Chapter 21: 3D Geological Modelling at the Polish Geological Institute

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Introduction

3D geological modelling was initiated at the Polish Geological Institute (PGI-NRI) in 2003 by setting up the first 3D model of the geology of Poland, showing deep structure from 6000 to 500 m below sea level (b.s.l.; Piotrowska et al. 2005). Numerous 3D models have been constructed since then, thus finally starting to tilt the PGI-NRI towards a 3D geological modelling culture. Good proof of impact seems to be the fact that some diehard analogue geologists have been convinced recently to use digital 3D tools, so the effort is both promising and gaining ground.

Our models comprise a broad variety of topics – from the planned 3D Framework Geological Model of Poland through multiscale 3D models of individual sedimentary basins to various purpose-built models. The level of detail available within these models depends both on the quality of data available as well as importance of individual stratigraphic systems to end users. We particularly pay attention to mineral deposits, energy resources (including geothermal and hydrocarbons) and strata which may be important for underground storage (such as natural gas) and environment protection (including major aquifers).

Our efforts shall soon become much more visible at the delivery end of the modelling process. Our web-viewer of 3D geological models is ready for release and will soon be available to demonstrate the geology to the geological community and the public in general – in a very accessible way. We hope it will provide a vehicle to significantly boost our client-base and, most importantly, increase interest in geological sciences and advocate for their importance to our everyday life.

Organizational Structure and Business Model

The Polish Geological Institute (PGI) was established a century ago on 7 May 1919, several months after Poland regained independence, and for now it has the longest history of any Polish research institute. In recognition of its organizational contributions to the development of Polish science and its economy, in February 2009, the Council of Ministers awarded it the status of National Research Institute. The Institute is supervised by the Minister of the Environment.

Research projects delivered by PGI staff led to the discovery of Poland's key deposits of mineral resources: copper, silver, native sulphur, coal, lignite, rock salt, potassium salt, iron, titanium, vanadium, zinc and lead ores. Several thousand wells drilled by the institute enabled a detailed investigation of Poland's geology, one of the most detailed deep drilling programmes in the world.

Acting on behalf of the State Treasury, the Institute collects geological data across the country. The data are available, in digital and analogue formats, from the National Geological Archives, and several specialized databases, including the Central Geological Database CBDG, Midas, Infogeoskarb, the Register of Mining Areas, and the Hydro Bank. The Institute has initiated measures aimed at implementation of the INSPIRE Directive, intended to standardize spatial data across EU Member States.

The PGI-NRI operates laboratories that are specialized in chemical, microscale, geophysical and engineering geology analyses. The microscale laboratory boasts an Ion Microprobe SHRIMP IIe/MC and an Electron Microprobe CAMECA SX 100. The accredited chemistry laboratory, counted among the largest in Poland, performs 500,000 determinations on 35,000 samples each year.

As a member of EuroGeoSurveys, an umbrella organization of European geological surveys, the Institute contributes to the development of reports by this Organization, and takes part in meetings of expert groups that provide advice to the European Commission. The PGI-NRI collaborates with geological centers in several dozen countries worldwide.

Almost 900 people are employed at the Warsaw PGI-NRI headquarters and seven regional branches (Gdańsk of Marine Geology, Kielce of the Holy Cross Mts, Kraków of Carpathian Mts, Lublin of Eastern Poland, Sosnowiec of the Upper Silesian Coal Basin, Szczecin of North-Western Poland and Wrocław of The Sudety Mts and the Lower Silesia). Most staff members hold academic degrees in geology, including several tens who are full or associate professors, and 140 PhD degree holders. Each year, the scientific staff of the Institute delivers several tens of national and international research projects.

The activity of the PGI-NRI is financed for the most part by the National Fund for Environmental Protection and Water Management and by the Ministry of Science and other scientific funding organizations. Commercial activities provide ca. 3% of PGI-NRI funding.

Pursuant to the Geological and Mining Law, the **PGI-NRI performs tasks of the Polish Geological Survey (PGS)**. The overarching task of the PGS is to take care of rational management of national mineral resources and to protect and monitor the status of the geological environment and to warn of natural hazards. Survey operations support key governmental strategies, including Poland's Environmental Policy and Poland 2030.

The Polish Geological Survey is primarily responsible for geological investigations, including projects of key importance to the national economy that are intended to identify new prospects for the mining industry, and to enhance mineral security of the country. PGS is involved in exploration for conventional and unconventional hydrocarbons, including coalbed methane. PGS also investigates the potential for tapping geothermal energy, as well as for the use of geological structures and formations for underground storage and disposal.

The Polish Geological Survey operates in close collaboration with central and local governments as well as with geological businesses and scientific research centres both in Poland and abroad, sharing experience and providing them with information. This arrangement allows for sustainable use of existing mineral resources and planning for mineral and economic strategies, as well as for counteracting the effects of natural disasters.

Detecting and monitoring of geoenvironmental hazards is a key responsibility of geological survey specialists. Our geologists investigate areas that are contaminated or subject to risk of mass movements. The latter are addressed by the Landslide Monitoring and Counteracting System (SOPO) established by PGS. The system is a project of national importance aimed at, first – creation of landslide susceptibility maps and, at a later stage, the development of a system for forecasting, assessing and reducing landslide risk in Poland. The project will have a major impact on the economy and finances of the Polish state and on the socio-economic wellbeing of its citizens.

The Polish Geological Institute also performs the responsibilities of the **Polish Hydrogeological Survey (PHS),** established by the Water Law of 2001. This document implements EU Directives on water management and protection. PHS primarily focuses on exploration, proving and protection of groundwater so as to minimize degradation of aquifers intended for consumption, and to ensure sustainable management of groundwater resources.

Research and data collected by the PHS are the key source of knowledge about the status of groundwater in Poland. PHS hydrogeologists monitor groundwater quantity and quality on a regular basis and collect information about the size of groundwater reserves and abstraction. They analyze reported changes, prepare forecasts, and draft hydrogeological maps, as required for efficient water administration and management planning.

PHS work is crucial, as seventy percent of Poland's population rely on drinking water supplied from freshwater aquifers. The safe yield of freshwater aquifers in Poland is almost 14 km^3 per year, while total groundwater uptake is in the order of 4 km^3 per year, thus Poland holds quite significant reserves of potable water. Nonetheless, effective conservation and sustainable management of these resources is key to counteracting degradation and assuring conservation of aquifers for future generations.

Overview of 3D Modelling Activities

Modelling activities at the PGI-NRI follow three scale-dependent, interrelated paths: country-scale framework geological modelling, basin-scale (or major tectonic unit) modelling, and local-scale, for-purpose modelling (mine, geothermal, mineral deposit etc.). Throughout the last 10+ years, the focus has been shifting between the three. We started in 2003 with a country-wide, general stratigraphic model of bedrock geology released in 2005. Then, several local models were built, a result of which was a greater recognition of modelling as an efficient research tool. We could thus embark on a more systematic approach to modelling: general-purpose 3D mapping of all sedimentary basins of Poland, and a strategy of systematic shallow model building, both outlined by Jarosiński et al. (2014). Recently, we made a loop by arriving at the conclusion that, besides basin-scale and local-scale models, we also need a greatly improved Framework Geological Model of Poland to hold together our more local interpretations and provide a tool for – surprisingly often requested – country-wide analyses. The current picture of our activities is thus the following:

The coming year (2019) will see a completion of our second basin-scale, general-purpose geologic model (Gorzów Block, Figure 1). It will be followed by the next basin-scale model located immediately to the north (Szczecin Syncline), thus allowing us to test cross-border harmonization with the Northern German Basin Model, within the pan-European GeoERA programme. It is our objective to gradually build multi-scale 3D geological models for all sedimentary basins, or large tectonic units in Poland.

In the same year, we will also start revamping our country-wide model – this time with much more data. Unlike the 2005 version, it will hold a geologic grid for parameter interpolation. The project is called Framework 3D Model of the Geology of Poland and will serve as a reference for all other models we produce. This project will also be an opportunity for a fundamental upgrade of our Central Geological Database and, hopefully, turning it into a 3D database.

Constructing purpose-built and local-scale models is finally arriving at the stage of a systematic activity for PGI-NRI. Most notable of these is 3D geological modelling down to 200 m for assessment of shallow geothermal resources, by making a series of heat conductivity maps that allow optimization of heat pump installations. This activity started within the framework of the TransGeoTherm project, and is currently conducted within the framework of the GeoPlasma project. The experience gained in these international endeavours is scheduled to be employed soon in most of metropolitan areas in Poland, and in the case of the capital of Warsaw with reuse of our existing urban geology 3D model.

Resources Allocated to 3D Modelling Activities

Full-time core staff dedicated to general-purpose 3D geological mapping

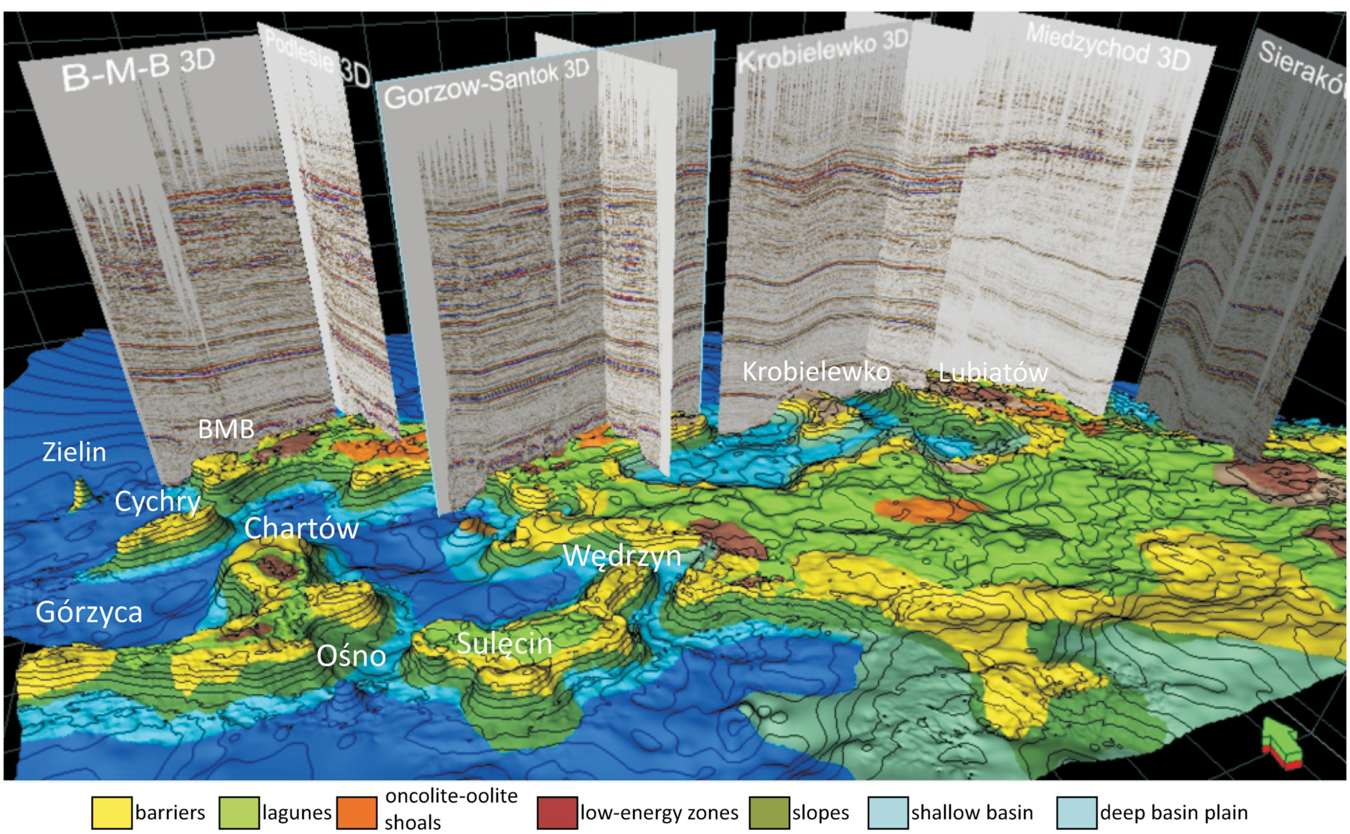

Figure 1. Lithofacies distribution of the carbonate platform of Zechstein evaporites in Gorzów Block sedimentary basin 3D model, NW Poland. Surface depth 2200-3300 m. Structure interpreted from 23 seismic 3D surveys. Facies derived from 300 wells. Oil and gas fields indicated. The region depicted is ca. 100 km across (east–west), with north is indicated by the green/red arrow in the right lower corner of the figure.

consists of 9 people. However, these core personnel are supported part-time by several regional-geology experts, geophysicists, IT, and database personnel. Thematic models, such as geothermal or engineering geology models engage a further 15 people approximately, either full- or part-time. Altogether, about 60 people are engaged in 3D modelling at the PGI-NRI.

The Framework Geological Model of Poland, commissioned for 2019-2021, is funded by the Ministry of the Environment and the National Fund for Environmental Protection and Water Management, with a total budget of between 1 to 1.5 million PLN per year (230 to 350 thousand Euro/year). The Gorzów Block (2016-2019) project has a similar budget, similarly as the subsequent Szczecin Syncline geological model (2020-2023). Separate funds are provided in thematic projects – such as engineering geology mapping of urban areas, or geothermal energy projects – to construct smaller, purpose-built geological models which will also finally be incorporated into the Framework Model of Poland. Altogether, estimated cost of modelling activities carried out at the PGI-NRI will approximately be 500 thousand EUR/yr.

Overview of Regional Geological Setting

The area of Poland stretches over the north-eastern part of the West European Platform and the south-western edge of the East European Platform, with the Trans-European Suture Zone, i.e. the Teisseyre-Tornquist Zone (TTZ), trending northwest to south-east and dividing it into two, almost equal parts (Figure 2). The sedimentary cover on the East European Platform started to form in the Late Proterozoic and its thickness ranges from less than 500 m in the northeastern corner of Poland on the Mazury Elevation to 5–7 km along the TTZ (Młynarski 1982).

The slightly larger, southwestern part of Poland originated from the Early Palaeozoic accretion of Caledonian terranes at the southwestern margin of Baltica, which remained passive until the Late Ordovician (Nawrocki and Poprawa 2006). This Caledonian accretion was followed by the Variscan collision, and creation of the thrust-and-fold belt, covering the majority of the area to the south-west of the TTZ. The Variscan belt is bound from the south-west by the Bohemian Massif, with the Sudetes along the border with the Czech Republic. The foreland basin to the north and north-east of the Variscan front is underlain by the Caledonian basement, while to the

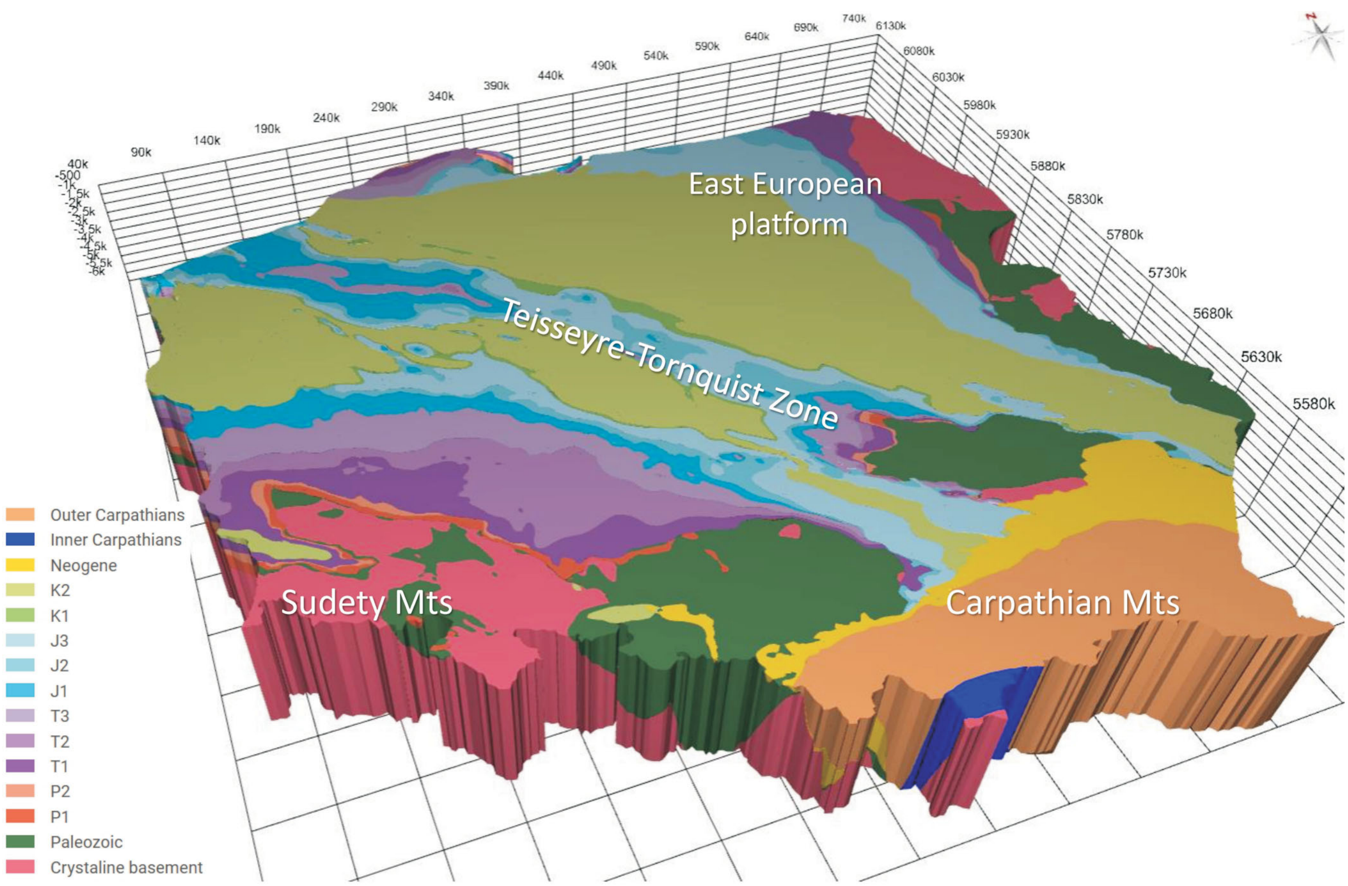

Figure 2. Bedrock model of Poland (2005) in depth interval 500–6000 m SSTVD. Vertical exaggeration x20. Legend abbreviations include Permian, Triassic, Jurassic, and Cretaceous strata.

east by the Brunovistulian and Małopolska Terranes associated with the Cadomian Orogeny.

The Lower Palaeozoic basement of the West European Platform is covered by Carboniferous and Permo-Mesozoic strata with a total thickness of between a few and several thousand metres. This sedimentary cover had the largest thickness immediately to the south-west of the TTZ, i.e. in the Mid-Polish Trough. During the Alpine Orogeny, however, the Mid-Polish Trough underwent tectonic inversion which transformed it into the Mid-Polish Swell (Pożaryski and Brochwicz-Lewiński 1979). At the local scale, the sedimentary cover was also deformed by salt tectonic movements associated with activation of the Upper Permian evaporates which started in the Triassic (Krzywiec 2002).

The southern edge of Poland lies within the reach of the Carpathian thrust-and-fold belt with its foreland basin filled by Neogene deposits in the Małopolska Region (Figure 2). Despite the significant rejuvenation of topography during the Alpine Orogeny, almost the entire area of Poland – with only exceptions for the southern parts of the country – was generally levelled by the Paleogene and Neogene sedimentation as well as by the Quaternary glaciations. During the latter, elevations were eroded and a thick cover of locally derived material mixed with that brought from Scandinavia was left, locally reaching well over 300 m.

Generally, the geological setting of Poland provides significant challenges for 3D geological modelling across the country, particularly with several km-high salt domes in the axial part of Polish Basin, and crystalline basement structures of the Sudety Mountains and the East European Platform. These bedrock modelling challenges are accompanied by further difficulties in shallow strata, such as thick Quaternary deposits left by several glaciations, with frequent glaciotectonic deformations, covering almost the entire country.

Data Sources

In accordance with Polish regulations, the State Treasury is the owner of all geological information obtained within Polish territory. This information can be used by the State (thus also by the Polish Geological Survey) to fulfill its tasks. It can be released to stakeholders (for a fee payable to the State and dependent on intended use of information) five years after the exploration license of the data provider expires. Earlier release is possible only after obtaining the permission from the exploration company. This does not apply to data obtained during most of the 1990s – in which case the company that collected the data is still its only owner and thus controls the right to use it.

Polish regulations indicate that geological interpretations (thus also geological models) can be released to the public without restrictions. Nonetheless, when models are built with the use of restricted-access data it is a good practice to agree with the data provider on the resolution and content of the final product to convey meaningful information without compromising the market competitiveness of the data owner. The legalities of access to data are thus largely favourable for the Polish Geological Survey.

In practice, our access to data is limited by the content of the Central Geological Database (CGD) managed by the PGI-NRI. This database is the largest Polish collection of geological data with over 11,250 seismic reflection profiles, 98 3D seismic datasets, over 13,000 boreholes deeper than 500 m and almost 200,000 shallower boreholes. These archives, except the well database, are nonetheless largely analogue, most notably in the case of seismic data and borehole geophysics, both key components of almost any modelling project. Digital versions of these data must thus often be obtained for a fee from third parties, which up to now requires a separate agreement for every project.

The whole country is also covered by gravity data with a density of between 2 and (locally) 10,000 measurement points per square kilometre. These data are stored in the CGD and is fully digital. We have a similar database for magnetic susceptibility data and there are also other geophysical surveys such as magnetotellurics or abundant electrical resistivity profiles used for shallow subsurface interpretations.

3D Modelling Approach

The PGI-NRI uses a spectrum of implicit and explicit modelling strategies. Intermediate (basin)-scale to country-wide models are constructed with either Petrel or Gocad/Skua, where a combination of the techniques is used, as both raw data (borehole and geophysics) but also interpretations (maps, outlines, cross-sections) and interpreter-driven corrections feed into a model and influence the final result. The result is explicit at a more general level, given that a model contains defined geobodies and a 3D grid constructed according to the decisions made by the interpreter, and semi-implicit at a level of populating the grid by parameters. The latter is mostly data-driven and input from the interpreter is restricted to cut-off levels, choice of interpolation algorithms, and choice of procedures to deliver the most likely scenario.

The modelling approach for large scale models actually tends to occupy either end of the explicit-implicit spectrum. In the case of models where seismic and well data are scarce, we rely on gravimetric and magnetic data. These models are constructed with Geomodeller and the approach is implicit, – although we can derive geobodies for the final presentation, the model itself neither contains fixed 3D surfaces, nor is there much room for interpreter-driven adjustments within the modelling workflow. On the other end of the spectrum are geomodels that are feeding into calculations of shallow geothermal potential maps. These models are explicit – they are constructed from interpreted cross-sections that are averaged into a 3D space, without much smoothing of the resulting surfaces. Subsequently, however, they are employed for calculating heat conductivities at any point in the geospace, and this procedure is in turn fully implicit, as it populates the grid according to measurements and a fixed calculation procedure.

Clients

General-purpose 3D mapping, such as the upcoming 3D Framework Geological Model of Poland or sedimentary basin-scale models, have a wide array of potential users – from educational institutions, academia, professionals and state and local administration. The scope of information conveyed in these models is purposefully broad so as to make them usable for a wide range of applications. Nonetheless, principal groups of stakeholders were identified and are the following:

The integrated 3D Framework Geological Model of Poland is aimed most of all as a decision-making aid for geological administration at the state level, in its most detailed form serving both the Ministry of Environment and the PGS. A generalized version will be freely available both as educational material delivered in a web viewer, and for research as downloadable files. It will be a powerful tool to bring the attention of society to the subsurface, and to raise awareness of its use for economic growth and environmental protection.

The individual models of sedimentary basins will inform both state and local administrations, academia, and private companies interested in geological contexts of areas of their interest. They will also be freely available for viewing and downloading. Regions selected for these kinds of models generally follow the "hot topics" for exploration companies, as this is where they have the potential to make the most difference. Nonetheless, for both – the Framework Geological Model of Poland and the sedimentary basin models – we increasingly recognize that we need a better insight from users so as to make our models still better adjusted to their needs.

Local-scale modelling is where interaction with stakeholders is the closest and recognition of their needs is best – for a simple reason that these models are either on-demand products or for-purpose endeavours, clearly aimed at solving a specific societal need. The best examples of the latter are models made for calculating geothermal potential maps or engineering geological models prepared in the Polish Geological Institute Department of Geohazards and Engineering Geology. The latter are usually site-scale models, developed to visualize geological conditions in the subsoil of a planned large engineering projects (for example: high rise buildings, metro tunnels or stations) with deep foundations like piles or trench walls. Geotechnical site investigation is carried out mostly within the area of the parcel where the construction works will be performed, on the base of detailed geodetic plans in scale 1:500 or smaller.

The provided engineering geological models are intended to fill the gap between geological regional mapping and databases (scales 1:10,000 and bigger) and geotechnical designers' needs. To perform proper geological risk management in such engineering projects, visualisation of geological conditions in a context broader than just the construction site is necessary (for example – to visualize the glaciotectonics of Pliocene clay layers, as it is presented on Figures 3 and 4).

The primary clients of such models are geotechnical and structural engineers, and project managers who represent the investor. Collaboration with clients at the stage of model preparation is mostly focused on access to all available archival data. Models after development are given to the client to facilitate decision making, both in means of time/budget issues and detailed technical design.

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

As an example that can showcase application of jurisdictional-scale 3D engineering-geological models developed at the Polish Geological Institute, we present the model of subsoil of a planned location of contaminated waste landfill (Figure 5). This model was developed to allow numerical simulations of contaminant transport in subsoil of a planned landfill. The main aim was to ensure that the thickness of natural non-permeable layers of glacial tills will be enough to act as a protective barrier for drinking groundwater reservoir.

The model was developed in Geoscene3D software as a voxel model. At first the layer model was prepared, including over 30 layers used to precisely model sand lenses. The next step was rectification of the layer model into a voxel model. Voxel size was chosen as 10 × 10 × 0.5 m. The criterion for model layers was based on lithology, genesis and permeability, followed by statistical evaluation of data and upscaling, in order to finally derive 3 main rock types that were modelled in 3D.

The model was developed on the basis of interpreted cross sections based on borehole and geological soundings data (CPTU, DMT). Geophysical methods, including electric tomogra-

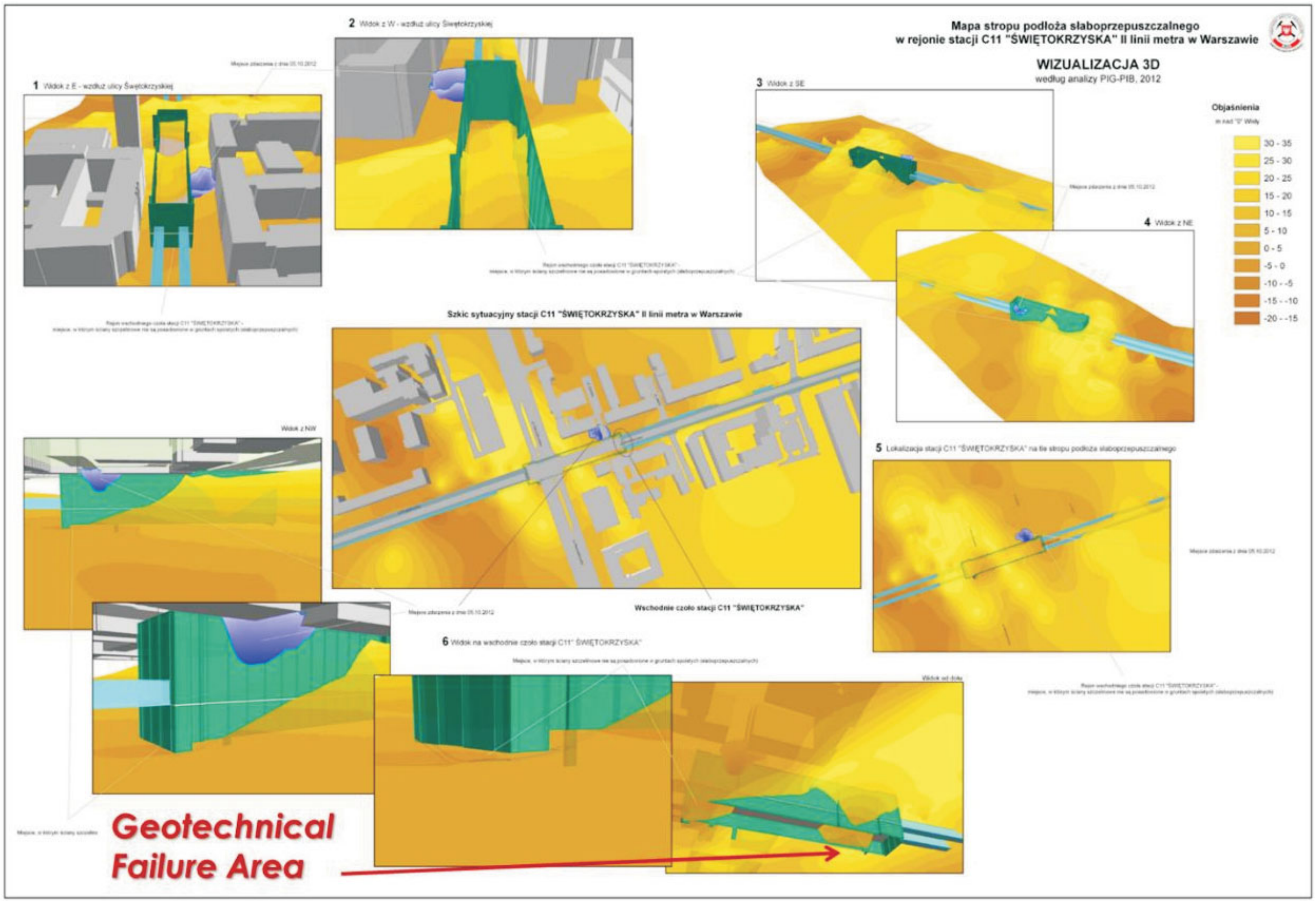

Figure 3. 3D visualisation of Pliocene clay deformation in an area of Warsaw Metro Line 2 Station "Świętokrzyska", where a geotechnical failure occurred due to hydraulic seepage of liquefied sands located in a clay pocket just below the trench wall foundation level. Each area depicted is about 0.7 km across. Green indicates the trench wall contour, blue is the area of sand liquefaction, and yellow to orange indicate the elevation of top of Pliocene clay layer.

phy (ERT) and seismic tomography (SRT) were used for model verification. The main issue in model preparation was to properly model small, isolated lenses of saturated fluvioglacial sands, that are crucial for contaminant transport.

The voxel model was saved in native Geoscene3D format and then exported to an ASCII file. This model was used for numerical modelling in Tough2 software that allowed a decision if an analysed location for landfill fulfils the safety criteria for groundwater protection. The numerical modeller was in constant contact with the geological team at PGI during the process of model development. The final model resolution in terms of voxel size and total voxel number was defined during project meetings.

Current Challenges

The most important challenges that we currently face relate to two factors: 1) quantity, quality and access to digital data; and 2) lack of an overarching policy to advance 3D geological mapping and modelling within the organization. Both of these factors make our urgently needed organizational switch to 3D geological data analysis and delivery still a somewhat remote goal.

In the case of digital data issues, although significant progress in digitisation of geological data has been made, a large proportion of these data is still stored in analogue format in CGD and, although formally state-owned, must be obtained in digital format for a fee from third parties. This is especially true in the case of seismic data and well geophysics – both the key base for most modelling projects. Moreover, as the PGI maintains several databases, there are issues relating to data integration, compatibilities between datasets, and the ability to trace the same objects, such as wells, between databases and related products, including CGD, the hydrogeological database, 1:50,000 geological maps, etc. Digital data stored in the CGD have quality issues too, such as roughly 10% of mislocated boreholes, and unharmonised stratigraphic interpretations.

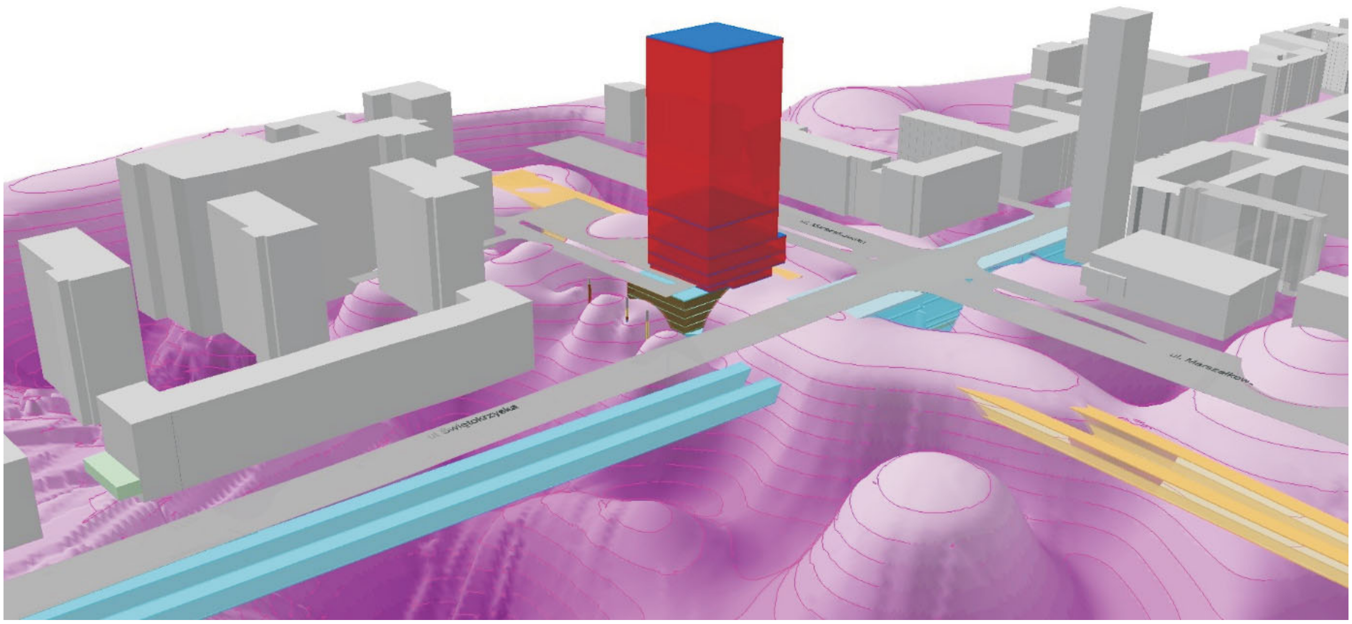

Figure 4. 3D Visualisation of glaciotectonic deformation of Pliocene clays in an area of a planned high-rise building in Warsaw, near the crossing of two main Metro lines. This visualisation was aimed at the geotechnical designer, to convince him that more dense borehole spacing below the planned building would be necessary to properly design the foundation pile depths and diameter. The area depicted is about 0.6 km across, north is to the left, and the colour gradient represents the elevation of top of Pliocene clay layer.

There is also still a lack of general confidence in the 3D approach to geological mapping and modelling within our organisation, partly due to large organisational and technological changes which would be necessary to set us on track towards a full 3D mapping policy. According to our experience, specialized staff would be eager to embrace 3D geology and the opportunities that come with it, however, for efficient employment of this approach we would need to re-think established workflows, database schemes, and data flow, as well as establishing schemes for quality assurance and storing of modelling results. This cannot be done without greater conviction and effort throughout the organization. The need to switch our geological mapping to 3D is becoming more and more urgent, and the drive to do so is emerging among staff, although this is a painstaking and not always successful enterprise. Understaffing is therefore a collateral issue, especially acute in the case of far too few geophysicists available to undertake data interpretation for modelling workflows, but also experienced geomodellers.

Lessons Learned

We can only describe here the lesson learned by a small group of gemodellers working for 15 years in the field of 3D geological mapping. The rest of our organization is still undertaking initiatives in this topic and we can foresee outcomes of this activity in a few years.

First, 3D geological modelling is a natural way of expression of geological knowledge on the rock formations and their structures. Unfortunately, large technology gaps visible in geological surveys stop most of staff from this natural approach. Those lucky people with access to adequate computers and software may undertake the task of building 3D geological maps with different modelling approaches. As we may observe, despite numerous international meetings and associated initiatives on standards of geological modelling, almost every geological survey follows its own way of modelling, discovered at some point of dealing with geospatial data. It seems naturally easier to give away the developed methodology to others than adopt methods offered by standardizing initiatives. Thus, we have parallel streams of modelling approaches, which are often incompatible at many points of the process. An opinion expressed recently in one of the modellers' meetings, about "not being able to harmonize models and workflows unless we really start working together" seems to express this point clearly. It follows that gathering information on our different approaches will not be enough to come up with workable standards that could be helpful to everybody. It seems to be time for a serious reflection about what such a common standard could be, and how to circumnavigate various legacy, site-specific issues that prevent us from producing a set of tools that would ease our modelling and exchange efforts and could kick-start 3D approaches in less-advanced organizations.

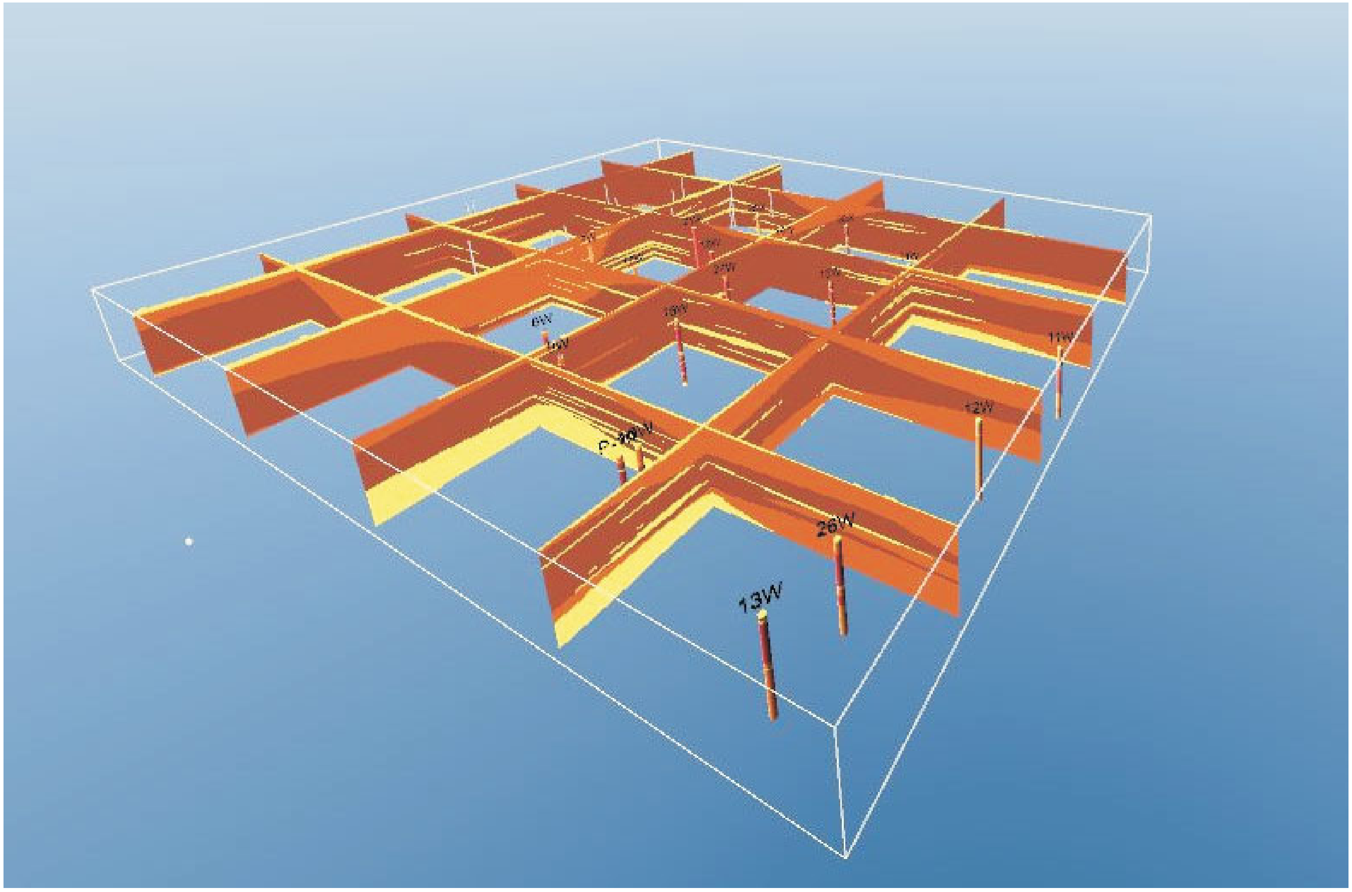

Figure 5. Fence cross-sections prepared in Geoscene3D software. The model was developed on the basis of interpreted cross sections based on borehole and geological soundings data (CPTU, DMT). Geophysical methods, including electric tomography (ERT) and seismic tomography (SRT) were used for model verification. The main issue in model preparation was to properly model small, isolated lenses of saturated fluvioglacial sands that are crucial for contaminant transport. Total depth is about 50 m, north is up, text annotation refers borehole number, yellow colour represents permeable fluvioglacial sand, light brown represents medium permeable glacial tills (sandy and silty clay) dark brown represents low permeable glacial tills (clay).

Next Steps

Our view is that the Polish Geological Institute needs to embrace a 3D culture as soon as possible. Both the geological community and the general public's interests drift away from 2D maps and towards 3D, data-rich, interactive geology. It therefore is our compelling need and our immediate plan to facilitate a switch to such culture. Notably, there is a growing interest within the organisation to incorporate and integrate into a single 3D space all available geological data such as information related to mineral resources, rock properties, formation temperature, hydrogeological data as well as interpretations such as 2D geological maps and, of course, existing 3D models.

To do that we need to build an integrated system for data digitization, verification and access – in other words to rethink and reorganize our Central Geological Database. This is already starting to happen, but will necessarily be executed in stages over the next several years. One near-future stage of this process is the establishment of a spatial relational geological database for mining data from Upper Silesia that will be a pilot for testing a full-scale extension of the CGD that could accommodate modelling data and results.

Selected modelling projects that are planned in the near future and that respond to different needs, taking into account differing levels of detail are the following:

- Framework Geological Model of Poland – for overarching geological context and data integration.
- Sedimentary cover of Szczecin Syncline (the northernmost part of the Polish–German border region) – the next sedimentary basin model and the continuation of cross-border harmonization.
- Several shallow geothermal potential models in different geological settings – for providing a pilot to satisfy societal demand for ready-

to-use tools that make a difference to real life problems.

In the longer term, we plan to model all sedimentary basins of Poland in 3D, and start realizing the strategy of systematic high-resolution modelling of the most vulnerable parts of the country – such as metropolitan areas and highly industrialized regions – in order to aid efficient spatial planning, allow better-informed risk mitigation, and avoid conflicts of use. We hope that our next steps in 3D modelling will be closer to standardized methods developed internationally, and will be visible to the public at home and to the modelling community abroad.

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