Three-Dimensional Geological Mapping, Workshop Extended Abstracts, October 26, 2013, Annual Meeting, American Geological Society, Denver Colorado, 29-33
http://isgs.illinois.edu/?q=2013-denver-colorado

THE PROJECT GEOMOL: TRANSNATIONAL 3D MODELLING AND 3D GEOPOTENTIAL ASSESSMENT IN THE ALPINE FORELAND BASINS

Gerold W. Diepolder[1] and the GeoMol Team[2]
[1] Bavarian Environment Agency – Geological Survey, 86179 Augsburg, Germany, gerold.diepolder@lfu.bayern.de
[2] www.geomol.eu

1. INTRODUCTION

Alpine Foreland Basins, due to their geological evolution, feature a unique geological inventory which can contribute substantially to meet Europe's ambitious targets for carbon emission reduction. The more than 5000 m deep sedimentary 'Molasse' basins along the northern and southern fringes of the Alpine mountain range (Fig. 1) offer abundant deep geothermal potential, storage capacity to attenuate intermittency of weather dependent wind and solar energy, and space for underground storage of gas or CO_2.

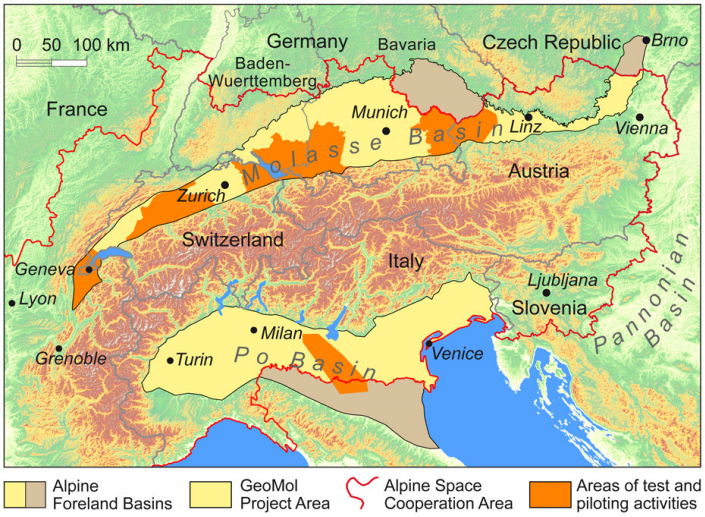

Figure 1: Map of the Alpine Foreland Basins, the GeoMol project area covering overall 89,000 km^2, and the GeoMol pilot areas for a more detailed assessment of specific geopotentials and the geological risks restricting their utilization.

Exploiting these subsurface potentials requires considering existing oil and gas claims as well as groundwater rights and, thus, must be based on a sound and holistic 3-dimensional assessment of the fundamentals: An adequate comprehensive understanding of the deep subsurface is a pre-requisite for the sustainable management and efficient use of geopotentials and reduces the financial risks. Avoiding usage conflicts and areas at risk demand cross-border coherent information on the structures and features of the subsurface based on 3D geological models.

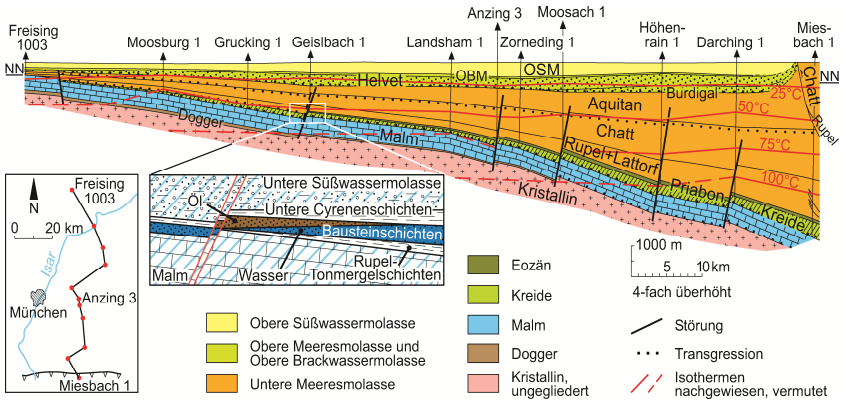

Figure 2: N–S cross-section of the North Alpine Molasse Basin east of Munich (after Lemcke 1988, from Diepolder and Schulz 2011) exemplifying two geopotentials: Temperatures up to more than 150°C in the Upper Jurassic (Malm) aquifer, giving rise to the most intensely used hydrothermal reservoir in Central Europe, and the typical setting of hydrocarbon structural traps.

The increasing relevance of geological information for policy and economy at transnational level has recently been recognized by the European Commission, who demanded a common European geological knowledge base. GeoMol's transnational approach responds to that, providing consistent information via an infrastructure for multi-dimensional subsurface data ensuring full interoperability among the involved GSOs "as the natural custodians of the subsurface (…) assisting governments, industry, and the general public to manage the subsurface in an integrated, holistic, and sustainable manner" (Kessler et al. 2009).

2. PUTTING UP THE SCAFFOLDING: DATA PREPARATION AND HARMONIZATION

An ongoing challenge in 3D modeling down to great depths is the availability of data with an adequate distribution and resolution to address issues trustworthy. GeoMol's 3D geological models are based on seismic data, scattered and clustered borehole evidence and the conceptual models of the basin evolution.
By far the largest data pool are seismic sections and, lately, 3D seismic surveys. More than 28,000 km seismic lines have been selected as the basis for structural 3D modeling and to interconnect existing 3D models in their true spatial relation. Originating from multiple sources and various dates of origin these data are subject to heterogeneous interpretations which have gone through several paradigm shifts over the last decades. Thus, it is imperative to standardize the data with regards to technical parameters and content prior to further analysis, exploiting the technical advances in seismic processing: An effort has been made to adjust all lines to the same reference level, amplitude and step of signal processing to avoid mismatching at intersections and at the country borders (cf. Capar et al. 2013). After applying the whole sequence of processing steps from scanned paper plots to filtered post-stack migrated SEG-Y files structural features can be identified more precisely and certain seismic pattern can be used in sedimentary facies interpretation. Both features are critical parameters for the existence of geopotentials: the fault network determines the rock mass permeability and the occurrence of structural traps, facies distribution controls the hydraulic conductivity of aquifers. To improve the accuracy and reach of correlating lithologies and their seismic signature, several synthetic seismograms based on drill hole measurements have been generated and parallelized with the bore logs.

The stratigraphic subdivision of the Alpine foreland basins has evolved from regional approaches and reflects the complex basin evolution featuring laterally varying sedimentary cycles. Grown historically different nomenclatures and subdivisions on the detailed scale are used. Thus, working cross-border requires also a semantic harmonization and the alignment of stratigraphic peculiarities to allow the correlation of a uniform litho-stratigraphic column with the prominent seismic reflectors traceable over the entire basins.

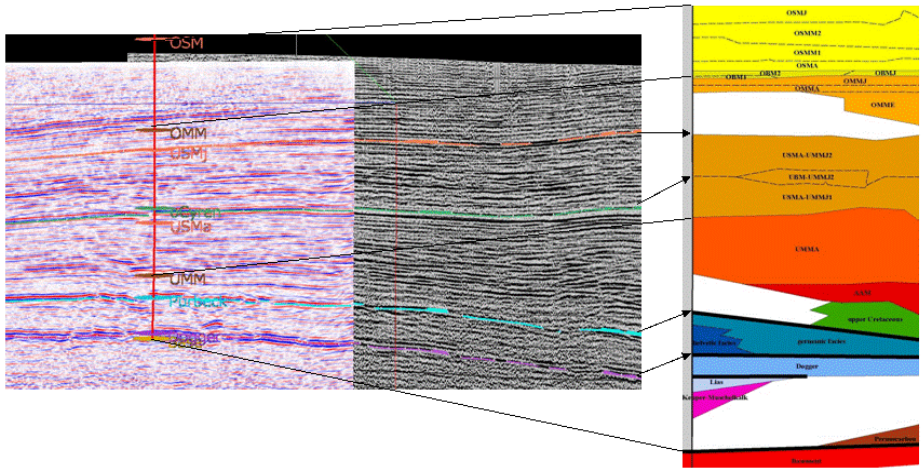

Figure 3: A pile of seimic reflectors, conspicuous after reprocessing, correlated with borehole evidence and the cross-border harmonized stratigraphic column of the Northern Molasse Basin.

As many data sets used in 3D modeling are classified data, access restrictions require that all model building may be implemented at the legally mandated regional or national GSO only. For a transnational project this means a maximum of coordination from the very beginning of the data preparation and the 3D modeling processes. GeoMol's 3D modeling procedure consists of several workflows customized to the specific needs of each partner, depending on the 3D modeling software used, and if modeled in time or depth domain (cf. Rupf et al. 2013). If modeling in time-domain, calibration of layer surfaces is done by borehole data re-converted into time-domain based on check shot data available for many hydrocarbon exploration drillings. Regionalized velocity models for time-depth conversion are applied at a late stage of modeling only, to facilitate later model refinement by additional seismic sections where needed. Trans-border accuracy of fit of the evolving 3D models and their intermediary products is verified by periodic check-up of all adjacent sub-territories during the whole modeling period. Since recently, with the deployment of the first modules of GST (cf. Chapter 4), the necessary transformation of country-specific coordinate systems for this cross-check runs real-time adapting the partners' reference system on the fly and does no longer require the cumbersome bilateral file exchange.

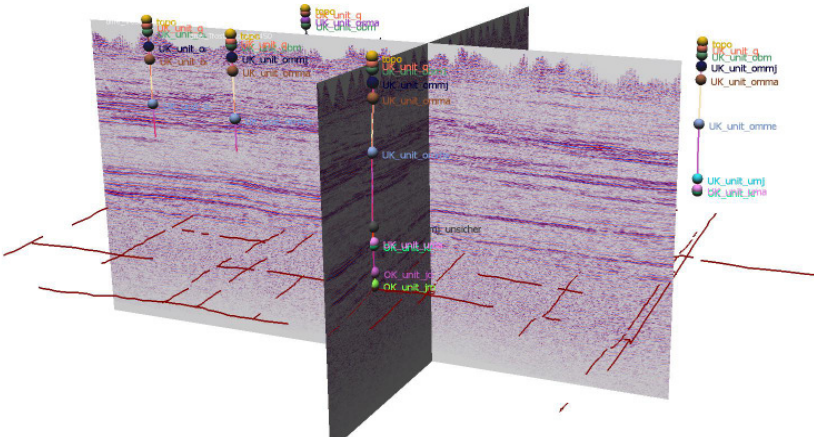

Figure 4: Calibration of interconnected seismic sections using borehole markers re-converted into time-domain. The red lines mark traces of the base of the Upper Jurassic (Malm) geothermal aquifer as picked from seismic sections.

3. 3D MODELLING AND GEOPOTENTIAL ASSESSMENT

Most of the geopotentials in the tilted sedimentary sequences of Alpine Foreland Basins are bound to structural features such as faults (fault traps, increased permeability) or anticlines (anticline traps). On the other hand, seismo-genetic structures like the buried Apenninic nappe fronts are the source of geo hazards – as the recently evidenced by the magnitude 5.8 May 2012 earthquake in the Po Basin – and thus a strong limiting factor for the utilization of geopotentials. A chief purpose of 3D modeling therefore is the three-dimensional visualization of the structural setup and characterization of the fault network.

Core of the project GeoMol (and additional model building beyond the project area) is a structural 3D subsurface model of the principal units for the entire Northern Molasse Basin covering almost 55,000 km^2, providing the framework to fit in all existing and emerging models in their true spatial setting. Five detailed models in pilot areas (Fig. 1) will be built to cover specific questions of subsurface use and/or seismic risk which might inhibit the utilization of geopotentials. These models will consist of up to 13 litho-stratigraphic units ranging from the Cenozoic basin fill down to Mesozoic and late Paleozoic sedimentary rocks and the crystalline basement.

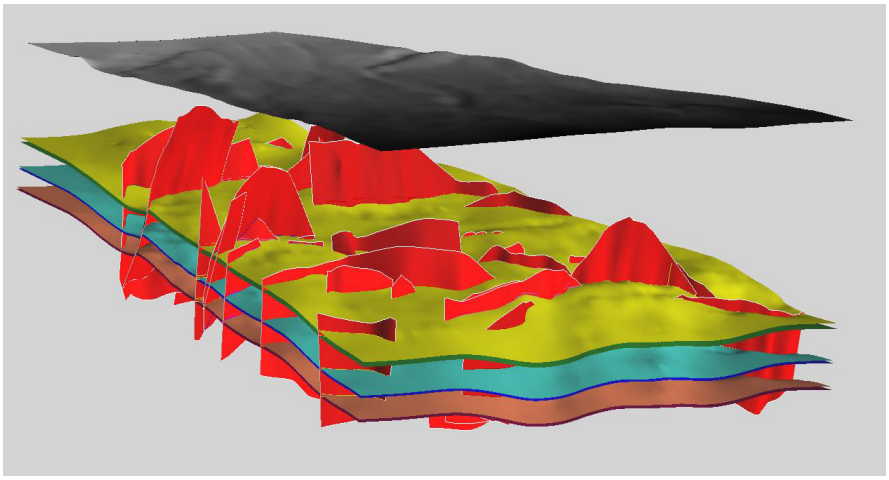

Figure 5: 2,000 km^2 clip of the preliminary framework model located in eastern Bavaria, showing six pre-Tertiary layer surfaces of the south dipping sedimentary sequence and a fault network reflecting the complex tectonic evolution of the basin.

A principal challenge in multi-claim wide geopotential assessment is the inadequate availability of datasets which allow the interpolation of rock properties at regional scales. Geologists commonly address these gaps between hard data through implicit knowledge, conclusion by analogy and process-based conceptual models, e.g. depositional models based on the facies distribution. Thus, the regionalized facies interpretation using seismic signatures will add further information on rock properties to the 3D structural models. Thanks to the numerous activities in the field of deep geothermal energy providing well-log temperature data, an improved geo-statistical temperature model taking into account bulk rock properties and indicating uncertainties will be integrated into the 3D geological models.

Porosity and permeability data, however, the key data for assessing subsurface storage capacities and for numeric modeling e.g. of groundwater flow, can be regionalized in certain areas only, such as the pilot areas. Equally, hydrochemical and hydraulic properties of the deep (geothermal) aquifers will be regionalized in exceptional cases only. Like all widely spaced evidence these parameters are subject matter of the metadata catalogue (Chapter 4).

4. GEO DATA INFRASTRUCTURE AND INFORMATION CHANNELS

The successful implementation of a transnational project facing diverse data policy, data base systems and software solutions requires a sophisticated tool for 3D data interoperability and web visualization. Even though many data exchange and information systems as well as web accessible tools have been developed the 3D geological community still lacks the ability to exchange 3D geo data efficiently across the diverse systems (Diepolder 2011). Thus, to set up and deliver truly seamless 3D geological information, a key issue of GeoMol is to provide a geo data infrastructure complying with both, the data policy of the project's member states (and beyond) and the European Commissions' request for harmonized geological information to support policy and economy at transnational level. This development in the making called GST, **G**eo Sciences in **S**pace and **T**ime (Gabriel et al. 2011), might be also an important contribution to the future pan-**E**uropean **G**eo **D**ata **I**nfrastructure as prepared and designed by the EGDI scoping study (http://www.egdi-scope.eu/).

Major technical characteristics and principal features of GST have been described previously (Diepolder 2011, Gabriel et al. 2011), the fundamental object-relational data model has been imparted in detail lately (Le et al. 2013).
In summary, GST's objective can be outlined as giving access to visualize and manipulate geoobjects using open standards, aimed at the generation of geomodels which will use thematic geo-information gathered at various scales to model and visualize the key spatial, geological, geophysical and geochemical parameters. A major concern is the management of large models, e.g. GeoMol's framework model(s), and the ability of 3D tiling into spatially restricted models with refined resolution, i.e. models of GeoMol's pilot areas.

GST will be the core of GeoMol's web-based data share and analysis system designed to serve the GSOs concerned and the scientific community. Recently common users spaces have been installed providing a central accessing point to manage locally stored data at each of the project partners IT site. This distributed-organized system allows to keep all data locally and to share just cleared portions of the data, thus adhering to national regulations on geo data access. As GST also allows for a dynamic generation of virtual drilling profiles (and thus enables to deduce classified borehole data) a role based log in is required giving full access only to the legally mandated or licensed bodies.

It is generally acknowledged that 3D models provide the best information to tackle geological and environmental issues. However, the stakeholder analysis implemented within GeoMol's work package 'Users' Needs' clearly revealed that only a miniscule minority of potential users have the facilities and capability required to directly exploit 3D models. The majority of stakeholders strongly prefer 3D derived 2D information, such as digital maps implement-able into GIS projects. To make sure that GeoMol's outputs are also a benefit beyond the geological community and academia they have to be converted into ready-to-use information customized to the needs of the users. Thus, two further channels for information distribution are provided, (1) to serve the administration and decision makers, and (2) to raise the awareness of the general public and to provide educational material.

GeoMol incorporates a variety of stakeholders and advisors from different areas of expertise to assist in the appropriate design of its products. To satisfy the users' demand for ready-to-use 2D products an interactive web mapping application will be implemented, where project results can be searched, spatially visualized and queried, also allowing for the dynamic generation of vertical and horizontal geological sections. In addition, web mapping services (WMS) will provide a metadata catalogue for information on the availability of spatial data, on the access to these services and their restrictions of use. This metadata database has to comply with both, the requirements of the EU directive INSPIRE and national spatial data infrastructures.

To meet the societal needs for information and the citizen's concerns about the impact of geopotential utilizations, GeoMol's website www.geomol.eu, now providing just static textual information, will be extended by a GST-based interactive visualization tool which enables the general public to slice through, explode and virtually pierce through the subsurface of the Alpine Foreland Basins – however, at a scaled down overview 3D framework model only.

5. REFERENCES

Capar, L. and the GeoMol Team 2013. Contribution of seismic processing to put up the scaffolding for the 3-dimensional study of deep sedimentary basins: the fundaments of trans-national 3D modelling in the project GeoMol: Geophysical Research Abstracts Vol. 15, EGU2013-5349-1.

Diepolder, G.W. 2011. 3D modelling at the Bavarian State Geological Survey – examples for cooperation towards 3D standards: Geological Survey of Canada, Open File 6998; Three-Dimensional Geological Mapping, Workshop Extended Abstracts, Minneapolis, Minnesota – October 8, 2011: 17-21, DOI:10.4095/289609, also available at: http://crystal.isgs.uiuc.edu/research/3DWorkshop/2011/pdf-files/diepolder.pdf

Diepolder, G.W. and Schulz, U. 2011. Tiefliegende Speicher- und Barrieregesteinskomplexe in Bayern – ein Überblick *[Deep reservoir and barrier rock units in Bavaria – an overview]*: Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften 74, 118-136. http://www.schweizerbart.de/papers/sdgg/list/74, DOI:10.1127/sdgg/74/2011/226

Gabriel, P., Gietzel, J., Le, H.H. and Schaeben, H. 2011. A network based datastore for geoscience data and its implementation: Proceedings of the 31st Gocad Meeting, Nancy; http://tu-freiberg.de/fakult3/IS4GEO/gOcad2011.pdf

Kessler, H., Campbell, C., Ford, J., Giles, J., Hughes, A., Jackson, I., Peach, D., Price, S., Sobisch, H.-G., Terrington, R. and Wood, B. 2009. Building on geological models – the vision of an environmental modelling platform: Three-Dimensional Geological Mapping, Workshop Extended Abstracts, Portland, Oregon, October 17, 2009: 24-30, http://nora.nerc.ac.uk/8423/1/BUILDING_ON_GEOLOGICAL_MODELS_final.pdf

Lemcke, K. 1988. Geologie von Bayern – I. Das bayerische Alpenvorland vor der Eiszeit: Stuttgart, Schweizerbart; 175 p.

Le, H.H., Gabriel, P., Gietzel, J. and Schaeben, H. 2013. An object-relational spatio-temporal geoscience data model: Computer & Geosciences Vol. 57: 104-117, DOI: 10.1016/j.cageo.2013.04.014

Rupf, I. and the GeoMol Team 2013. 3D-modelling workflows for trans-nationally shared geological models – first approaches from the project GeoMol: Geophysical Research Abstracts Vol. 15, EGU2013-8924-1.

6. ACKNOWLEDGEMENT

The project GeoMol integrates partners from Austria, France, Germany, Italy, Slovenia and Switzerland and runs from September 2012 to June 2015. The project is co-funded by the Alpine Space Programme www.alpine-space.eu as part of the European Territorial Cooperation 2007-2013. For further information please refer to www.geomol.eu.