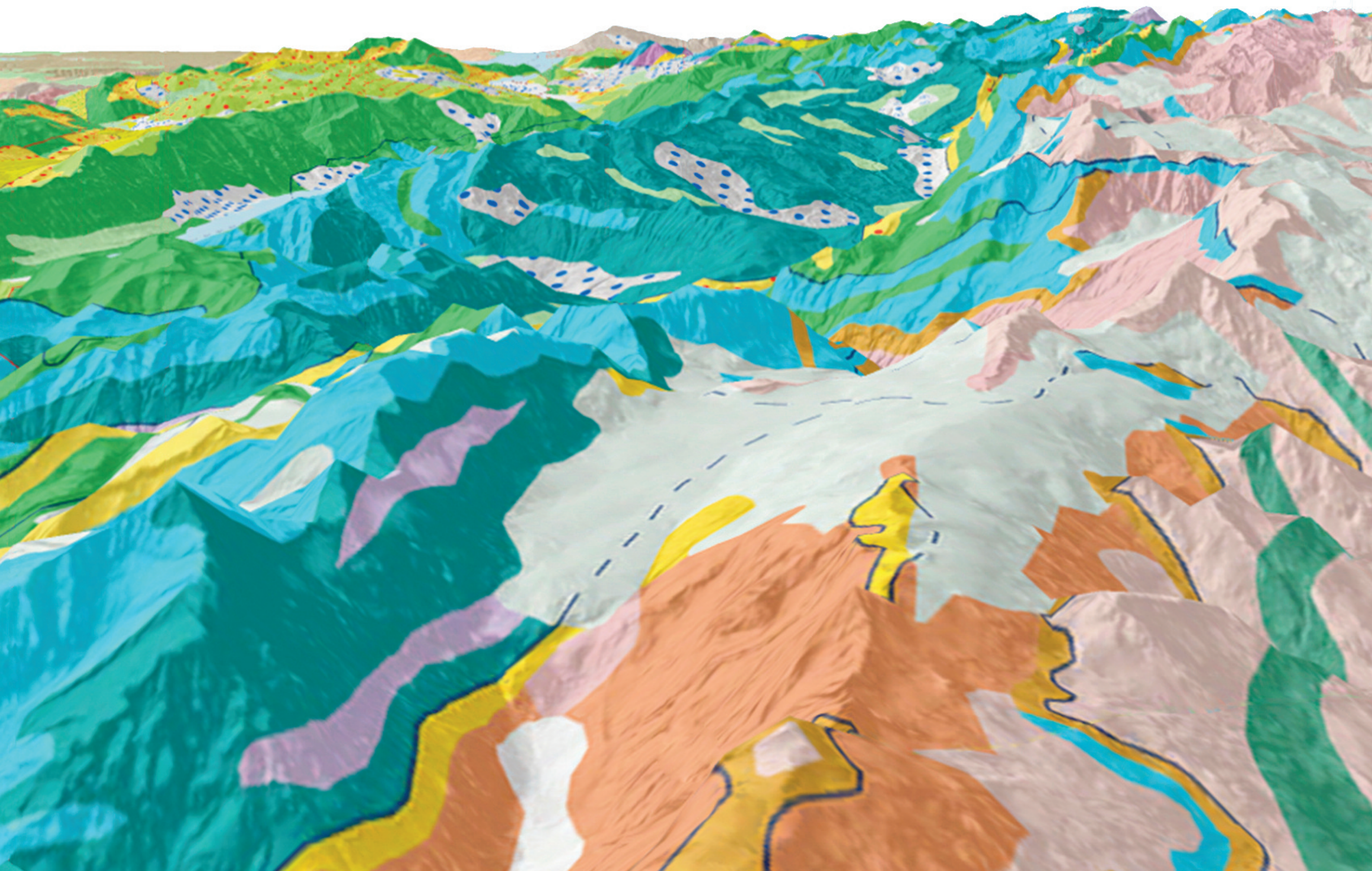
XYZ

Additional benefit from 3D geological data



XYZ – Additional benefit from 3D geological data

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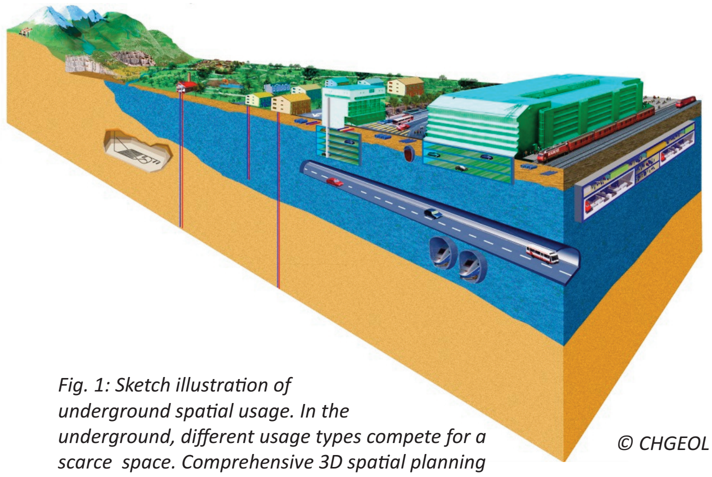

Fig. 1: Sketch illustration of underground spatial usage. In the underground, different usage types compete for a scarce space. Comprehensive 3D spatial planning is preferable, while accounting for geology

Eighty percent of political decisions are related to spatial data, which is information of any kind related to geographical coordinates. In most cases, spatial data is understood as 2D data describing the surface. Until recently, little attention had been paid to the subsurface, where three dimensional representations of the underground denote the main means of visualisation.

Many of Europe's economic hotspots are places of residence as well as workspaces with a high population density. Usually, these areas are characterised by an intensive usage of the underground resources (e.g. groundwater, ground heat) and infrastructure (e.g. public transport, roads, energy transport). Some of these hotspots are also located in hydrocarbon extracting areas and also mining activities (mineral resources). It is evident that upcoming challenges and developments will increase the pressure on the usage of the subsurface. Advances in technology (e.g. unmanned goods traffic) and growth of population will rely more on the integration of the subsurface as a planning area. Additionally, in line with most unsolved contemporary energy supply problems (e.g. radioactive waste disposal), the challenges of the energy transition (e.g. geothermal energy production), and climate change (e.g. CO_2 production and its underground storage), public interest is going to focus on these subsurface potentials. As a consequence, using the subsurface will not only be key for facing these future challenges but will also generate usage conflicts. **(Fig. 1)** Interfering utilisation (e.g. heat wells against groundwater) must be addressed laterally and vertically and additionally will also be an interface between surface and subsurface interests (e.g. natural conservation area against exploitation of mineral resources). Thus, the sustainable management of the subsurface, which is a finite resource, is relevant not only for the society and economy, but also for earth sciences. In line with the increasing importance of the subsurface as sketched above, geological data itself have become increasingly important to decision makers, planning authorities and even the broad public. To summarise, politics must provide the framework conditions for the regulation of the subsurface and the handling of usage conflicts. However, the tools needed (reliable, accessible and harmonised three dimensional data sets of the underground) are not present in most of the cases, at least not on national levels.

Why 3D geological models?

Geology is a three dimensional science and geologists always wanted to visualise the earth's structure in three dimensions. In old times, this was done using wooden block models, hand drawings or panoramic visualisations **(FIG.2)**. During the past 10 to 15 years, powerful computing systems and elaborated software packages became available and affordable, boosting computer aided 3D modelling to new levels. Relying on these prerequisites, the visualisation of the subsurface using 3D geological models has been pushed all over the world, also affecting many of the Geological Surveys. Today, it is common understanding that 3D geological

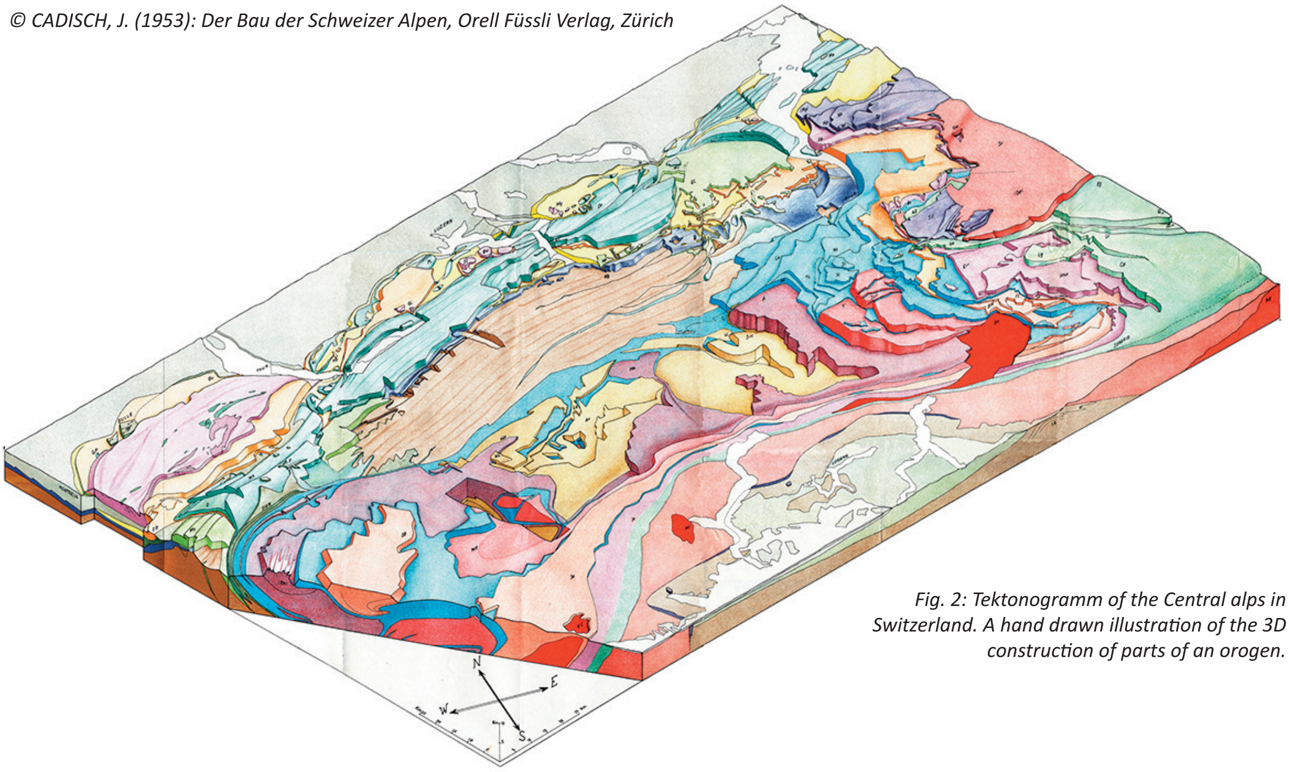

Fig. 2: Tektonogramm of the Central alps in Switzerland. A hand drawn illustration of the 3D construction of parts of an orogen.

models provide an interpretation of the subsurface. It became possible to introduce a wide range of input data into models, which increased their quality. As it is a model, the interpretation remains still wrong to some extent. However, despite being afflicted with a certain uncertainty, such 3D representations of the underground evolved from being relatively simple displays to high quality visualisations, which allows them to provide reliable information influencing decision making processes.

Strengths and dependencies of 3D geological modeling

3D representations of the subsurface have several strengths: (1) Visualisation of geological facts, (2) service as data hub and (3) service as instrument for quality assurance (also for 2D data).

The integration of other IT developments puts the representation and analysis of subsurface data in a nutshell. Professionals as well as non-geologists can easily access 3D geological models using a web browser and are able to drill artificial drill holes or slice through the model in many ways. Using such tools, geology becomes visible and more approachable for the masses and does not remain an expert's topic **(FIG.3)**.

In order to develop 3D geological models, modellers are forced to integrate, process and interpret many different input data-sets in new contexts. A borehole would then not only be a borehole with a very limited local influence, but is contributing to the interpretation of a lithological horizon of regional extent.

By bringing different sets of input data together in one model, they can be cross-checked against each other to estimate their quality (e.g. geometrical consistency, accuracy etc.). By integrating additional, previously unused subsets of input data, it can seem to falsify the model, which denotes the negative approach of model verification.

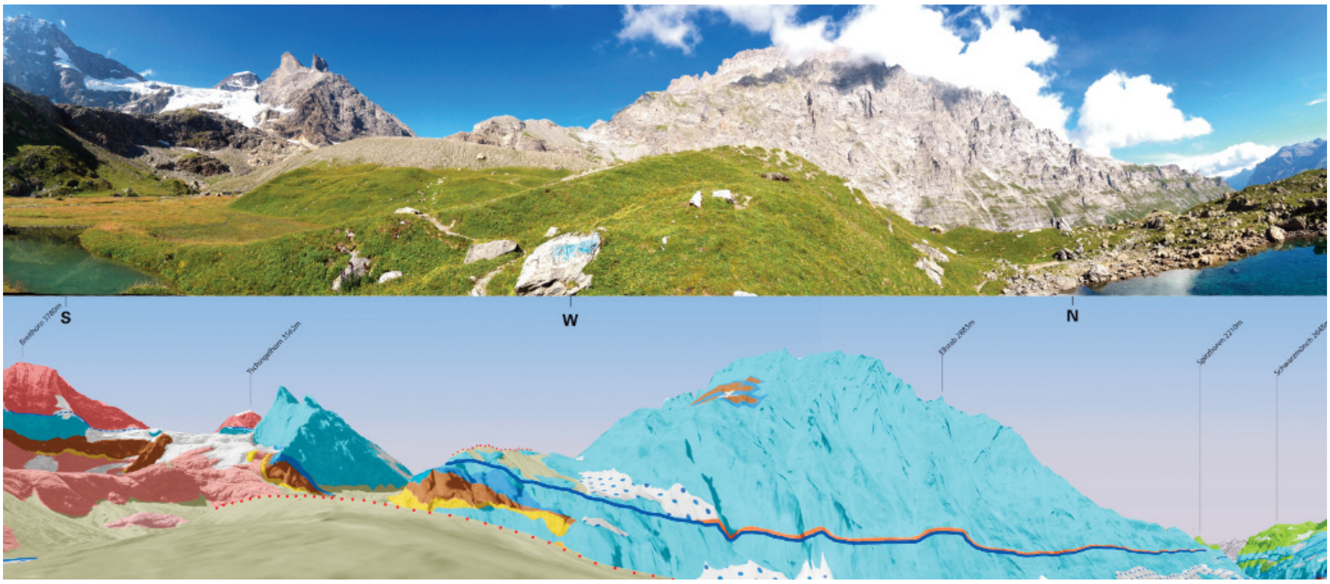

Fig. 3: Photo and projected geology onto it, providing distinct geological information to the user. *© swisstopo*

The development of 3D geological representations heavily depends on the availability of input data, for example boreholes, wells or seismic data. Therefore, the general availability of subsurface data of either type, source and age is one the key factors to develop meaningful, accurate and reproducible 3D representations of the surface. Unfortunately, regulations about the access, usage, processing, supply and distribution of input data are not uniform, neither within, or between countries within Europe for example.

Data availability

The above-mentioned dependency on spatial data for political decision making and facing future challenges sets a spotlight on the broad, easy, fast and cost-efficient or even free availability of such data for the benefit of the society. Though the availability of data is one of the major prerequisites for an efficient, comprehensive and most accurate development of geological data in general, its importance and its consequences to the society is widely neglected. Free data flow from acquisition to dissemination saves money and has a major impact on the economic benefit for the society. Data will be available easier and to less costs, therefore more applications can be developed, which has itself an impact on the positive stimulation of competition amongst data users. Additionally, free and public access to a comprehensive data basis would increase the quality of data sets as well as widen the point of view on data production. New ideas and approaches would be developed and tested against existing ideas. Therefore, from a legal point of view, governmental authorities must ensure that access to raw data and interpreted input data – for model construction – is as public as possible and – for model dissemination – is as cost-efficient as possible. Thus, it is in the peculiar responsibility of governmental bodies to set up and enable general framework conditions that allow an easy, fast and cost-efficient access to spatial data in general. The role of politics is two-fold: First, politics is hooked in some ways to the availability of spatial data as a client. Second, as a legislator, it must guarantee the framework for a beneficial development of 3D geological models.

Scope of 3D geological models

3D geological models denote the starting point for further developments only. While providing insight into the earth's structure, they give way for many new products, practical applications and services, which depend on the availability of such a basic data set.

Products: As outlined above, the subsurface will be of key interest for facing future challenges. Geothermal energy production, underground storage of waste, as well as infrastructure planning will not be possible without involving 3D geological information and data. 3D visualisations of temperature distribution, permeability and porosity, isothermal surfaces, geometries and thicknesses of deep aquifers will be key data for the planning of future geothermal projects. Stress field analysis, 3D geometries of fractures, 3D distribution of density and other rock parameters will be most important for the planning of underground waste deposits. Such products must rely on strong, reliable and comprehensive 3D geological data sets.

Applications: Combinations of all possible 3D data sets are needed for developing new applications. The assessment of subsurface potentials (e.g. geothermal energy, gas storage, conventional and unconventional hydrocarbons, mineral waters etc.) as well as information systems for such Geopotentials, which serve as instruments for visualisation, information and analysis to the target audience, will rely on such products and data incorporating the third dimension.

Services: One of the strengths of 3D geological modelling is their ability of constantly being updated in short cycles and to relatively low costs. New data, new interpretations and scenarios can easily be integrated,

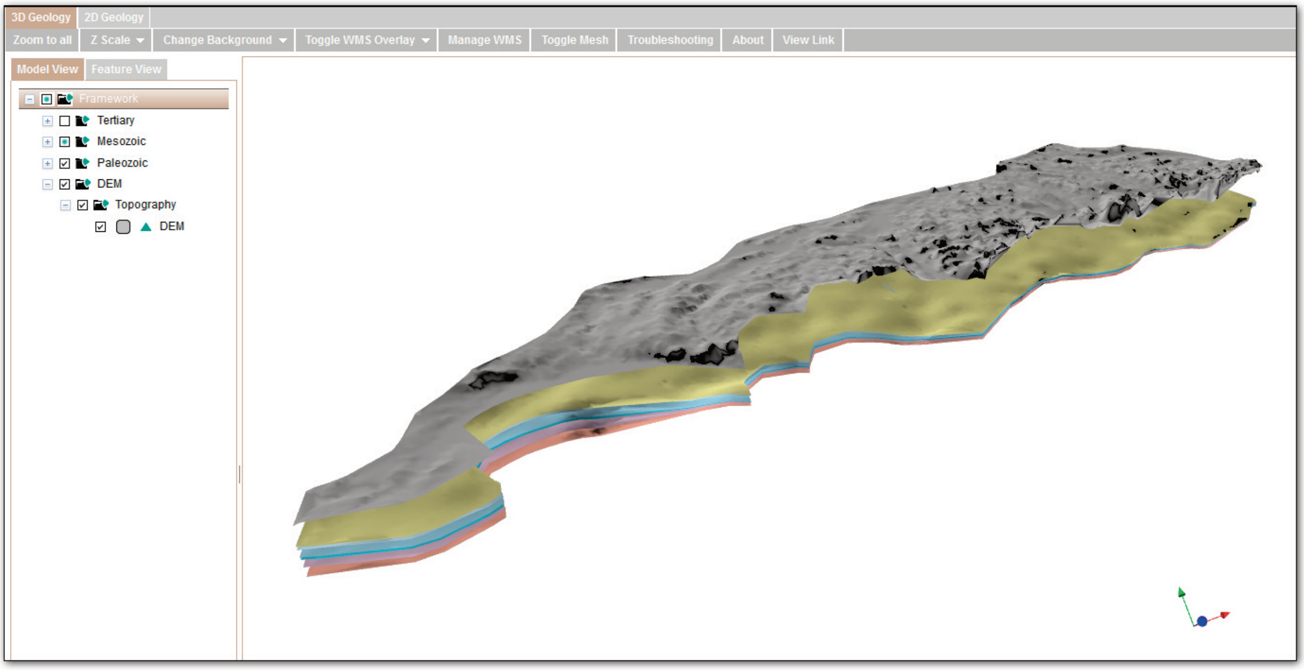

Fig. 4: 3D web viewer. 3d geological information must be accessible easy and fast. State-of-the art presentation via the web represents one approach.

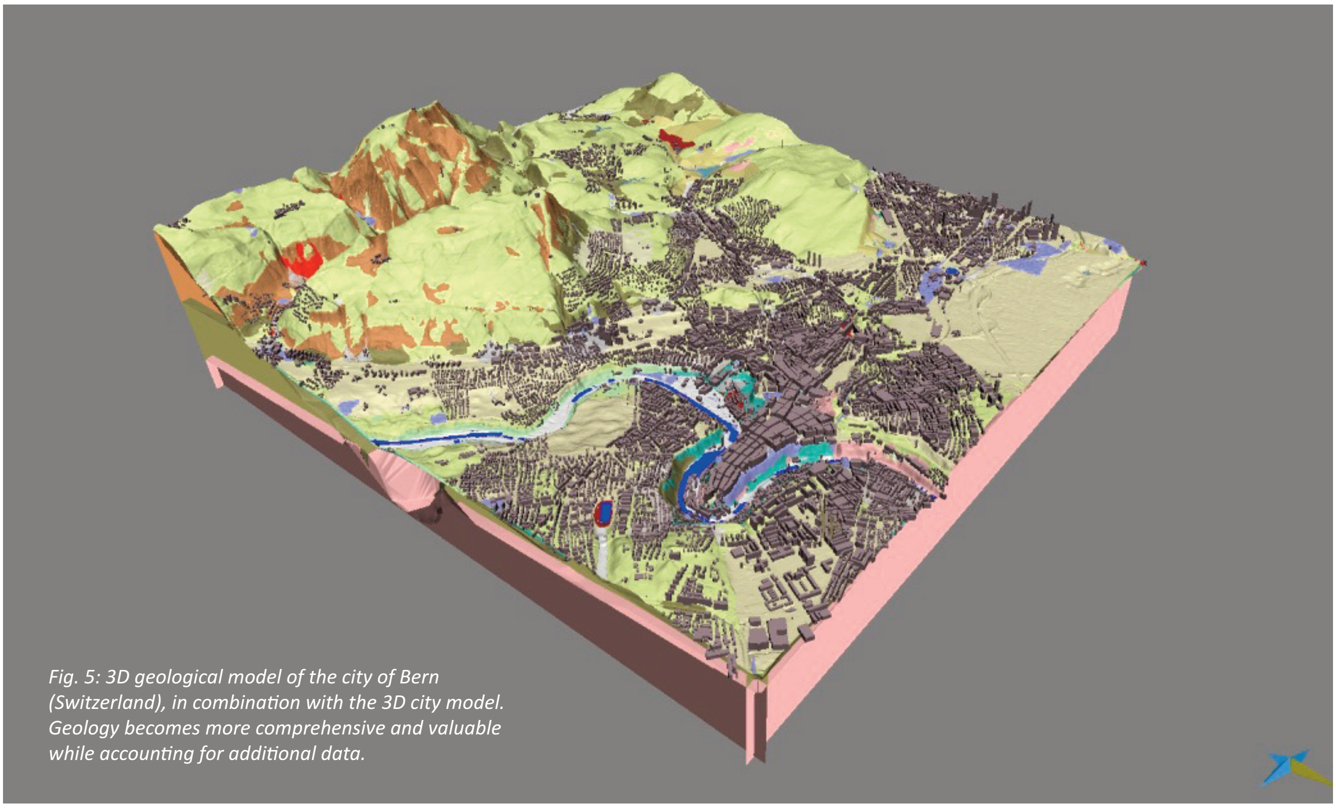

Fig. 5: 3D geological model of the city of Bern (Switzerland), in combination with the 3D city model. Geology becomes more comprehensive and valuable while accounting for additional data.

which is crucial for the acceptance of 3D geological models. Based on such up-to-date and state-of-the-art basic data on different scales and resolutions means beneficial services can be offered to the target audiences **(FIG. 4)**. Users may display the models in their web browser, slice through the data using their fingertip, cut out cross-sections and even drill virtual boreholes on the fly in any direction. Such user-specific data will ease and support planning as well as approval processes in many fields of application.

Besides the simplest form of 3D geological models, the horizon models also known as “flying carpets”, demand focus increasingly on the production of volumetric models. The former model type is predestined to allow easy and quick insights in the subsurface, while representing only the top or bottom side of each geological formation as discrete horizons. The latter type, built out of regular XYZ grids (volumetric pixels = voxels) or stacked or nested tetrahedrons, can be parameterised with rock properties, be it in the centre of the voxel or tetrahedron or on the edges. This arrangement allows you to three-dimensionally visualise and calculate rock properties as well as join the results with other spatial parameters (e.g. depth, distances, etc.)

The limits of 3D geological models

First, such models always represent an interpretation of the real settings. Therefore, the model is usually wrong to some extent. This is one of the most important topics in the communication of geomodels. However, since there are no striking alternatives, 3D models nevertheless represent a very good approach to the visualisation of the unknown subsurface. Additionally, it becomes clear that such models are not the salutary solution to all problems related to the subsurface. However, they may serve as an instrument to point out and visualise problems related to spatial interferences. Some examples: 3D geological models can’t solve the spatial interference between a heat well and critical geological formation or a deep well with groundwater reservoirs for example. Such models only help to visualise the interference in the case of usage conflicts. It is their intrinsic aim to increase the understanding of geological facts.

Benefits of 3D geological modelling

Most Geological Surveys started data acquisition parallel to their mapping campaigns. Over decades, a huge amount of analogue and digital data was acquired and is typically stored in isolated analogue archives or digital databases. They are usually not stored in a context sensitive manner, which means that data dealing with the same geological aspects are not connected, but remain separated. For the construction of geological 3D models, the data needs to be found, extracted, checked (relevance, quality), interpreted and processed. After a long and multi-step workflow, the data is ready for use in a geological 3D modelling process. Studies say the economic benefit of one published analog map sheet is six to eight times higher than the value of the input data processed. In the case of a geological map, data from the deep subsurface is usually not taken into account. In the case of a 3D geological model, this additional and usually expensive input data is integrated **(Fig. 5)**. Accounting for the value of these additional data-sets augments the economic benefit.

It must therefore be one of the main tasks of a geological survey to compile the data available in its archives and databases. When this data becomes available in a structured and context-sensitive way, and is integrated in a comprehensive and detailed manner, the benefit of 3D geological modelling can prove its strengths.

Model dissemination

Technology has arrived at a stage where (simplified) model analysis and interrogation is not the task of an expert any more. Simple web-based tools allow a user-friendly interaction with this type of geological data. In combination with common technical achievements, users may not only visualise, turn, pan, zoom and slice the models, they should also be allowed to directly download and integrate the data into their typical workday. Such an approach can only be true for the newly generated 3D models. Regarding the input data, which may be covered by copyrights or full owner property rights (unless legal regulations release them to the public domain), special emphasis must be paid to not harm any legal obligations. Again, as pointed out before, the legislator is in charge to provide general conditions for reasonable treatment of spatial data.

The future

Today, 3D geological models fulfill all prerequisites to serve as a hub for geological data, although not all input data is stored in three dimensions. However, with some effort, this data can be transformed into the third dimension. Since geological data is 3D data, it should be the aim to keep all input data as generic data sets, while not accounting for special applications or dimensions. Therefore, the inter-dimensional limitations between 2D and 3D data will disappear in the future. Acquisition, processing, production, supply and distribution of geological data is going to be radically transformed. Already, geological mapping can be performed with underlying data models and Digital Elevation Models, resulting in fully attributed 3D data sets. Traditional processing and production workflows will also change, with 3D models being created first with a subsequent derivation of 2D vector data and maps. Data will be stored in a generic data store, which will allow an unlimited range of applications and usages. Finally, distribution and visualisation of geological data will not be bound to specific portals (map viewer, 3D viewer etc.) anymore. With ongoing improvement of the models, advancements of the underlying technology as well as further developments of the geological 3D modelling software packages, the quality and comprehensiveness of three-dimensional geological models will further improve. Thus, the vision of a virtual earth could come true, where seamless geological data can be shown in its real surroundings. A vision that is in line with the idea of EuroGeoSurveys towards a Geological Service for Europe.

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