web viewers.

Challenges of 3D geological and geothermal models of the northeastern Slovenia (Pannonian Basin)

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The western outskirts of the Pannonian Basin (northeastern Slovenia) are a regional and transboundary geothermal play. Geothermal aquifers are located within the Neogene as well as the pre-Neogene basement, while the Plio-Quaternary and Quaternary sedimentary successions store drinking water resources. The geothermal play can be divided into three segments.

The first segment encompasses loose Plio-Quaternary sedimentary succession at depths between 0 and 500 metres. It is important for shallow geothermal energy use (open and closed-loop systems) and has a considerable potential for Underground Thermal Energy Storage (UTES). The second segment is the transboundary geothermal aquifer of the Mura formation. This segment is spatially restricted to areas where the highly permeable horizons of the delta-front facies are located at suitable depths for thermal energy production, i.e. between 700 and 1800 metres. The third segment is represented by the pre-Neogene basement. The greatest potential for deep geothermal energy use in this segment is found where the depths exceed 3500 m and temperatures are suitable for direct power generation (above 150°C), however, its yield capacity has yet not been properly tested.

In recent years, several European (INFO-GEOTHERMAL, SI-Geo-Electricity) and national (RSF/DFP INRIGeoTeam) research projects have addressed the tasks of establishing national guidelines for direct use of thermal water, working towards a harmonised geological and geothermal 3D database and identifying discrepancies and uncertainties in existing datasets and models. These are largely a consequence of poorly defined tectono-stratigraphic concepts and misconceptions about the relationships between lithostratigraphic boundaries, historical well-log markers and the hydrofacies of the aquifer. Therefore, detailed predictions about the depths and thicknesses of the permeable intervals for future investments are fraught with financial risk. We collected and published metadata on 245 deep wells and 330 reflection seismic cross-sections to help identify available datasets. These were published on the 3D digital geothermal model of NE Slovenia along with geological surfaces and temperature models. It is accessible via the *Geo3D Viewer*, developed by the Polish Geological Institute: https://geo3d.pgi.gov.pl/Slovenia/index.html. It enables a pre-investment analysis of the geological- and temperature potential.

Acknowledgements

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Capabilities of Empirical Kriging 3D and IDW 3D Analyses in ArcGIS Pro Software for Creating Three-Dimensional Models of Uranium Ore Deposits

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In the Republic of Uzbekistan, three distinct types of industrial uranium ore deposits are present, the most prevalent of which are sandstone-type uranium deposits located in the Central Kyzylkum region. Uranium ore horizons are situated within Paleogene and Cretaceous deposits, at depths ranging from 200 to 600 meters below the surface. Many deposits in the Central Kyzylkum region were primarily discovered and subjected to geological exploration during the 1960s-1980s of the past century. Understandably, all geological data processing at that time was manually plotted onto paper maps.

To date, the introduction of modeling software into geological exploration has led to the emergence of integrated modeling capabilities for the geological parameters of deposits, with depth considerations. Nevertheless, the documentation of geological works conducted in the past century remains preserved as paper maps. In this research, raster maps of the South Bukinoy uranium deposit, located in the Central Kyzylkum region, were digitized using ArcGIS Pro software, and three-dimensional (3D) modeling was conducted utilizing the software's modern capabilities. The workflow involved compiling data related to radioactive ore from samples obtained from boreholes within the deposit into an Excel file. This Excel file comprised borehole coordinates (X, Y), elevation relative to sea level (altitude-Z), vertical depth or elevation difference (H) for each measurement point, uranium content (C) at each measurement point, and other parameters.

Utilizing the modern capabilities of ArcGIS Pro software, a three-dimensional model of the Aulbek deposit was created for the first time, demonstrating the potential of novel Empirical Kriging 3D and IDW 3D analyses within this context.

The relevance of this research lies in its potential to enhance the efficiency of uranium exploration and broaden the scope of geological forecasting through data visualization and precise modeling. 3D modeling facilitates a more accurate visualization of geological structures and aids in the identification of prospective ore deposit zones.

The practical significance of this research is that the utilization of this method enables effective investigation of mineral deposits, optimization of investment evaluation processes, and planning of mining operations. Furthermore, employing 3D analysis and voxel models significantly simplifies the study of the depth-wise distribution of uranium deposits.

Web-Based Visualization of Live 3D Earthquake Data

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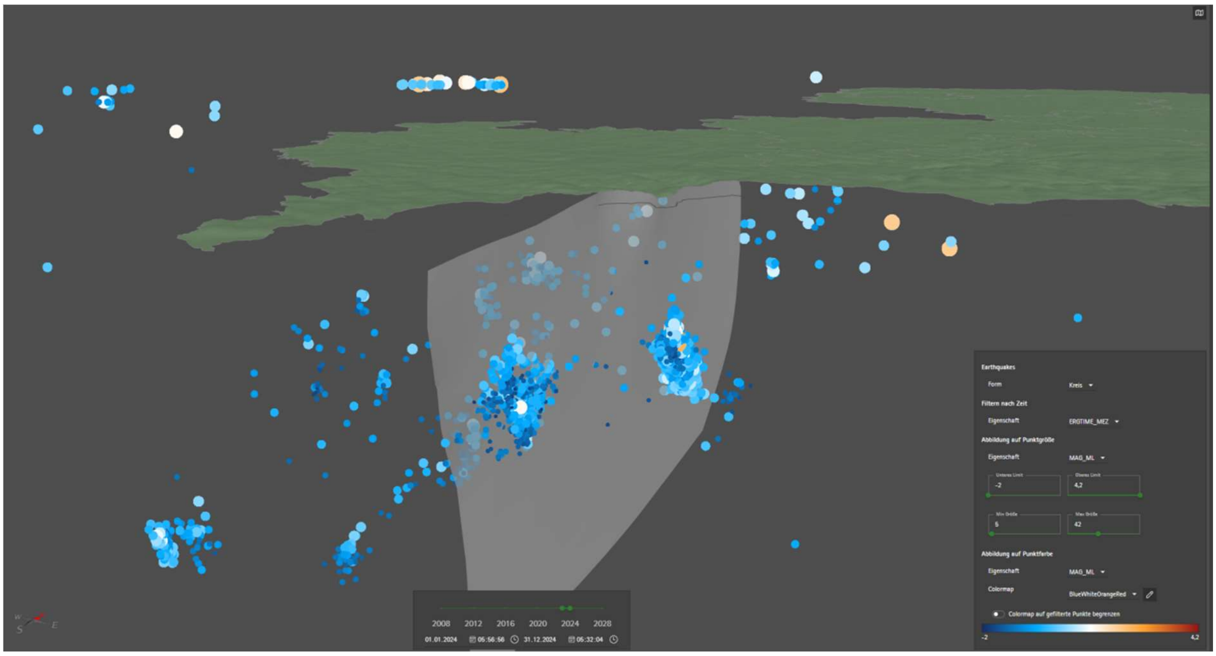
Seismic activity in Germany predominantly occurs along young fault zones, with significant events documented in regions such as the northern Alpine margin, the Upper Rhine Graben, and the Vogtland. The Vogtland, in particular, is known for recurring earthquake swarms, driven by geological stresses and the ascent of crustal fluids and gases. Recent advancements in seismological monitoring have enabled the continuous automatic registration of seismic signals from approximately 50 stations across Central Germany and Northwest Bohemia, providing high-resolution data on event location, depth, and magnitude.

This presentation introduces a web-based 3D visualization tool operated by the Geological Survey of Saxony. Leveraging data from the ANTARES service, GST-Web retrieves, processes, and displays seismic events in an interactive web viewer. Users can filter data by parameters such as time, magnitude, and event type. Furthermore, the viewer integrates seismic data with 3D subsurface models, enabling the identification of fault planes and other geological features.

Key advantages include simplified communication of earthquake metrics, enhanced data validation through comparison with other localizations, and improved decision-making for authorities. Additionally, the tool facilitates spatiotemporal trend analyses, contributing to a deeper understanding of seismic phenomena and supporting earthquake preparedness in the region.



The use of geological models in practice

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For over a decade, we have been working, as governmental agency, together with several partners, including TNO Geological Survey of the Netherlands, to develop several cross border subsurface models (the so called H3O-models) in the southern part of the Netherlands. They provide highly detailed subsurface models to a depth of approximately 5km, that connects with the geo(hydro)logical models in both Germany and Flanders.

With these models it's possible to get an indication of both the presence or absence of geo(hydro)logical units on a specific location. But these models can also be used to get more insights in both opportunities (mining, storage) or potential threats (subsidence, washout, faults). In practice, we use these models as a basis to estimate the potential for geothermal energy, (heat) storage, to find the best spots for the extraction of drinking water or infiltration. Shallow geological models are also frequently used for both spatial planning and civil engineering, in the planning phase for new residential areas or for the construction of tunnels and roads.

But besides the high quality of our current geological models, we also conclude that there is a huge gap between the use and understanding of geological models by geologists and citizens or those with (semi-)professional interest. Geological models are often experienced as complicated and difficult to interpret without geological knowledge. There seems to be an increasing need for more applied models or maps (opportunities or threats), which have already been translated into understandable products by professionals with geological knowledge.

We want to show by using a number of practical examples the relevance of geo(hydro)logical model, but also the challenges for using them in a broader social context.

A probabilistic 3D voxel modeling framework for integration of multiple data sources.

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Geophysical data has long been an integral part of geological modeling, providing valuable subsurface information when combined with borehole records and other geological datasets. In data-rich regions like Denmark, where geophysical surveys cover more than 50% of the country, there is significant potential for developing high-resolution geological models. However, manually interpreting large and diverse datasets is a cumbersome task, and the increasing demand for uncertainty estimates among end-users and decision-makers adds further complexity. Additionally, integrating vast and diverse data sources increases the risk of inconsistencies. To address these challenges, we are developing a novel probabilistic 3D voxel modeling tool designed for semi-automatic model generation. The approach is scale-independent, allowing for applications ranging from local to regional models, while ensuring comprehensive data integration, easy updateability, and explicit uncertainty estimation.

In the proposed method, all available information is represented as probability distributions of model parameters (e.g. lithology classes), directly incorporating sources uncertainty. Keeping the information in a probability space allows not only to use observation of the model parameters as information, but also to integrate all available information, provided a reasonable relationship exists between the data and model parameters. Examples include geophysical resistivity models, where the resistivity-lithology translation is non-unique, and hydrological data, such as pumping tests, which indicate coarse sediments through high hydraulic conductivity.

Considering each piece of independent information, the probability distributions of a data point is extended onto a 3D voxel grid with a spatial relation based on geological knowledge and the nature of data. The spatial impact of a piece of information (comparable to a variogram) are allowed to take any shape, extent and weight in the 3D space. This gives the opportunity to fully control the area of impact of an information source. By controlling the spatial impact of information, it is possible to handle geological knowledge on e.g. mapped structures (like faults or buried valleys) or knowledge of spatial relationships due to depositional environments. This step results in a 3D probability grid for the model parameters for each independent data source. The information can then consistently be integrated by calculating the joint probability distribution, given all available data. The resulting probabilistic model explicitly expresses uncertainties relating to data uncertainty, data density, and data consistency.

Integrating Geological Priors into Probabilistic Geophysical Inversion for Enhanced Subsurface Modelling

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This study represents a paradigm shift in geological modelling of Transient ElectroMagnetic (TEM) data. Instead of the traditional sequential approach, where a single geophysical model serves as the basis for geological modelling, we propose to integrate geological priors into probabilistic geophysical inversion and hereby generating an ensemble of plausible models that are consistent with the geological prior knowledge and input data.

A key component of any geological modelling workflow is the integration of multiple datasets – such as borehole data, surface geological information and/or geophysical information. Geophysics enable rapid and cost-effective data acquisition of large areas and geophysics are therefore often acquired to inform geological models. However, geophysics, like the electromagnetic data, needs to be inverted into geophysical (resistivity) models to contribute with indirect information about the subsurface. These inversions are typically conducted using generic settings in a deterministic framework, yielding a single resistivity model that does not capture the full range of possible, geophysically equivalent solutions. Traditionally, geophysics are among the first steps in a sequential workflow, where geological models are constructed based on a single resistivity model.

In this study, we challenge the conventional sequential workflow by integrating geological prior information directly into probabilistic geophysical inversion. This approach generates an ensemble of plausible subsurface models that are consistent with both the geological priors and the input data, explicitly accounting for the non-uniqueness of geophysical inversion. The resulting ensemble enables probabilistic analyses, allowing for a more rigorous quantification of uncertainties and a deeper exploration of potential subsurface scenarios.

We demonstrate this approach through a case study related to landslides, utilizing a probabilistic inversion setup to generate an ensemble of geological models. Geological priors are formulated using information from geological maps, geomorphology, topography, literature, and borehole data. The primary datasets include towed Transient ElectroMagnetic (tTEM) surveys and borehole data. The resistivity-lithology relationships are derived from neighbouring boreholes with resistivity logs. By incorporating geological prior information directly into the inversion process, we enhance the consistency and reliability of the subsurface models, ultimately improving their applicability for geological resource assessments.

3D modelling of the Cenozoic groundwater resources of Mecklenburg-Western-Pomerania (NE Germany)

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A combined geological-hydrogeological model of the Cenozoic of the German Federal State Mecklenburg-Western Pomerania with an area of approx. 23.000 km² is under construction since 2020. The model is based on comprehensive geological and hydrogeological maps of the Cenozoic developed in the 1970s and 1980s at a scale 1:50,000. The maps follow uniform concepts and contain lithological and hydrogeological information in a “2.5 D” approach. The maps were not finally harmonized and not updated after completion in the 1970s and 1980s; thus a general revision is necessary. Another data source is the borehole database hosted at the Geological Survey, which has significantly grown since the 1980s and currently comprising more than 130.000 boreholes. In addition, seismic data in depth and time domain are also taken into account, especially for the Tertiary and deep glacial channels.

The source data and model data are consistently managed in 3D and structured in an updatable and expandable stratigraphic framework. The geological model is developed using the SKUA/GOCAD® program package. It can be parameterized with regard to various issues (e.g. lithological, hydrogeological or geothermal aspects), but it will also be used as the base for hydrogeological models using program packages FEFLOW® and MODFLOW. Currently, coupled hydrological models are developed for pilot areas in catchment scale to testify workflows and capabilities.

The long-term goal is to develop a state-wide hydrogeological model that is harmonized with neighbouring federal states and can be used at different scales for various purposes:

- A state-wide structural and balance model – used as static model, but also for large-scale modelling (e.g. for climatic scenarios)
- Regional management models on the scale of catchments / groundwater bodies (dimension ranging from a few 100 to >1,000 km²)
- Local detailed models for specific issues, e.g. aspects of local water supply

The talk will present model structure and modelling concepts, the current status of the project and results.

A Collaborative Platform for Large-Scale 3D Geological Modeling

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The increasing accessibility of geophysical methods, facilitated by reductions in cost and operational effort, has resulted in an exponential growth in subsurface data acquisition. Concurrently, Denmark has conducted extensive groundwater mapping initiatives over the past 25 years, necessitating the development of a dynamic and continuously updateable three-dimensional (3D) geological model.

In response to this requirement, a national-scale geological model, designated the FOHM 3D model, was established in 2020 through the integration of an extensive array of pre-existing 3D models. This integration process involved the assimilation of over 200 individual models, necessitating a systematic approach to resolving disparities in establishing a reference geology within constrained period of time.

The successful compilation of this unified model has facilitated its deployment in daily administrative applications by the Danish Environmental Protection Agency (EPA), the Geological Survey of Denmark and Greenland (GEUS), as well as various public and private sector stakeholders.

The dynamic nature of geological modeling, particularly in light of the continuous influx of new geophysical and hydrogeological data, underscores the necessity for an adaptable model update framework. The FOHM 3D model is subject to iterative refinement and modification by multiple entities, including the Danish EPA, GEUS, and a consortium of private geological consultancies. To ensure the integrity and efficiency of this collaborative update process, a robust model management system, termed LARCOS (Large-Scale Geo Model Management and Collaboration System), has been developed.

LARCOS provides a structured platform that enables multiple geoscientists to concurrently engage in model modifications while maintaining stringent version control protocols. Through an integrated check-in/check-out mechanism, the system ensures data consistency, prevents conflicts, and facilitates systematic validation of modifications.

This talk delineates the methodological framework employed in the synthesis of the FOHM 3D model, detailing the technical challenges and solutions encountered during its development. Furthermore, the operational principles and practical applications of the LARCOS system are shown, highlighting its role in geological modeling on a national scale and the model’s significance in supporting informed decision-making in environmental planning, groundwater management, and resource exploration.

Hydrogeological Model of the Upper Silesian Coal Basin to Support Sustainable Mining Transformation and Groundwater Protection

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A detailed mathematical groundwater flow model has been developed for the Upper Silesian Coal Basin (USCB), addressing the critical need for sustainable water management in this actively transforming mining region. The model is built upon a robust geological foundation, derived from the 3D geological model of USCB and meticulously transformed into a hydrogeological and subsequently mathematical framework. This sophisticated tool is designed for accurate forecasting of groundwater levels and flow regimes within the basin's aquifers, essential for both ongoing mining operations and post-mining transition planning.

Leveraging a high spatial resolution, the model allows for water balance calculations across diverse scales, from individual mining excavation areas and coal deposits to entire municipalities and regional groundwater management units. This granularity is crucial for understanding localized impacts and informing site-specific mitigation strategies. The model's predictive power stems from its ability to simulate dynamic changes in key hydrogeological parameters. Users can define and adjust scenarios involving varying groundwater abstraction rates from wells, magnitudes of mining drainage, and fluctuating effective infiltration rates due to precipitation changes, including those projected under climate change scenarios.

A key feature is the model's lithostratigraphic layering, enabling detailed analysis of groundwater flow and resource availability within specific geological formations. This layered structure facilitates the assessment of impacts within individual stratigraphic levels under different operational and environmental scenarios. Given the continuous evolution of mining activities in the USCB – including both ongoing exploitation and eventual decommissioning – this model provides essential long-term forecasting capabilities. It can be used to predict crucial parameters such as necessary dewatering levels in urbanized areas to prevent flooding, and to estimate future water pumping requirements. This foresight is vital for mitigating surface flood risks associated with altered drainage patterns post-mining, and for ensuring the long-term protection of groundwater resources for communities.

Beyond groundwater flow, the model platform is designed for expanded applications, with the potential to simulate mass and energy transport processes. This broader capability further enhances its value for comprehensive environmental assessments and sustainable resource management in the USCB, supporting a responsible transition for the region.

How to use a 3D geological voxel model to answer societal questions.

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GeoTOP is a 3D voxel model providing insight into the shallow subsurface of the Netherlands (up to a depth of 50 m below sea level). Each voxel of 100 x 100 x 0.5 m gives information on the geological unit it belongs to, the most likely lithological class it contains, and the probabilities for each of the possible lithological classes. Since the start of the development of this nationwide 3D geological voxel model in 2007, the amount and variety of questions related to the subsurface has grown substantially. Fuelled by the energy transition, intensification of land-use and population growth, the societal need for knowledge of the upper 50 m of our subsurface has increased. However, in many cases, these societal questions ask for additional parameters, a higher resolution, or the incorporation of data from other sources than those used in the current modelling workflow.

Through several case studies we will show how we use our nationwide model and its workflow as a starting point to address challenges that need more or different information than GeoTOP as such provides. These challenges vary between land subsidence due to peat degradation, spatial planning, surface effects of induced seismicity, dike reinforcements, predicting groundwater flows and dealing with heterogeneous ground conditions in an urbanised area.

Our case studies demonstrate that, starting with the stratigraphy and lithology of GeoTOP, it becomes relatively simple to either add parameters that make the model suitable for e.g. groundwater modelling or land subsidence predictions, but also to estimate amplification of seismic waves in the shallow subsurface based on the combination of stratigraphy and lithological class. Also, the existing modelling workflow has been used as a basis to incorporate additional data and build a lithological voxel model with a higher resolution (smaller voxels).

To keep up with the growing needs of society, we will have to keep adding flexibility to the robustness of the existing modelling workflow. Doing so we allow GeoTOP to have a firm position in the value chain that supplies our end users with information: from subsurface data to a descriptive geological model and from there to predictions and answers to questions.

A Knowledge-Driven Method to Improve Efficiency and Accuracy in High-Resolution TEM Data Interpretation

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We present a novel method for creating multiple scenario-based 3-D models of material distribution, using a combination of geologic knowledge, high-resolution TEM resistivity estimates, and other observational datasets. The main goals of this method are to provide a way of generating multiple models that: 1. fit the specified scenario parameters; 2. incorporate relevant geologic knowledge; 3. honor TEM and other observational data; 4. incorporate the geologists' understanding of the uncertainties in their interpretations; and 5. enable elicient material interpretations, even in settings with complex sediment distributions.

The method features the identification and use of "electro-lithic" stratigraphic units that are defined from patterns in resistivity values; water well logs, sample set descriptions and wireline logs; and, expectations (hypotheses) in material distribution from the regional lithostratigraphic and sedimentologic framework. These electro-lithic formations are quickly identified and mapped from the HTEM soundings, and enable a rapid assessment and subdivision of the sediments.

While the delineation of these electro-lithic formations is simple and elicient, their resolution is too coarse and contains too much internal variation in resistivity values to meet the typical project goal of predicting the distribution and character of aquifers and non-aquifers. To interpret the distribution of sub-units within these formations, we developed techniques to create formation-specific models of the resistivity:clay fraction:texture relationships. These techniques utilize knowledge of particle size distributions associated with local lithostratigraphic formations, observations of material type from well and boring logs, and hypothesized within-formation patterns in material type.

Once the formations are delineated and the resistivity:clay fraction:texture models defined, individual scenario-based models can be generated. We recommend that geologists meet with stakeholders to present their understanding about the deposit distributions and explain ambiguities that reduce the reliability of the interpretations. From these discussions, a set of goals can be generated, each of which defines a specific scenario. One model is created through an iterative assignment:review:revision process, where the final model is ensured to meet the targeted sediment distribution from the scenario parameters. This process can be repeated as often as needed to generate a set of models that addresses the stakeholder's needs and fits various scenario-based constraints. The small set of output models generated through this process is typically preferred by stakeholders, because they can be more practically applied to process modeling. The increased likelihood of stakeholder use of the small scenario-based model sets, in-turn can help them create a more-informed risk analysis for subsequent decisions.

Making the Invisible Visible: Challenges in Visualising and Communicating 3D Geological Models

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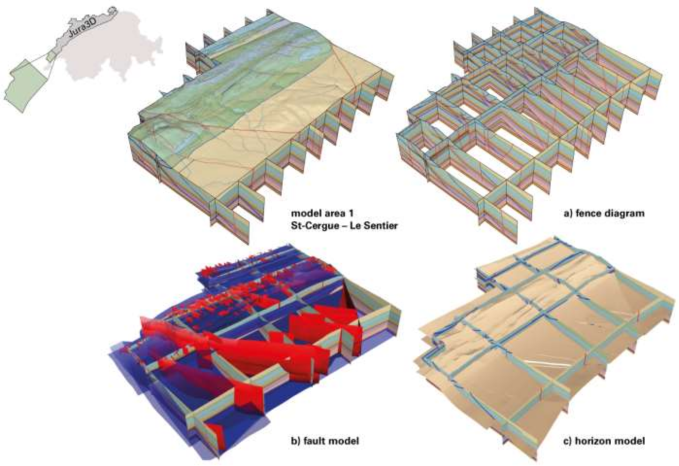
The Swiss Geological Survey is developing a coherent 3D geological model for the Swiss part of the Jura (Internal and External Folded Jura) northwest of the Swiss Molasse basin to the national borders with France and Germany. The aim is to create a 3D geological model that is conformable with the geological maps at the surface and provides a consistent interpretation of the subsurface geology. To achieve this, Jura3D consists of three key components (see figure below): a network of geological profiles (fence diagram, 1-2 km spacing), modelled fault surfaces (fault model) and a fully modelled reference horizon surface (horizon model 'Top Dogger').

At surface, the main input data for Jura3D comes from the geometrically harmonised vector data of the Geological Atlas of Switzerland (1:25,000 scale). However, subsurface data remain heterogeneous due to a lack of comprehensive harmonisation efforts in the past. Existing geological profiles, well data and geophysical information vary in distribution, quality and interpretation, requiring careful geological interpretation, especially regarding the tectonic development of the fold and thrust belt.

To create a consistent geological 3D model of the Jura, a plausible tectonic interpretation and a strategic approach for the kinematic development of the structures are crucial. Therefore, an overall tectonic concept was developed and is continuously refined as well as adapted to detailed mapping at the surface. This conceptual refinement goes hand in hand with the step-by-step densification of the geological fence diagram, which provides the foundation for the detailed modelling of the fault surfaces and the modelled 'Top Dogger' horizon surface.

With the completion of the first sub-area, the focus is now on effectively communicating the results to different target groups. While geologists and 3D modelers will continue to use the data for technical purposes, a broader audience – including decision-makers and other stakeholders – requires a clear and accessible presentation of the geological structures. Effectively visualising complex 3D geological models for non-geologists presents a significant challenge.

Based on the complicated 3D structures present in the Jura, this presentation explores various approaches and invites discussion on best practices for communicating 3D geological models.



Urban geology and three-dimensional (3D) city models: a symbiotic relationship

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The integration of urban geology with 3D city models has been a subject of interest for some time. While 3D city models have been standardised (e.g. via CityGML) and made publicly available for many years, geological information as part of these models has so far only been considered in isolated cases. This is despite the fact that the near-surface subsurface in particular plays a central role in urban planning processes in many cases. The reasons for this can be found in the technical and semantic complexity of the available geological content, as well as in the insufficient resolution (XYZ) and lack of standards. To overcome these barriers, the Hessian Agency for Nature Conservation, Environment and Geology (HLNUG) has been working on the topic of "urban geology" for several years, and is currently cooperating closely with the cities of Darmstadt and Kassel. The following goals are being pursued:

- The definition of requirements for the "urban geoparameters" by the cities
- The consolidation of all available geological information
- The development of high-resolution and customized geological 3D information
- The analysis of the IT infrastructure used
- The implementation of interfaces and exchange formats
- Service-based interoperable provision of the customized geological information in both 2D and 3D.

From an economic point of view, the project results should help to i) accelerate approval procedures and ii) enable more reliable and sustainable assessments and decisions. Concurrently, the geological survey's workload is projected to undergo a reduction due to the substantial automation and the availability of semi-automatic workflows.

Geological modeling in QGIS: initial results and pending challenges to address

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Since the first attempts to adapt CAD software to model geological bodies, numerous geological modeling software packages have been developed. Often initially designed around a specific interpolation technique, some have evolved into mature and comprehensive software suites. BRGM, the French Geological Survey, has utilized and continues to use several of these tools. It has also developed its own to implement in-house expertise. In each case, the cartographic approach and the use of georeferenced data have made Geographic Information System (GIS) functionalities extremely structuring and central to the tools developed. Indeed, whether in 2D or 3D, geological modeling involves interpreting and harmonizing a wide variety of spatial data.

GIS systems are very powerful to work simultaneously on multiple data sources and visualize or interpret them in the form of maps. Consequently, these tools are naturally used by geoscientists as an integration platform to prepare data for geological modeling. Given the growing popularity of the open-source GIS system QGIS and its very active and innovative community, BRGM considered the possibility to produce and explore 3D geological models within QGIS. Our talk will present our initial achievements and the steps we still need to take to fully reach our goal.

We first refactored algorithms from our legacy modeling software into modular software components, exposed as Python packages, and developed a common theoretical framework to produce hybrid models combining all techniques. Then, while it is relatively easy to develop QGis plugins to generate geological models using third-party libraries, maintaining a modular architecture and managing dependencies between plugins can quickly become complex. This often requires the use of dedicated tools and the involvement of IT department.

Moreover, from a technical standpoint, GIS software has been primarily designed for 2D applications. Recent developments in QGIS have moved towards 3D, driven by emerging needs such as Building Information Modeling (BIM), the use of large point clouds like LiDAR or managing and visualizing boreholes database. However, QGIS still lacks crucial functionalities for 3D geological modeling. To address this, we have sponsored the development of core QGIS functionalities, such as the ability to add and edit 3D points on cross-sections ("elevation profiles") and we are involved in writing formal QGIS Enhancement Proposals (QEPs). Collaborative efforts to invest in the development of core QGis functionalities useful for 3D geological modeling would enable the rapid evolution of 3D capabilities beneficial to the entire community.

visualkarsys.com, a webtool for building and communicating 3D geological models

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visualkarsys.com is a web-based software developed for building 3D geological models online and using them for various applications (hydrogeology, etc.). Geological models are calculated using an implicit approach using the GmLib library (potential field method). The use of the webtool is free of charge and has almost 1700 users. It is also used as a teaching tool at universities (Besançon, Lyon, Neuchâtel, etc.) and public courses are regularly organized (approx. every 3 months).

While development objectives are mainly in the field of hydrogeology in heterogeneous rocks (conceptual groundwater models, dynamic flow animation, tracer and contaminant pathways), many developments strictly concern geological aspects. Three of them in particular have been improved in recent months:

The calculation processes have been significantly accelerated and stabilized, as part of a project funded by swisstopo. Currently, calculation times have been divided by 3, and more significant progress is expected over the next 2 years.

The "metaproject" module, which enables data/information to be combined between several models of different extension and scale, has been improved. This module represents a significant step towards (i) "nested" models (upscaling, downscaling) and (ii) traceability of geological data.

Fault management has been improved. The interface is now better able to manage complex networks of faults, thrusts and strike-slip faults with antecedent relationships.

The entire workflow and functionalities linked to 3D geological model calculations have now been grouped together in a standalone application, independent of visualkarsys.com. "GeoCruncher" has now been made *open source*, and is available for everyone as a complete standalone application [1] which can be used from another geological webservice.

These developments make visualkarsys.com an efficient, high-performance tool for geological modeling. Development perspectives for 2025 concern aspects related to geological data quality and an initial 3D assessment of geological model uncertainties.

References:

[1] https://github.com/ISSKA/geocruncher

Expanding the Reach of Geo3D Geological Model Viewer

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Model visualisation has been a thorny issue for as long as 3D models have been used. Much of the visualisation depends on the stakeholder's capabilities and understanding in order to communicate subsurface information in a manner that people can grasp. All too often visualisations are too complicated, the software is complex and creates a barrier, the technology is slow and clunky and people lose interest. With the advent of better web visualisation techniques, the Polish Geological Institute (PGI) has been working towards a web platform that allows these barriers to be broken down. The PGI Geo3D Model Viewer allows the user to upload their models, retain the model on their own premises, but give access to anyone in the world to view the model.

The web software allows the user to rotate, zoom, and change settings much like many of the viewers we've seen over the years, but this PGI 3D Model Viewer runs via the web, therefore not requiring any software to be downloaded on the user's machine. It can deal with multiple different formats in visualisation, and most importantly, can display data fast. From anecdotal experience, this is often the biggest barrier to visualisation and can make or break a model delivery process. The PGI 3D Model Viewer removes that barrier and gives the user total control on slicing the model in three dimensions, displaying property information where required, and adding standard or custom basemaps to help orientation.

To further enhance accessibility, the Geo3D project team is actively developing Geo3D Builder, a new web application that streamlines the process of preparing and publishing models within the Geo3D Viewer. This initiative, involving collaboration with the British Geological Survey (BGS), addresses the challenge that users are not able to build Geo3D scenes by themselves. The Geo3D Builder will feature a user-friendly wizard-like interface, guiding users through data loading, scene configuration, and publishing. This solution will allow for easier creation, configuration, and then publication on the Geo3D platform.

The presentation will discuss the progress made by PGI and how recently the British Geological Survey has assisted with the development of the builder by engaging from a user's perspective to make the model loading process as smooth as possible. We will showcase the design of a user-friendly interface of the Geo3D Builder and demonstrate how the collaboration with the User Experience team contributes to this application to make 3D geological data more accessible to a wider audience.

Web-based 3-D geological model viewers for open viewing accessibility: Case study for southern Ontario, Canada

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With increasing competition and concerns for surface land use, subsurface management, and natural resource development, the value of three-dimensional geological modelling is ever increasing. Nevertheless, challenges remain in communicating the content of complex models developed in proprietary and expensive software with limited open access viewing options. Even when free viewing software options are available, computer hardware demands and IT security protocols may pose challenges and restrictions on installation, particularly in academic settings. To address these technical and accessibility barriers, the Polish Geological Institute (PGI) has developed a web-based viewer for 3D geological models, enabling cross-platform compatibility, including mobile device access called Geo3D. PGI currently hosts a suite of global case studies and continues collaborative development with many geological survey organizations worldwide.

One such collaboration with the Geological Survey of Canada (GSC) is previewed here from southern Ontario Canada. This large 110,000 km^2 regional lithostratigraphic model consists of 52 siliciclastic and carbonate layers subsequently reclassified to 14 hydrostratigraphic groupings. Initially exported from LeapFrog geomodelling software in Wavefront OBJ format, the model, consisting of 26 million triangles, was imported into the open-source software Blender. Subsequent processing involved iterative mesh simplication to reduce the overall model size to < 6 million triangles while maintaining accurate layer geometries and apparent surface resolution. Considerable file reduction was achieved through resolution reduction in areas of minimal geometric change (flat areas) and vertical faces. Although producing satisfactory viewing results, this workflow required considerable time and intervention prior to model viewing.

To support scalable web-based visualization of massive 3D geological models, an alternative multiresolution method called Nexus (Ponchio and Dellepiane, 2016) was evaluated on the southern Ontario model. Although the Nexus approach is not strictly necessary for online visualization of the southern Ontario model – since the unprocessed raw model already loads rapidly in Geo3D – it becomes critical for smooth and interactive visualization of detailed models spanning more extensive geographic areas. This method, analogous to Google Maps' dynamic streaming but extended to 3D, efficiently delivers portions of the model at resolutions appropriate to the viewer's perspective and zoom level, seamlessly blending them in real time over the web. Preliminary results demonstrate visualization efficiency and scalability for large 3D geological models. Future research will focus on evaluating Nexus's performance with even larger and more structurally complex geological models.

References:

Ponchio, F., and Dellepiane, M. (2016). Multiresolution and fast decompression for optimal web-based rendering. Graphical Models, 88, 1-11.

Uncertainties in geological 3D-models - a challenge in the search for a repository for HLW disposal in Germany

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Uncertainties in geological 3D-models - a challenge in the search for a repository for HLW disposal in Germany

The Federal Office for the Safety of Nuclear Waste Management (BASE) is the central supervisory authority for the disposal of high-level radioactive waste (HLW) in Germany. In this function, the BASE monitors the site selection procedure (StandAV) for the search for a site with the best possible safety for a repository for HLW-disposal.

During the processes in the search for a site for a geological repository for HLW, 3D models are playing an increasingly important role. Only 3D models make it possible to obtain a holistic picture of the geological subsurface and to analyse and evaluate it. In order to evaluate the necessary surface exploration programmes for a repository for HLW, it is necessary to identify, quantify and visualise uncertainties in the 3D models of the host rocks in Germany: rock salt, clay and crystalline rock. Only on this basis is a well-founded evaluation of the potential siting regions with the best possible safety for a repository for HLW possible.

The poster deals with the question of the main causes of uncertainties in 3D models, which can be e.g. 1) quality of geological data, 2) complexity of the geological environment, 3) experience of the modelling geologist, 4) modelling methodology or 5) used model application. How can the best possible assertion on the safety of the repository site be made despite uncertainties? What opportunities do 3D models offer for the assessment and avoidance of risks in the search for a repository site in Germany? In particular, the experience gained from dealing with uncertainties in the neighbouring European countries of Finland, Sweden and Switzerland should also be taken into account.

The start of a corresponding BASE research project 'Evaluation of methods for the assessment of uncertainties in the application of geological 3D models (Eva3D)' is planned for mid-2025. In addition to evaluating the methodological approach, the research project will also deal with the prediction and visualisation of uncertainties in geological 3D models. Evaluation criteria for the potential host rocks in Germany are to be determined.

Regional structural models – challenges and limitations. An example from Szczecin Trough (NW Poland).

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Developing regional geological models involves challenges such as large spatial extents, vast datasets, uneven recognition levels, and complex geological structures. Recent advancements in modelling tools have improved this process, nevertheless effective integration of diverse data remains a critical task. This paper presents the methods used to create the Szczecin Trough geomodel, focusing on solutions to key challenges like data inconsistency, outdated seismic information, and integrating pre-existing models.

A major challenge was the integration of data collected over different years, leading to inconsistencies in borehole locations and reference levels. This issue was addressed using WellMatch Python QGIS plugin developed by the PGI-NRI team, which automated the correction of borehole positions and standardization of reference levels. Additionally, the absence or low quality of borehole geophysics was managed by manual verification, applying the most current and suitable stratigraphic divisions for the area.

Inconsistencies in stratigraphic nomenclature across databases were resolved by manual unification of terminology and validation of well top depths. Archival seismic data, varied in quality and processing techniques, posed another challenge. To manage this, archived seismic profiles and published cross-sections, initially in raster form, were converted into 2D seismic format using the "Blueback Toolbox" plugin by Cegal. This allowed precise placement of seismic lines and enabled direct seismic interpretation without fragmenting the raster images.

The integration of existing models of varying resolutions, accuracy, and purposes required aligning corresponding horizons and assessing quality in buffer zones to choose the most reliable interpretations. The Petrel software’s “Workflow” module was extensively used to create macros for repetitive tasks, enhancing efficiency and consistency in the modelling process.

The Szczecin Trough geomodel was created using data from 178 boreholes and over 50 different 2D/3D seismic surveys. For some datasets, guide horizon interpretations were obtained and supplemented with the authors’ interpretations. Georeferenced archival maps and cross-sections were also used. Well tops were imported, verified, and supplemented, while checkshots for 83 boreholes were quality checked. Time-domain profiles were converted to depth domain for consistency. Key structural surfaces were generated, ensuring correlation with previous PGI-NRI models. Modelling was performed using the Corner Point Gridding method in Petrel software, with fault and skeleton models created before populating horizons and layers in the final 3D grid.

The “Szczecin Trough 3D” project is financed by the National Fund for Environmental Protection and Water Management on behalf of the Ministry of the Environment, and is using data provided by PGNiG – Orlen Group.

Three-dimensional analysis of GIS layers of the project their advantages in the allocation of preliminary forecast areas of Mount Bukatau

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GIS technologies have emerged as an innovative approach in traditional geological research. These technologies are based on integrating various objects and processes, where the key unifying element is geographic information. A topographic foundation enables researchers to organize, analyze, and interpret large datasets efficiently. This approach provides a comprehensive representation of geological structures, facilitating decision-making in mineral exploration and structural geology.

In the central part of the Bukantau Mountains, advanced geological research was conducted using digital remote sensing data. Within these studies, GIS projects were developed to process and analyze remote sensing materials in a three-dimensional space. Thematic GIS layers were created to refine geological maps, structural frameworks, and the composition, age, and boundaries of deciphered geological formations. The comparison of structural schemes with thematic layers of mineral deposits and geochemical anomalies allowed researchers to determine the ore-forming role of remotely identified complexes and structural elements. The spatial positions of these structures were further refined through geophysical data analysis, leading to a better understanding of the geological framework of the region.

Each geological map contains multiple thematic layers displayed in its legend, where colors and symbols indicate the age and composition of geological formations. More saturated and darker shades correspond to older rock formations, while intrusive rocks of mafic composition also appear in deeper tones. Off-scale geological bodies are depicted using specific symbols and conventional notations. This approach enables an efficient and standardized representation of geological data, allowing for easier interpretation and analysis.

The transformation of geological map legends into thematic GIS layers is a relatively simple process using modern high-tech methods. Remote sensing data analysis often involves spectral and specialized processing techniques that utilize the overlay method. This method integrates vector and raster maps from different thematic layers, allowing researchers to identify faults, decipherable structural complexes, ring structures, and other key geological features. Additionally, this method enables the spatial correlation of traditional geological data with remote sensing-derived information, enhancing the accuracy of geological interpretations.

One of the most significant advantages of GIS-based analysis is the ability to visualize large volumes of data effectively. Advanced visualization techniques are applied to generate multi-layered maps that integrate geological, geophysical, and remote sensing data. These integrated maps help identify promising areas for mineral exploration based on the analogy method and geological-geophysical characteristics of reference deposits in the Bukantau region.

Applications of the 3D subsurface model of Mecklenburg-Western Pomerania (NE Germany)

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The 3D model of the State of Mecklenburg-Western Pomerania, located in north-eastern Germany, was created between 2014 and 2020. It encompasses 13 lithostratigraphic horizons, ranging from the base of Zechstein to the base of Oligocene (Rupelian), 12 salt diapirs and 201 faults, of which 67 extend into Mesozoic sediments (Obst et al. 2024). As part of the harmonized subsurface model of the North German Basin (TUNB project), it can be applied for sustainable planning of the underground space down to a depth of 5 km including visualization of subsurface uses and potential conflicts between different utilizations.

Currently, the model is used to visualize geothermal resources in the Mesozoic strata, e.g. for planning of hydrothermal doublets for carbon-free heat production in larger communities, spa towns or seaside resorts in Mecklenburg-Western Pomerania. It provides detailed insights into position and depth of sandy distributary channels from various fluvial and deltaic systems in the Middle and Upper Keuper as well as in the Lower and Middle Jurassic. Combined with data on sandstone thickness and reservoir quality, these information will support political and economic decision makers to identify suitable sites and assess renewable energy opportunities.

Additionally, workflows are developed to incorporate seismic velocity data in the existing model to derive cross-border harmonized and seamless 3D-velocity fields in the framework of a new project TUNB Velo 2.0 (Jahnke et al. 2024). These velocity fields will allow large-scale depth-time- and time-depth-conversions of subsurface data to support seismic campaigns and processing.

Furthermore, new layers such as Quaternary base and the top of Rupelian Clay have been added to the 3D subsurface model. These additions are essential for various applications such as assessing the distribution and maximum depth of fresh ground water resources and evaluating the position of deep subglacial channels in discussions regarding potential underground sites for high-level nuclear waste storage.

References:

Obst, K., Brandes, J., Matting, S., Wojatschke, J. & Deutschmann, A. (2024): Das 3D-Untergrundmodell des Landes Mecklenburg-Vorpommern: Datengrundlagen, Modellierungsergebnisse und Anwendungsmöglichkeiten. – SDGG 100: 59-92. DOI: 10.1127/sdgg/100/2024/59

Jahnke, C., Makyeyeva, N. & Obst, K. (2024): Regional velocity modelling of the North German Basin: The approach of Mecklenburg-Western Pomerania. – GeoSaxonia, Conf. Abstracts. DOI: 10.48380/gsh7-qk76

What should be taught in a 3D geological modeling course?

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Due to changing strategic objectives and increased financial pressures, the British Geological Survey (BGS) have been assessing 3D modelling software and requirements internally and externally. As part of this process, we have been asking ourselves at the BGS what should be taught in a 3D geological modelling course? Should it be software specific or should it mainly be based around theory? It is probably a mixture of both. Alongside the distribution, and amount of data available, and the type of geology will often dictate the modelling software and methodology used. It is not easy to come up with a course that covers all scenarios especially in the UK where the data richness varies significantly, and the diversity of the geology mean hybrid approaches are required. So where do we start?

Issues with courses that are software specific are that they can become a click button exercise without much thought. Also, the evolving 3D geological modelling software landscape and ever-increasing financial pressures that geological survey organisations are under means software specific courses can become redundant after two or three years.

Theory is important for showing the philosophies of implicit, explicit and probabilistic modelling techniques and how these should be applied but can mean you lose sight of the practical application of what a geologist wants to be able model. Sometimes what is wanted it is only a single horizon or a cross-section!

A hugely important aspect is the input data. 3D geological modelling can be used as a data cross-validation exercise whereby the 3D geological model becomes a by-product. What becomes critical is ensuring the input data is checked against other data, corrected where required and fed back into corporate database for future use.

This cross-validation of the data and knowledge gained through the process of creating the 3D geological model is in some respects what should be captured and documented, which in turn makes a 3D geological model more trusted for future use, but also redundant as the input data is key and not the model output.

This talk describes the process of designing a 3D geological model course while trying to balance the multiple requirements of a geological survey organisation.

Strategies for Enhancing Communication and Visualization of 3D Geological Models adopted at the Servizio Geologico d'Italia - ISPRA (SGI)

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The Servizio Geologico d'Italia (SGI) supported by the Next Generation EU project GeoSciences IR, is working to enhance the accessibility, understanding, and diffusion of 3D geological models. Effective communication of 3D models requires an integrated approach that combines the collection of the models, their interactive visualization, and the production of communication resources to significantly improve their diffusion to a wide range of stakeholders, including researchers, government agencies, professionals, but also to non-experts and to general public.

The core element of such strategy is the development of a "Geological 3D Models Database," for organizing and storing 3D geological data. The development of a well-designed database has required the implementation of an ad-hoc data model structure and the creation of standardized metadata possibly harmonized with controlled vocabularies. These steps are essential for ensuring data consistency and interoperability and guarantee that models can be effectively diffused.

To further enhance user interaction and comprehension of the complex information attached to 3D geological models, the GEO-IT3D web viewer has also been developed. The viewer is a truly interactive platform that allows user-defined cross-sections, maps and virtual holes, with interactive results that can be exported as reports.

In addition, SGI has committed to producing a range of dedicated communication resources to support knowledge transfer and promote engagement with 3D geological models also to non-experts. These resources include technical guidelines on the data-scheme, video tutorials offering step-by-step instructions to the correct use of the web-viewer, and animated educational content designed to explain key geological concepts in a visually appealing manner, making the information more accessible to a broader audience.

The goal of disseminating 3D geological models is ambitious and requires the involvement of experts from different specializations. In this context, the support received from EU projects (GeoSciences IR and MEET) and national projects (CARG) aimed at disseminating geological data has been fundamental, and it will be important to extend this network in the future.

Evaluation of anthropogenic transformation of urbanized areas based on archival topographic maps and its impact on modeling of geological structure

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Using the Engineering-Geological Database (BDGI), a voxel model of the terrain in the area around Bytom was created. In the same region a series of archival digital elevation models (ADEM) were created based on topographic maps from the years 1883, 1958. Geomorphone maps were prepared for the present DEM and ADEM, the comparison of which made it possible to show both natural and anthropogenic changes that have occurred on the land surface over the years. The voxel-based 3d model was compared with the geomorphon maps and the area of high uncertainties resulting from changes in the land surface was determined. The analysis aims to highlight the impact of anthropogenic transformations on the quality of geological models.

The differences between ADEM and present relief are shown below.

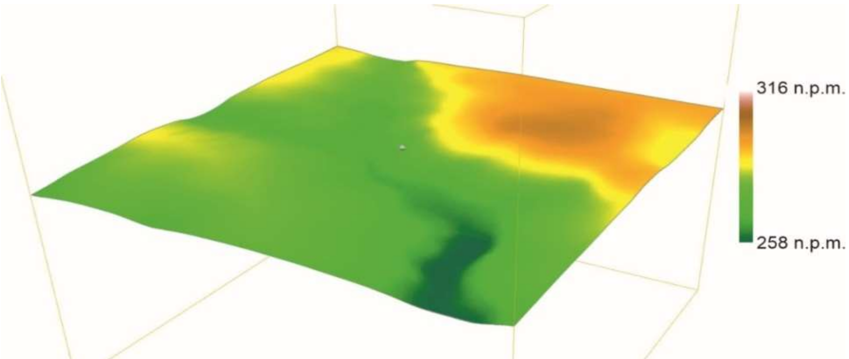

Figure 1. Archival digital elevation model (ADEM)

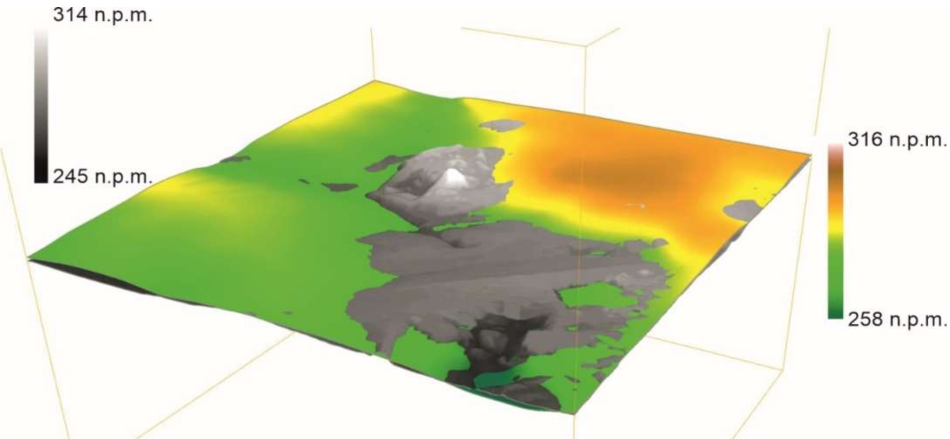

Figure 2. Overview of ADEM and DEM

Shallow modelling: squeezing more out of imperfect borehole and outcrop data

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The Swiss Geological Survey periodically updates the 3D geological model of the Swiss Molasse Basin (GeoMol) and at the same time uses these results to facilitate the production of new map vector data and map sheets for the Geological Atlas of Switzerland (1:25,000 scale).

The modelling of Molasse horizon surfaces (geological formation tops or bases) in the Swiss Molasse Basin, especially in the shallow subsurface, relies primarily on borehole and outcrop data. The borehole data often contain only partially drilled geological units or do not intersect the horizons of interest e.g., 'Top Obere Meeresmolassse (OMM)' and 'Top Untere Süsswassermolasse (USM)'. Similarly, the outcrop data, which are already relatively scarce due to the extensive Quaternary cover, seldom depict a horizon contact.

We present a number of methods (and examples from a recent project area) for extracting more out of the available data sets. These methods both extend the modelling possibilities and improve the quality of the results. The various outputs are used as a planning tool for field mapping, as well as a basis for new vector data, map sheets and 3D model components. In addition, certain quality control mechanisms provide a means to identify anomalies which could be either erroneous data or geological features; or to highlight potential errors in historical geological maps. The above methods are semi-automated and form part of a larger iterative workflow which involves both field work as well as desk-based analysis and modelling.

Incorporation of geological models into BIM approach

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The widely accepted open IFC format was used in recent years in planning of strategic investment projects in the Czech Republic. The most significant examples comprise construction of two nuclear sources in the vicinity of two existing power plants, where the BIM approach was employed after initial stages of geological exploration. Another example represents the Čertovka locality, site of recent research for siting of a deep geological repository of spent nuclear fuel. In this case, the BIM model including geology was created mainly for collaboration purposes among different specialists involved in the repository preparation works - to facilitate tighter cooperation between geologists, stakeholders and building engineers. Such cooperation across different disciplines outlines the general importance of our work. It enables detailed and effective interdisciplinary collaboration in case of large and significantly expensive construction projects, whose substantial part is located below ground, in the geological environment.

Until now, individual geological and geotechnical models existed as proprietary and mutually difficult to coordinate information in different file formats. Interoperability of software tools used by the different groups of experts covering different disciplines was limited, leading to considerable loss of information during export-import between the software tools. Moreover, the related large portion of work did not rise any added value, being focused only to transcription of knowledge between differing disciplines.

The added value of our approach is not only the innovative application of the AEC widely used ISO standard: Industry Foundation Classes (IFC), to completely different types of buildings, but also the completion of the missing standardised IFC structures. The resulting geological IFC structures comprise three principal constituents: (1) volumetric model of rock (lithostratigraphic) units, (2) voxelized rock bodies and (3) planar geological objects – fault planes, ground water tables etc.

The result of our ongoing work is a standardisation of geological structures (entities, parameters and relations) in widely used ISO standard for BIM models, that is readily available for engineering geologists, building engineers and planning of additional geological/geotechnical surveys. The resulting synergy of differing disciplines in such early stages of project preparation and realization then leads to significant cost reduction by (1) optimized planning and design during exploration and designing phases and (2) minimalization of geological/geotechnical risks during construction and operation phases of the buildings.

Shallow geothermal energy potential 3D modeling in PGI-NRI

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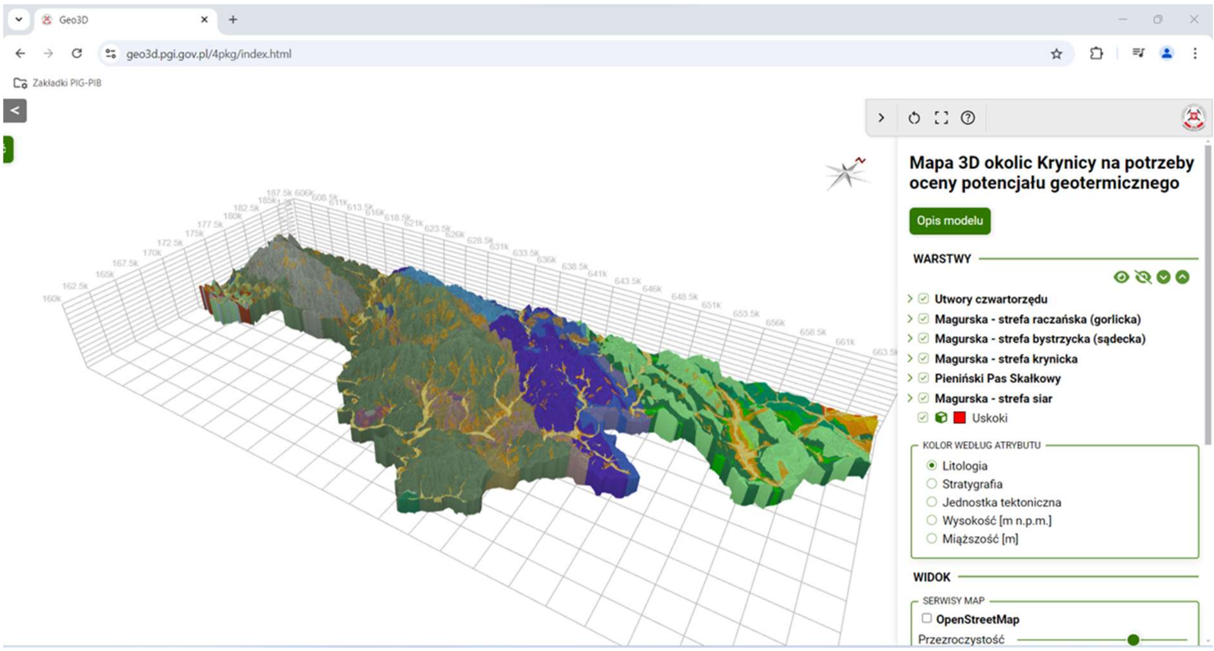
GIS tools and 3D models are essential for evaluation of shallow geothermal energy potential in the subsurface of the urbanized areas. To boost the development of ground source heat pumps technology and its implementation in renewable heating and cooling sector it is very important to visualize the subsurface layers with geothermal potential to stakeholders, designers and investors.

PGI-NRI creates 3D models of shallow geothermal units for urbanized areas down to depth of ~300 m. These models are used to calculate 2D maps and GIS layers, which then can be used as an input data for determination of potential geothermal energy under the buildings of housing districts that can be extracted with the use of borehole heat exchangers technology (BHEs) and to perform scenario analyses of depth and spacing variants for BHEs.

Presented workflows, used in PGI-NRI for 3D modelling and further scenario analyses, are a scalable solution. Further research and applications can include the use of CityGML data, WFS services used in open access browsers, especially those presenting city scale 3D data. Automation of such analyzes is possible and therefore they can be used as tools to make faster pathways for the EU energy transition.

On the poster selected examples of 3D shallow geothermal energy potential modelling from Poland will be presented with comments regarding the used tools and workflows.



Improved representation of anthropogenic deposits in a nationwide 3D geological subsurface model

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Humans are increasingly altering the urban subsurface. Tangible evidence is the existence of so-called anthropogenic deposits that have not been formed by natural processes, but by direct human action. These deposits may consist of reworked and/or displaced natural rocks and sediments, but also include a wide range of non-natural materials (also known as 'novel anthropogenic' or 'secondary' materials). Anthropogenic deposits are found not only in historic city centres, with their often thick and heterogeneous subsurface archives related to urban development, but also below modern residential and industrial areas, built on extensive sheets of filling sand.

Anthropogenic deposits are sometimes represented on subsurface maps and in 3D models. However, despite their obvious volumetric importance, mapping geologists have so far mostly avoided characterising the anthropogenically disturbed subsurface below urbanised areas. The lateral extent and thickness of these deposits are generally not well constrained, and relevant information on the lithological properties of the deposits is often lacking. At the same time, the demand for complete and detailed subsurface information in the built environment is increasing and relates to anything from building stability and ground heat extraction to preserving cultural heritage and mitigating the effects of climate change.

This presentation focusses on the (interrelated) lithological characterisation and stratigraphical subdivision of anthropogenic deposits to improve their representation in 3D geological subsurface models. We evaluate current stratigraphic approaches and present the principles of the approach that we have developed in the Netherlands. We discuss the practical consequences and give examples of how to bring our approach into practice. Ultimately, a well-thought lithological description and classification system of anthropogenic deposits is a prerequisite to produce reliable subsurface and coupled surface-subsurface models. In that way, we can address the many challenges related to the ever-increasing use of urban (subsurface) space and thus improve the wellbeing of our citizens.

3D model of Intrasudetic Synclinorium (SW Poland) for use in geothermal prospecting and modelling

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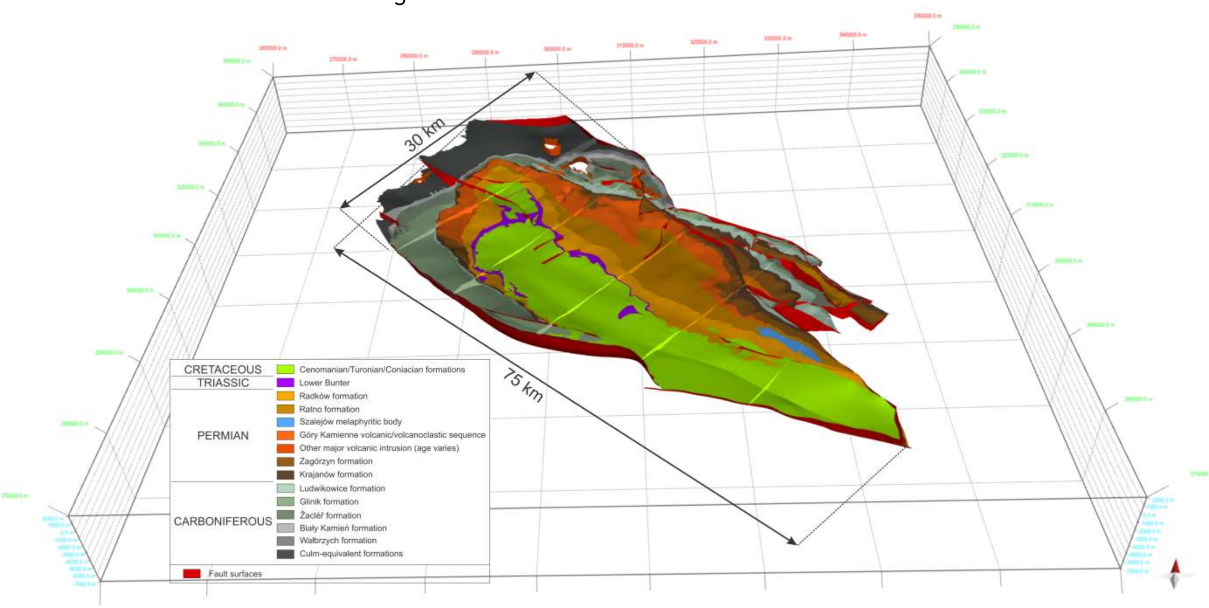
The Intra-Sudetic Synclinorium infill consist of thick layer of sedimentary rocks, which strongly contrast, in terms of thermal parameters, with the crystalline rocks that dominate in the majority of the Sudetes mountains. Additionally, depending on parameters such as porosity or mineral composition, individual sections of sedimentary layers may also differ significantly in these parameters. For this reason, in order to enable a correct assessment of the geothermal potential in this area, thorough knowledge of the geological structure of the area is necessary. For this purpose, a digital, three-dimensional structural model of the synclinorium was created.

Midland Valley Move software was used to model geometry of major fault zones of regional importance, as well as the major lithostratigraphic units of sedimentary, volcanoclastic and volcanic rocks covering the area. The model is based on a large set of data, including archival borehole logs, various geological maps and cross-sections and seismic interpretations, which were used to construct a geologically viable image of the subsurface in the relevant area.

The model is intended to be used in further work on identifying the geothermal potential of the synclinorium by determining the course and geometry of the most important fault zones on a regional scale, their geometry and mutual relations; the depth of the crystalline substrate; determining the thickness and geometry of individual sedimentary rocks and taking into account the role of numerous volcanic intrusions in this area. Ultimately, the geometry prepared in the model can serve as a domain for advanced numerical modelling.



3D oblique view of the horizon and fault surfaces, along selected cross-sections, of the Intra-Sudetic Basin structural model

Establishing a nation-wide 3D geological model of Denmark: a key enabler for geothermal energy, carbon capture storage and natural hydrogen exploration

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The Danish subsurface holds significant potential for contributing to the green energy transition. Its 2 – 10 km sedimentary buildup contains favorable rock formations that support geothermal energy production, carbon and hydrogen storage, and potential natural hydrogen/helium exploration. These projects may compete for the same subsurface space, as gas storage can raise pressures far beyond the project location, leading to a 'race for subsurface space.'

Robust 3D geological models of the Danish subsurface are essential not only for exploring these green energy technologies but also for assessing the impact of one project on another. The Geological Survey of Denmark and Greenland is consolidating existing subsurface interpretations from seismic and borehole data. Automated gridding workflows are being used to obtain consistent 3D horizons, forming the backbone of a nationwide 3D geological model. As new seismic data is acquired, the workflow can semi-automatically update the grids.

A novel workflow will couple forward stratigraphic, diagenetic, and fracture modeling to key aquifers, resulting in more accurate property models necessary for the techno-economic performance of projects (GO-Forward project). Engaging with key stakeholders ensures that the models and underlying data are accessible through fit-for-purpose portals, making them available to the public. These steps will prepare Denmark for more efficient subsurface usage and accelerate green energy projects.

Towards an integrated framework model of the Dutch subsurface

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TNO – Geological Survey of the Netherlands builds and maintains a suite of four national subsurface models. Down to a depth of about 7 km, DGM-deep maps Carboniferous to Neogene seismostratigraphic horizons. DGM-deep, originally designed to serve the hydrocarbon industry, now plays an important role in the exploration of geothermal potential. Down to about 500 m, the country is covered by the layer-based models DGM and REGIS II. DGM maps the geometries of Neogene to Quaternary lithostratigraphic units. REGIS II further subdivides DGM into hydraulically parameterized hydrogeological units and is essential to regional groundwater flow models. Down to a depth of 50 m below MSL, the multi-purpose GeoTOP model maps both lithostratigraphy and lithology. In addition to the national models, a large number of project-based, regional subsurface models exist, each built to fulfill specific user requirements.

All models describe the same Dutch geology but differ in depth range, scale, and resolution, in the data sources used, as well as in modelling methods. As a result, the models are not consistent with each other, which is very confusing from an end-user's point of view, especially when they are exploring the subsurface in areas and depth ranges where multiple models offer different geometries and parameters.

We are therefore in need of a general-purpose framework model in which all lithostratigraphic and hydrogeologic layers are uniformly defined over the entire depth range, and are consistent on a national scale. From this model, the individual national models with a specific focus and application can be derived.

A first step towards a consistent model was the integration of the workflows of the layer-based models GeoTOP and DGM, combining a high level of detail of the Holocene deposits (featuring 35 different layers) with Pleistocene and Neogene formations, respectively. We recently added the hydrogeologic layers of REGIS II to this integrated workflow.

The next step, the integration of the models of the shallow and deep domains, will be more challenging. Teams that used to operate independently now collaborate to create a single model using different data types, modelling methods, and software systems. The integrated framework model will also face the challenge of speeding up work processes to meet the demands of rapid, regional model updates that utilize newly incoming data.

In summary, the Survey is facing a challenging program to build an integrated, consistent layer-based model of the Dutch subsurface from which the national models can be derived.

A 3D Geological Model of the Morsleben repository in Germany: Modelling complex intra-salt deformation

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Low- and medium-level radioactive waste is stored in the Morsleben repository in Northern Germany. The repository is going to be decommisioned with the radioactive waste left in place, a task that is assumed by the Federal Company for Radioactive Waste Disposal (BGE). In this context, a preliminary 3D geological model of this former salt mine was built within the scope of a model study by the Federal Institute for Geosciences and Natural Resources (BGR).

Input data for the model are well data, underground geological maps, mine maps, a 3D model of the mine workings, geophysical measurements such as seismics, electrical resistivity tomography (ERT) and ground penetrating radar (GPR). In addition, pre-existing vertical and horizontal cross-sections (Behlau *et al.* 1997) constitute a fundamental basis for the 3D geological modelling process. We use the AutoCAD based 3D geological modelling software openGeo (Bicad), which is useful for modelling the complex folds abundant within salt structures and for evaluating GPR data.

Here, we present exemplary parts of the 3D geological model of the Morsleben repository. Modelled horizons comprise a potash seam and halite and anhydrite layers of the Late Permian Zechstein formation. Being prone to brittle deformation resulting in the occurrence of individual blocks, the anhydrite posed a challenge both from a technical perspective as well as concerning the inherent uncertainties associated with location and size of individual blocks.

A reliable 3D geological model is necessary for further geomechanical model calculations to assess the integrity of the salt barrier and stability of the mine workings. The modelling approach used can be applied to mineral deposits, different host rock formations regarding radioactive waste disposal and other settings where complex geological structures are present.

References:

Behlau, J.; Mingerzahn, G. & Bornemann, O. (1997): ERA Morsleben - Erarbeitung eines geologischen Lagerstättenmodells. Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Abschlussbericht, Vol. 1-2: 73 pages; Hannover.

Utilizing Modern 3D Visualization Techniques for Communicating Geological Models

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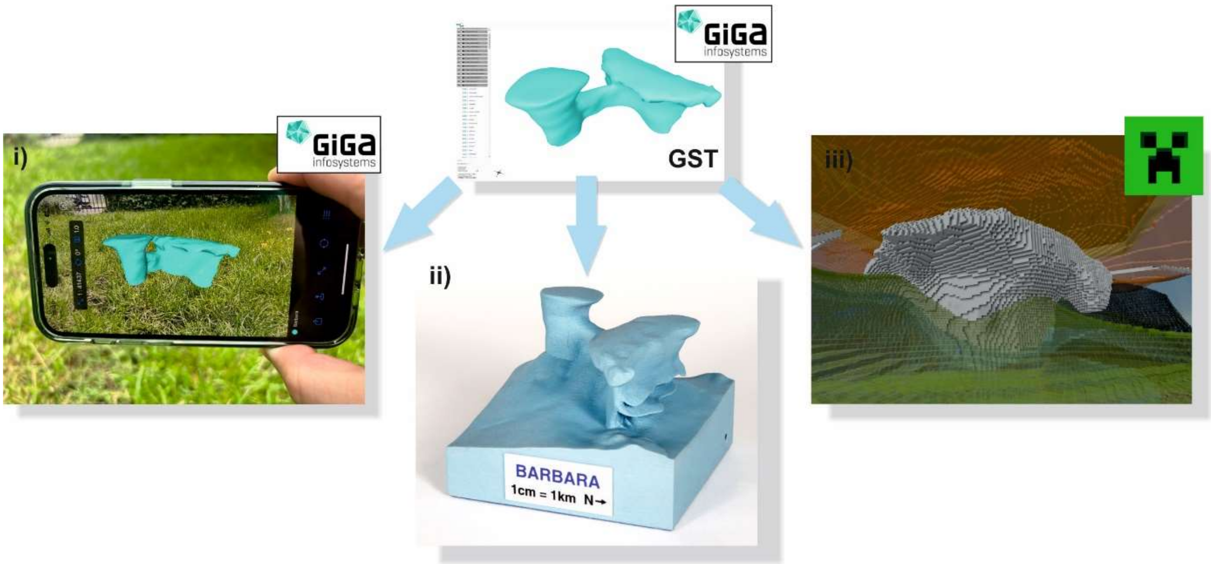
Geological 3D models are essential not only for visualizing subsurface structures but also for conducting analyses on scientific and applied topics, such as assessing the utilization potential of the deep underground. Effectively communicating these often complex geological concepts to a broader audience requires the use of advanced 3D visualization techniques.

As part of the public outreach efforts of the Department of Subsurface Use of the Federal Institute for Geosciences and Natural Resources (BGR, Germany), different technologies are being tested and implemented within the last years to improve accessibility and comprehension of geological information. Actually, four key technologies are being used and further developed to visualize geological models: Augmented Reality (AR), Virtual Reality (VR), 3D printing, and computer gaming software (e.g. Minecraft). Each serves different audiences and applications. **AR, accessible via smartphones, is ideal for education, fieldwork, and public outreach, reaching a broad audience since anyone can use it on their own device.** VR, requiring headsets, offers deep immersion but is limited to controlled environments like universities and museums. **3D printing creates tangible models for hands-on education and stakeholder presentations, characterized by haptic impressions and the advantage of being readily available once printed.** To engage emerging audiences, selected geological models have also been integrated into "**Minecraft**" for playful learning.

In this study, we aim to analyze the advantages and limitations of each approach currently used within the BGR and present best practices concerning resource allocation and supervision efforts. As part of our poster presentation, we will also showcase selected techniques on-site.



Visualization of a 3D model of a salt dome provided in 'gst'-platform through different techniques: i) augmented reality ii) 3D printing and iii) the gaming software Minecraft.

Effectiveness of interactive 3D viewers on stakeholders' understanding and communication of geology

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When local decision makers can improve their understanding of local geology, it opens up new ways for them to make informed decisions about resources, economy, land-use and conservation. We have found that interactive, online 3D tools and strategies are most useful and impactful for stakeholders to grasp and communicate critical aspects of the local geology. We explore modeling methods, visualization tools and model-query strategies targeted at a range of stakeholder needs, such as water-resource planning, infrastructure security, or land-use planning. We use case studies from Illinois, USA, to evaluate the effectiveness of static maps, derivative map products and interactive viewers (all based on 3D geologic models) on the successful conceptualization of geology by stakeholders.

Relevance, functionality and accessibility are key parts of 3D viewers that create impact for users. For example, regional water resource specialists use our online, 3D geologic model viewers to show constituents their local subsurface geology to clearly communicate aquifer locations and infer aquifer protection strategies. The 3D geologic model data have also been used to develop derivative resource protection maps for long-term planning strategies. Some engineering firms use our 3D viewers daily to rapidly create cross sections and communicate geology in reports and conversations with their clients. These firms are typically interested in shallow geology related to local soil strength and textural variability. We are also working with local transportation-government branches to develop online tools to query geology and geotechnical information in 3D. Despite having tools to query geotechnical data in a mapviewer, these geotechnical engineers seem to be most interested in 3D geology. Engineers must measure on-site soil strength regardless, but knowing local 3D geology can help them create more efficient workplans and budgets.

These 3D viewers are typically robust, but users still sometimes face problems related to their functionality and accessibility. On many occasions, the 3D viewer may not be accessible due to an unknown hardware backup or software upgrade, which breaks the links between the viewers and the data. Firewalls in network systems have prevented some viewers from using international 3D model viewers. Sometimes, symbolization malfunctions, which makes interpretation of cross sections very difficult or unresolvable. Lastly, the geologic context of the viewer may be unclear, so descriptions of geologic units must be referenced to other literature or reports for a more comprehensive understanding of the model. Nonetheless, users of our 3D model viewers have generally had great success communicating complicated geologic concepts to clients and constituents, but continued development and refining are needed to optimize their impact.

Juggling the challenges of 3D Modelling

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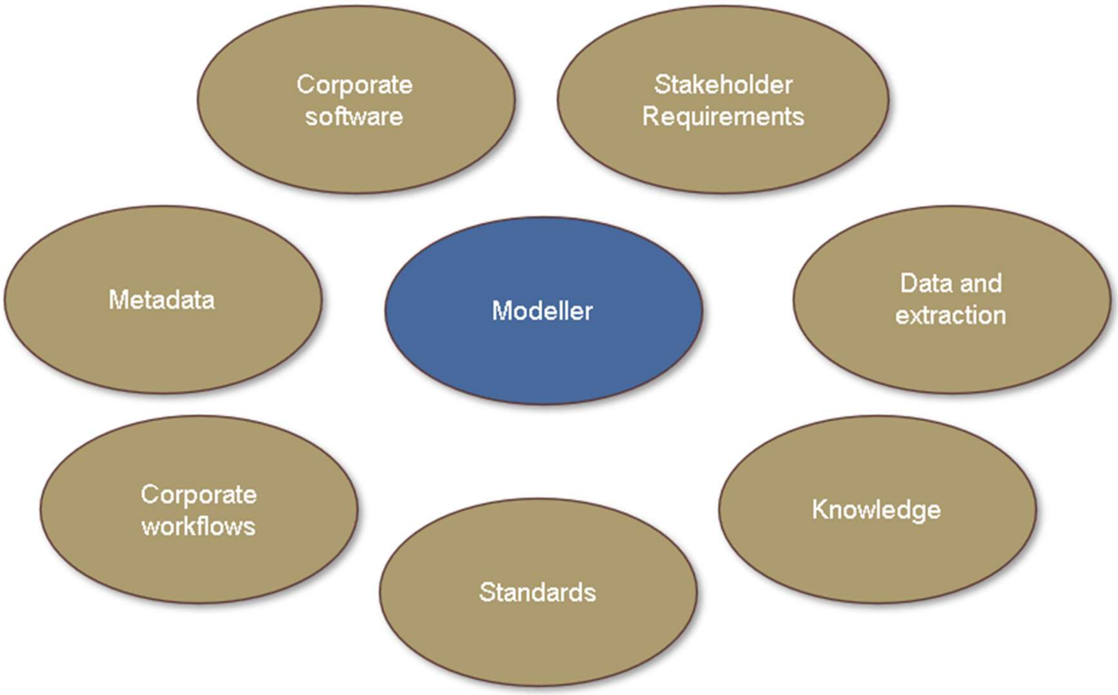
Geological modelling is a very misunderstood and undervalued set of techniques and methodologies to build a digital representation of the subsurface in 3D using the best and most complete set of data available to the geologist or modeller. However, what is really happening is that the geological modeller is at the ultimate intersection between fundamental endpoints. These endpoints could be data related, they could be business related or they could be stakeholder related. The role of the modeller is to operate at this intersection by bringing the various elements together and weave the geological story.

This presentation will discuss the various endpoints identified below and show how each has levels of complexity, its own idiosyncrasies, issues and challenges and where the modeller must navigate through in order to produce the best interpretation.



This network of endpoints is intrinsic to all modellers, but the communication of these endpoint challenges often becomes accumulated and its impact is felt in project delays, overspends, staff stress and ultimately nothing improves. At the British Geological Survey the journey towards communicating these challenges is well underway but far from complete. This results in more valuable conversations when developing 3D modelling projects as it means being able to communicate these challenges with others (non-modelling experts or senior managers, for example) so that the modelling process can be properly costed, planned and staffed. This presentation will look at these challenges and the improvements measures that BGS has implemented to address them.

Harmonization of 3D models in poor exploratory scenarios based on the integration of geological, gravimetric, petrophysical and seismic data; a case study in the Southwestern Pyrenees

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The harmonisation of subsurface information is a significant challenge in exploratory scenarios where data or information access is limited. This is particularly relevant in the exploration and evaluation of geoenergy resources and gas reservoirs throughout Europe. In the case of the southwestern Pyrenees, the issue is not the lack of seismic coverage, which is relatively dense due to the discovery of a gas reservoir in the 1970s, but rather the accessibility of that information. The privatisation of former public companies in the 1990s has restricted access to seismic and borehole information, as current governmental databases are incomplete. Additionally, ongoing and long-lasting exploration permits impose a temporal embargo on subsurface information. In our study case, only 6% of the digital information (*.sgy files) was available for 3D reconstruction, with the rest comprising image scans of seismic sections with varying levels of processing. In total, less than 50% of the seismic information was available, and much of this was of very low quality, making it impossible to reprocess. This situation may also happen in other EU regions that will have to be evaluated in the frame of the transition of the energy system (Green Agenda), as in the southwestern Pyrenees, where a potential deep geothermal reservoir has already been pre-evaluated in the region with good prospects.

In this case study, we sought to achieve a reliable 3D reconstruction of the subsurface. To this end, we built a 3D model by integrating gravimetric and seismic exploration and joint modelling (geological, geophysical and petrophysical). We acquired more than 3,100 new gravimetric stations in the study area (mostly in the main target area, about 2000 km^2 in surface) and combined them with previous datasets. The final Bouguer anomaly is based on more than 8,500 gravimetric stations, evenly distributed for optimal results. In addition, we acquired and harmonised petrophysical data in more than 300 localities, with over 800 density determinations. About two thousand seismic reflectors (stratigraphic horizons) and faults were identified from 142 seismic sections. The integration of this comprehensive set of data has enabled the creation of a new 3D model of the southwestern Pyrenees, which will support subsurface interpretation and facilitate informed decision-making processes.

Bouguer residual anomalies (specially the 6 km upward continuation) strongly correlate with the basement topography in areas supported by seismic exploration. The basement rocks (Paleozoic and lower Triasic rocks) have the highest density of the formations evaluated, resulting in the greatest contrast with other rocks in the overlying units (remainder of Mesozoic and Cenozoic units). Consequently, gravimetric modelling is an effective approach to harmonising subsurface information in this region, especially where seismic data are not available or accessible.

3DGeoEU WP6 Team (by alphabetical order): Ayala C.; Bohoyo F.; Calvín P.; Casas A.M.; Clariana P.; Elena Fernández de Arévalo E.; Ezquerro L.; García A.; Gimeno A.; González A.; Izquierdo-Llavall E.; Jiménez J.; Llorente J.M.; Marín C.; Martín León J.; Mochales, T.; Montañés A.; Navas J.; Oliva-Urcia B.; Pérez Bielsa C.; Peropadre C.; Pueyo Anchuela O.; Pueyo E.L.; Rey C.; Rubio F.M.; Santolaria P.; Soto R.; Toro R.

Building a Lithotectonic Framework for Belgium

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Almost all geological subdisciplines depend, to varying extents, on regional geological knowledge. Stratigraphic terminology is typically well-defined, while other concepts rely on generally accepted definitions or hierarchical schemes, such as palaeontological, structural and magmatic terminologies. This is much less the case for the regional geological building blocks. Their nomenclature is usually composed of a reference to a geographical locality and a geological term. Examples from Belgium include the (Anglo-)Brabant Massif, Campine Basin, and Malmedy Graben. Despite wide recognition, such terms often lack precise definitions and may even present conflicting interpretations across different contexts and authors. Even when their meanings have drifted or become less precise, these terms continue to be utilized.

Increased awareness has led to significant yet isolated initiatives aimed at improving the structure and definition of regional geological information [1-3], recently brought together through pan-European cooperation [4]. Lithotectonic unit appears to be the most effective concept for encompassing all geological features. A lithotectonic unit is characterized by its composition, structural elements, mutual relations, and/or geological history [5]. Following a geotemporal conceptual approach, lithotectonic units are defined and bounded by relative limits in time and space [6]. Lithotectonic limits are planar features corresponding to geological events which have formed and define these units. Examples of lithotectonic units include orogens, terranes, sedimentary basins, and grabens, while examples of lithotectonic limits include deformation fronts, faults, and unconformities.

This approach facilitates the organization and formalization of relationships between units and limits through ontologies. The data model can be linked to established ontologies, such as the ICS Geological Time Scale Ontology [7], and allows future extensions, such as attribution to orogenic cycles [2]. The associated concepts can be linked to 2D and 3D visualizations, thereby adding an important layer of knowledge to geological maps and models.

Primary objective of the newly established Lithotectonic Working Group, under the National Commission for Stratigraphy in Belgium, is to create a comprehensive lithotectonic framework, that systematically defines and describes the main geological units and limits of Belgium. This initiative aligns closely with emerging standards currently being developed and implemented at European level [4] and largely based on GeoSciML [8].

References:

[1] Hintersberger et al. 2017, *Jb Geol B-A* 157:195-207.

[2] Németh 2021, *Miner Slovaca* 2:81-90.

[3] Le Bayon et al. 2022: https://doi.org/10.1051/bsgf/2022017.

[4] GSEU 2022-2027: https://doi.org/10.3030/101075609.

[5] INSPIRE 2015: https://inspire.ec.europa.eu/theme/ge.

[6] Piessens et al. 2024: https://doi.org/10.31223/X5RT28.

[7] Cox & Richard 2005: https://doi.org/10.1130/GES00022.1.

[8] GeoSciML 2016: http://www.opengis.net/doc/geosciml/4.1.

Enhancing 3D geological models: Regional geological mapping with planned 2D seismic survey in Brandenburg

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Mapping the deeper subsurface is typically limited to a few exploration methods. Cored drilling is arguably the most precise method but also very expensive for greater depth and restricted to a single-point exploration. Alternatively, mapping the deeper subsurface can also rely on geophysical methods such as seismics. While seismic surveys leave a higher margin of inaccuracy due to a higher grade of interpretation, it can provide geological information on a broader scale (2D-lines or even 3D surveys) at lower initial cost.

In Brandenburg (Germany), a new 2D seismic survey is planned between Cottbus and Guben, near the German-Polish border. Targeting depths of up to 4000 m, the survey aims to enhance understanding of the Mesozoic and upper Paleozoic geological structures in the region. It will provide valuable insights into the Zechstein, Rotliegend, and the top of the basement.

The planned 2D seismic survey in Brandenburg is crucial for 3D geological modeling, as it enhances subsurface imaging, refines structural interpretations, and improves model accuracy. It provides updated insights into fault systems, stratigraphy, and basin architecture while reducing uncertainties in existing 3D models. By integrating new seismic lines, models can be validated, and previously unknown geological features can be identified.

Seismic data collected by the geological survey will be classified as state (or public) data and made publicly accessible under the Geological Data Act (Geologiedatengesetz). As a result, this survey will not only advance geological mapping and 3D modeling but also support drilling optimization and infrastructure planning, including geothermal energy development.

The Geological Service has been commissioned by the Brandenburg Ministry of Economics (MWAEK) to carry out the seismic campaign. The geological survey is financed through funds allocated from the distribution of the resources of the former GDR's parties and mass organizations (Parteien und Massenorganisationen der DDR; PMO-Mittel). Currently, the project is in the planning phase, with a focus on stakeholder management and geophysical survey design. The seismic survey is expected to take place in fall 2025.

Cookie-cutting 3D Geological Models

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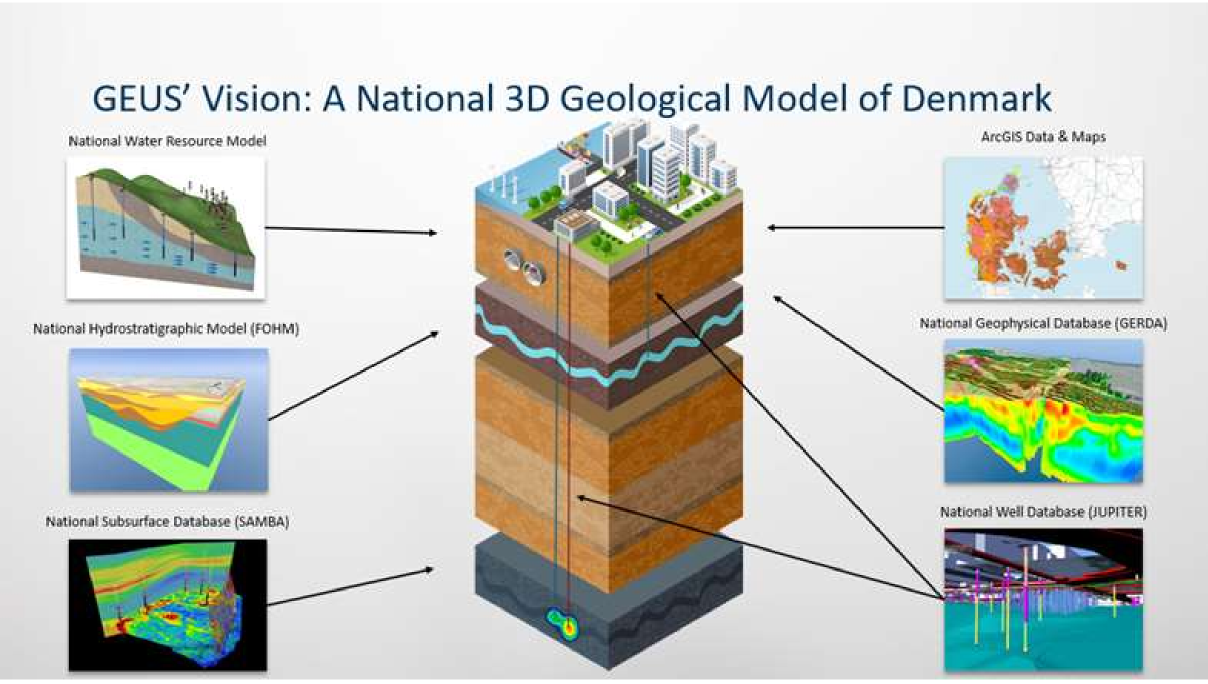
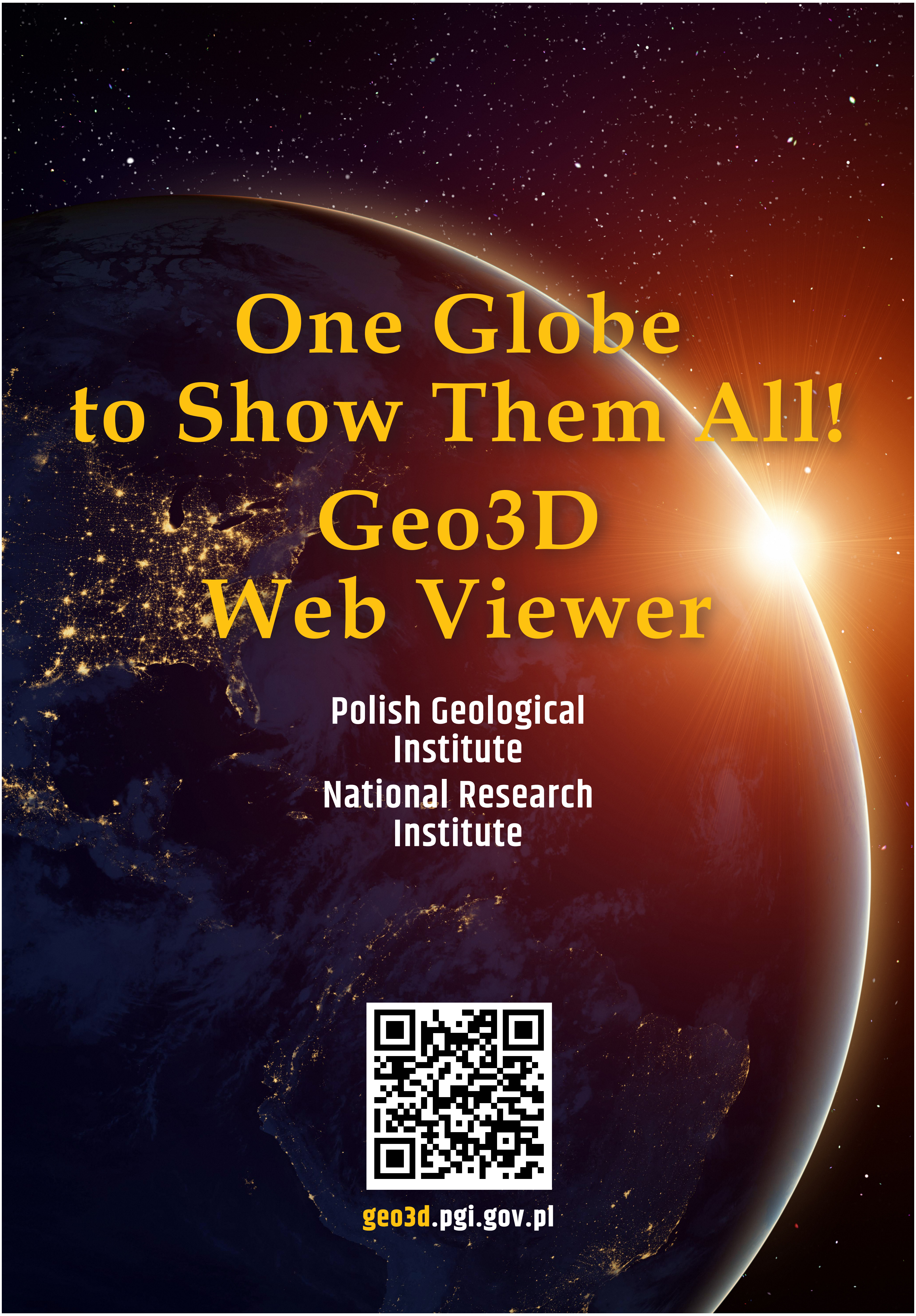
We would like to present our work on a comprehensive geological model of Denmark, testing how GEUS' 3D database and viewer can compile and disseminate knowledge about the subsurface. 3D models at GEUS are developed within specific domains: models of the deep underground (geothermal and CO2 storage), and models of near-surface hydrogeological units (water management), both modeled as grids. Also, a voxel model of the upper 30 meters is being developed, and a database of faults as vector lines or surfaces. A growing challenge for 3D viewers is that web visualization slows down as the models get larger and more detailed.

At GEUS participants from various departments work together to find out: What type of data is requested by stakeholders, with which attributes, and in what formats? How to delimit the models so they can be displayed simultaneously? How can a model's uncertainty be visualized so that it is easy to understand?

The goal of the project, continuing throughout 2024, is to demonstrate a prototype for a smaller test area that shows a 'cookie-cutter' slice of a composite geological model for a smaller area, encompassing everything from the voxel model below the terrain to the deepest modeled layers and faults.

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