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3D geological modelling at the Swiss Geological Survey: Development of national-scale models

Eva Kurmann[1], Philip Wehrens[1], Ferdinando Musso Piantelli[1], Salomè Signer[1], Anina Ursprung[1] and Lance Reynolds[1]

[1]*Swiss Geological Survey, Federal Office of Topography swisstopo, Bern, Switzerland*

EGU European Geosciences Union

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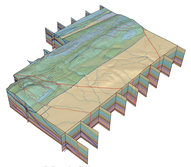
Jura3D

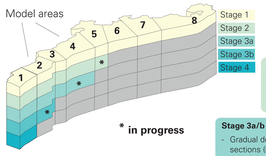
The 3D geological model Jura3D is a three dimensional representation of the subsurface of the Swiss Jura, from northwest of the Molasse Basin to the national border.

The Jura3D model output consists of three central components: a dense network of geological cross-sections (fence diagram), fault surfaces, and a lithostratigraphic reference horizon surface (Top Ifenthal Formation).

The primary data source is the geometrically harmonised surface mapping vector data from GeoCover. In the subsurface, the model is based on geological cross-sections, borehole and geophysical data with varying spatial density. A consistent kinematic interpretation is therefore essential to create a geometrically and conceptually coherent 3D geological model.



Model Area 1
St-Cergue – Le Sentier



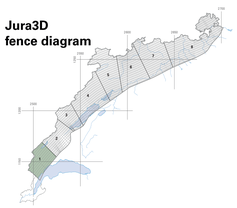
Stage 1 Overall geological concept
- Tectonic, stratigraphic, and methodological guidelines
- Tectonic overview map, including eight reference sections, reference horizon: Base Mesozoic.

Stage 2 Detailed tectonic concept
- Kinematically coherent, laterally consistent interpretation documented on control sections spaced at intervals of no more than 6km
- Adjustment to local geological conditions.

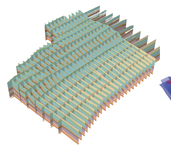
Stage 3a/b Densification / extended densification
- Gradual densification of the cross-sections between the control and reference sections (initially at greater intervals [3a], then up to 1km [3b])
- Continuous refinement and adaptation of the geological interpretation in GeoCover
- Creation of constructional fault surfaces that represent the relationship between the sections.

Stage 4: Finalisation of Jura3D
- Finalisation of Jura3D through consistent modelling of the fault surfaces and the reference horizon, as well as the creation of longitudinal sections.
- Attribution and integration of the model components into the final 3D model.

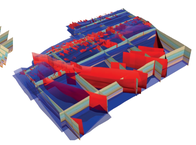
Jura3D fence diagram



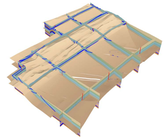
Model components



a) network of geological cross-section (fence diagram)



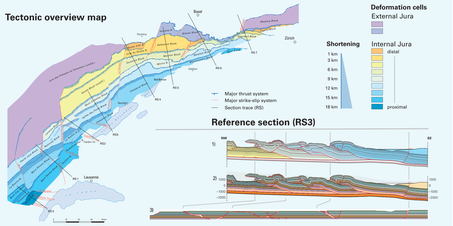
b) fault surfaces



c) Top Ifenthal Formation surface

A coherent tectonic interpretation and kinematic framework form the basis for a reliable 3D geological model of the Jura. The tectonic concept is continuously refined and aligned with surface mapping, while the geological fence diagram is progressively densified to support detailed modelling of fault surfaces and the Top Ifenthal Formation horizon.

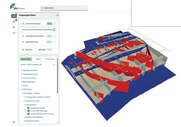
Tectonic overview map



Reference section (RS3)

Simplified tectonic map of the Swiss Jura with major structures and deformation cells, guiding regional interpretation (after JORDAN et al., 2023). Reference sections show subsurface deformation cells (1), tectonic architecture with lithostratigraphic units (2), and are balanced (3).

A harmonised, well-structured dataset from the first model area includes a fence diagram, fault surfaces, and the reference horizon. Organised by deformation cells and fault hierarchies, these geometrically consistent elements provide a robust basis for further development and enable implicit modelling in a complex geological setting.



View and download model & documentation
→ viewer.swissgeol.ch

Best viewed on tablet or PC

GeoMol

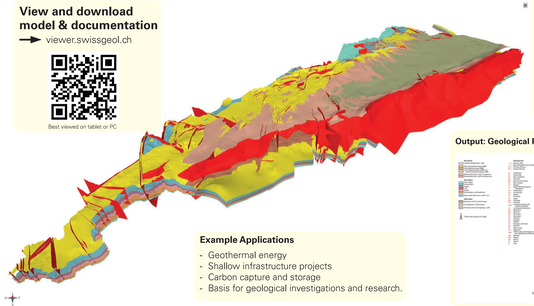
GeoMol is a 3D geological model of the Swiss Molasse Basin at a national scale, stretching from Lake Geneva in the southwest to Lake Constance in the northeast and bounded by the Jura in the northwest and the Alps in the southeast.

The model output consists of three main components: 14 lithostratigraphic horizons (Cenozoic, Mesozoic and Permocarboniferous) and around 520 fault surfaces; horizon structure maps; NW–SE geological profiles.

The model's primary data sources are deep boreholes, 2D and 3D reflection seismics as well as surface mapping data. First published in 2017, the result of a collaborative project between swisstopo and five partners, the model receives regular updates based on more recent data.

View and download model & documentation
→ viewer.swissgeol.ch

Best viewed on tablet or PC

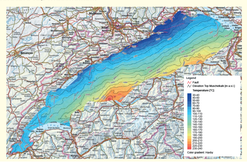


Example Applications
- Geothermal energy
- Shallow infrastructure projects
- Carbon capture and storage
- Basis for geological investigations and research.

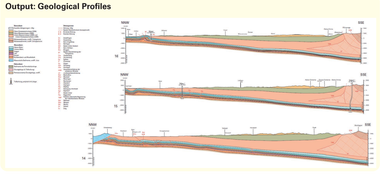
Derived Models

To date the GeoMol model has been used as a framework for creating a temperature model of the Swiss Molasse Basin down to a depth of 10km. Output includes 3D temperature surfaces and maps for selected horizon tops, depths below ground level and isotherms.

Temperature Top Muschelkalk

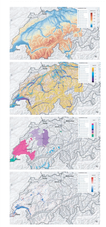


Output: Geological Profiles



swissBEDROCK

Raster band information



swissBEDROCK is a comprehensive model that provides detailed information on Switzerland's bedrock surface. In addition to the bedrock elevation model (BEM), it includes information on the thickness of unconsolidated deposits (TMUD), details on uncertainty, authors and changes compared to previous versions. The model is structured as a multi-band raster (10 x 10 meter cell size) with 11 information bands per cell.

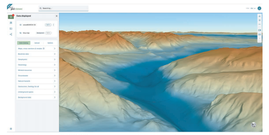


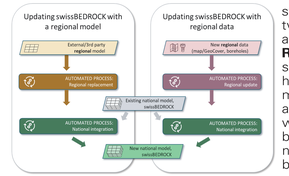
Image of swissBEDROCK in the swissgeol.ch viewer. As seen in the panel on the left, each individual information band can be displayed.

Band can be queried per cell (10x10m).

The system:

Modular – Components are independently replaceable
Automated – Minimise manual work, consistent processing
Reproducible – Regeneratable results
Quality Assurance – Traceability of input data
Easy to update – Designed for efficient integration of new data and models

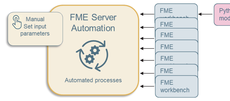
Automated Data Integration



Overview of the two approaches: Regional Replacement (left) and Regional Update (right). Indicated are the individual automations.

swissBEDROCK uses two different update approaches. **Regional Replacement**, which seamlessly blends high-quality 3rd party models into the dataset, and **Regional Update**, which recalculates the bedrock surface using new regional data e.g. boreholes.

This process is driven by a fully modular pipeline where efficiency is achieved through automation.



Schematic overview of the modular workflow within one automation.

At the technical core, FME automations orchestrate the workflow, connecting numerous FME workbenches to handle complex data transformations and Python scripts for modelling in a hands-off environment.

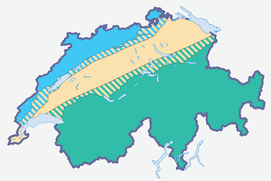
Download and documentation
→ www.swisstopo.admin.ch/en/swissbedrock-en

Visualisation and analysis

Best viewed on tablet or PC

Download

NGM 3D geological modelling projects



Within the **National Geological Model program** (NGM, 2022–2030), the Swiss Geological Survey (swisstopo) is developing nationwide 3D geological models. Switzerland comprises three major geological domains with distinct structures, lithologies, and data availability, requiring tailored modelling approaches. The 3D modelling workflow is structured according to the main geological domains of Switzerland. Each model integrates geological maps, borehole data, geophysical data, cross-sections, and conceptual constraints to build consistent structural and stratigraphic representations.

Objectives

Achieve full spatial coverage of Switzerland with harmonised geological models

Develop consistent representations of major geological units and fault zones.

Provide a coherent national framework for subsurface modelling and spatial planning

swissAlps 3D

The project

- **Eight modelling projects** to build a **3D Geological model** of the main lithostratigraphic units and fault systems of the Swiss Alps subsurface.
- The structural interpretation and subdivision of the modelling projects based on the new Tectonic Map of Switzerland.
- Scale of detail of the input data: 1:25 000.

Role of swisstopo

- **Planning** of the project in collaboration with modelling partners.
- **Management** of the project and **QA** over the delivered work.
- **Coordination** of the communication between the modelling partners and projects.
- **Publication** of model and results.

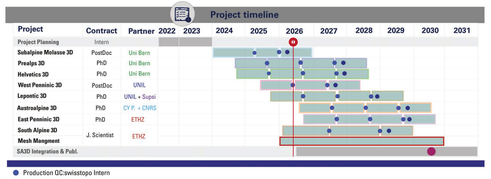
Key results

- A consistent large-scale **3D geological model** of the Swiss Alpine nappe stack.
- **Key knowledge and digital visualisation** of the main lithostratigraphic units and fault systems of the Alpine subsurface.
- A **3D modelling community** with Alpine region expertise.

Impact

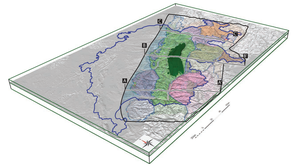
- Strategic **subsurface insights** for future **geo-resources and geo-energy** management and exploration.
- A **framework model** of the Swiss Alps as basis for high resolution 3D models for infrastructure planning, groundwater studies and natural hazard analysis.

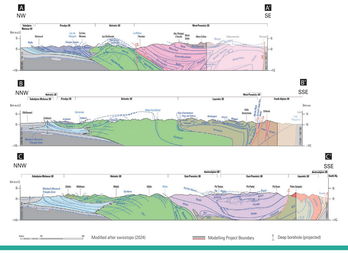
Project timeline



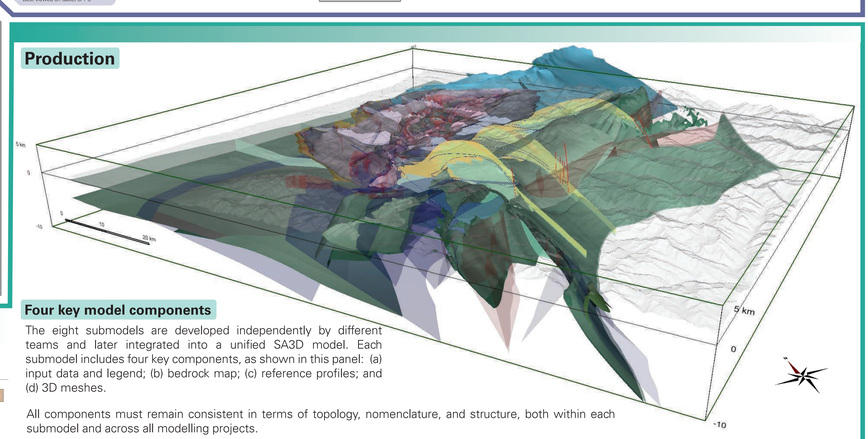
In collaboration with: UNIL, SUPSI, ETH zürich, CY UNIVERSITE, UNIVERSITÉ DE STRASBOURG

The eight submodelling projects





Production

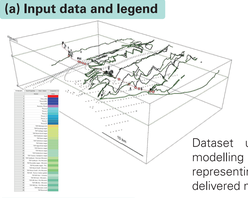


Four key model components

The eight submodels are developed independently by different teams and later integrated into a unified SA3D model. Each submodel includes four key components, as shown in this panel: (a) input data and legend; (b) bedrock map; (c) reference profiles; and (d) 3D meshes.

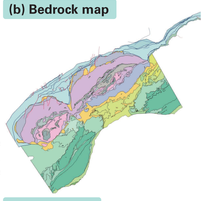
All components must remain consistent in terms of topology, nomenclature, and structure, both within each submodel and across all modelling projects.

(a) Input data and legend



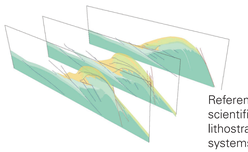
Dataset used as input for the modelling project and report, representing the contents of the delivered model.

(b) Bedrock map



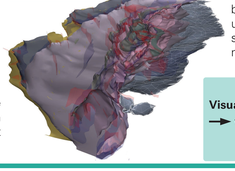
Bedrock map at a scale of 1:25 000 depicting the main modelling elements of SA3D (lithostratigraphic units and fault systems defined by TK500).

(c) Reference profiles



Reference profiles illustrating the scientific concepts of the main lithostratigraphic units and fault systems in the subsurface.

(d) 3D meshes



3D meshes representing the top or bottom of the main lithostratigraphic units and fault systems in both the subsurface and above the topography, modelled using additional profiles.

Visualisation of SA3D models
→ viewer.swissgeol.ch

Best viewed on tablet or PC