SEISMIC SYNTHESIS OF THE SWISS MOLASSE BASIN

REPORT FOR 2007

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ABSTRACT

The geologic interpretation of the seismic sections is now completed all the way from western Switzerland to canton Bern (central region). Data interpretation in central and eastern Switzerland is nearly finished and the digitization of the interpreted sections is in progress. Parameters allowing computing the grids of the nine interpreted horizons across the entire Swiss Molasse Basin were decided on. Maps in two-way travel time and in depth will thus be derived for each of the horizons as soon as the interpretation is finished. Final parameters to compute velocity maps at the basin scale were also set using available borehole information. Some examples of maps that will be included in the atlas, although still partial, are shown. An animation of a 3D geological model of the western part of the Swiss Molasse Basin is shown that allows visualisation of the basin from base Tertiary all the way down to base Permo-Carboniferous. Finally, the way the project results will be presented was established. Three contributions are planned with a paper version of an atlas, a publication in a scientific journal and a digital version of the atlas.

RÉSUMÉ

L'interprétation géologique des sections sismiques de Suisse occidentale jusqu'au canton de Berne (région centrale) est maintenant terminée. L'interprétation des données en Suisse centrale et orientale est presque finie et la numérisation des sections est en cours. Les paramètres permettant de calculer les grilles des neuf horizons interprétés à l'échelle du bassin molassique en Suisse ont été déterminées. Des cartes en temps double et en profondeur pour chacun des horizons ainsi que des cartes d'isopachs seront tracées dès que l'interprétation sera terminée. Les paramètres pour calculer les cartes de vitesse ont également été finalisés à l'échelle du bassin à partir des données de forage disponibles. Quelques exemples de cartes, bien qu'encore partielles et qui figureront dans l'atlas, sont présentés. Un modèle géologique en 3D de la partie occidentale du bassin a fait l'objet d'une animation qui permet de visualiser le bassin, de la base du Tertiaire à la base du Permo-Carbonifère, selon différents angles. Enfin, nous avons déterminé comment les résultats finaux du projet seront présentés. Il s'agira de trois contributions comprenant un atlas en version papier, une publication dans une revue scientifique et un atlas sous forme numérique.

1. INTRODUCTION

The objectives of the project were described in preceding annual reports (see Marillier et al., 2004, 2005, 2006). The project is now nearing completion in terms of data interpretation and the next and final phase is to prepare the final product. This required detailed planning throughout 2007 not only to decide on the content of the report and the way it will be made accessible, but also to take constraints into account imposed by the limited time and financial means.

It was decided in agreement with the Swiss Geophysical Commission that the final products of the project will include a paper report called “Seismic Atlas of the Swiss Molasse Basin” and a digital version that will include results presented in the paper version but also additional intermediate files and maps that could not be included in the Atlas. Finally, a paper will be prepared that will deal with scientific questions that the results of this project will enable us to address.

Here we also report on progresses made in the seismic data interpretation, on the further elaboration and display of maps (two-way travel time, velocity and depth or isopach maps), and finally we present a summary of the geological interpretation in the western Swiss Molasse Basin as geological model. It is shown in 3D from various angles with a short movie that provides new insights into the geometric configuration of the Mesozoic sequence and of the base of the Permo-Carboniferous layers.

2. DATA INTERPRETATION

We subdivided the seismic data set into three areas A, B and C (Fig. 1):

Area A: Data interpretation in cantons Geneva, Vaud and Canton Fribourg was finished in 2006. Interpreted seismic horizons as well as faults were digitized and later loaded into our ARCGIS data base. Two-way travel time (TWT), isopach and velocity maps were constructed as well as depth maps (see Figs 2, 3 and 4)

Area B: Data interpretation in the Bern and Lucerne areas was completed in 2007 and it is currently being digitized (early 2008).

Area C: In this area, interpretation needs is in progress. In the northern part of Switzerland, data interpretation will benefit from the already existing interpretation carried out by NAGRA and Interoil; in the most eastern part, data interpretation will be discussed with Dr. Naef.

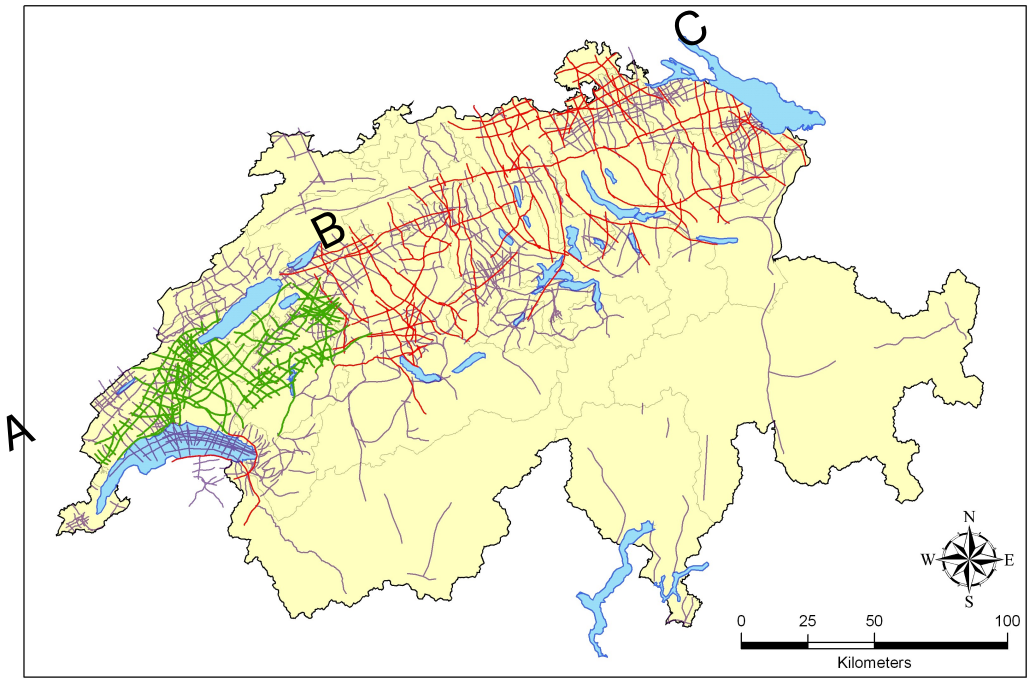


Figure 1: Location of seismic lines and their subdivisions in three areas A, B and C according to progresses of the geological interpretation with time (see text for explanation).

3. HORIZON MAPS

The eight seismic horizons were digitized from the interpreted seismic sections. The data were later corrected for two-way travel time miss-ties, gridded and finally contoured. Combination with velocity information enabled us to convert the data to depth.

Work techniques to interpret seismic lines were presented in the 2006 and 2007 reports. We remind that the following horizons were mapped: Near Base Tertiary (BTer), Near Top late Malm (TlMa), Near Top early Malm (TeMa), Near Top Dogger (TDo), Near Top Liassic (TLi), Near Top Triassic (TTr), Intra Triassic (TMuka), Near Base Mesozoic (BMes), Intra Permo-Carboniferous 1, 2 and 3 (PC1, PC2, PC3).

Two-way time maps

Two-way Time contour maps for the western Molasse Basin were constructed for each interpreted horizon (Fig. 2). Color scale ranges from +500 ms to -2500 ms with a different color for each horizon. Figure 2 is an example of a large plate to be printed in the Atlas (see Chapter 5 of this report, Final products of the Atlas).

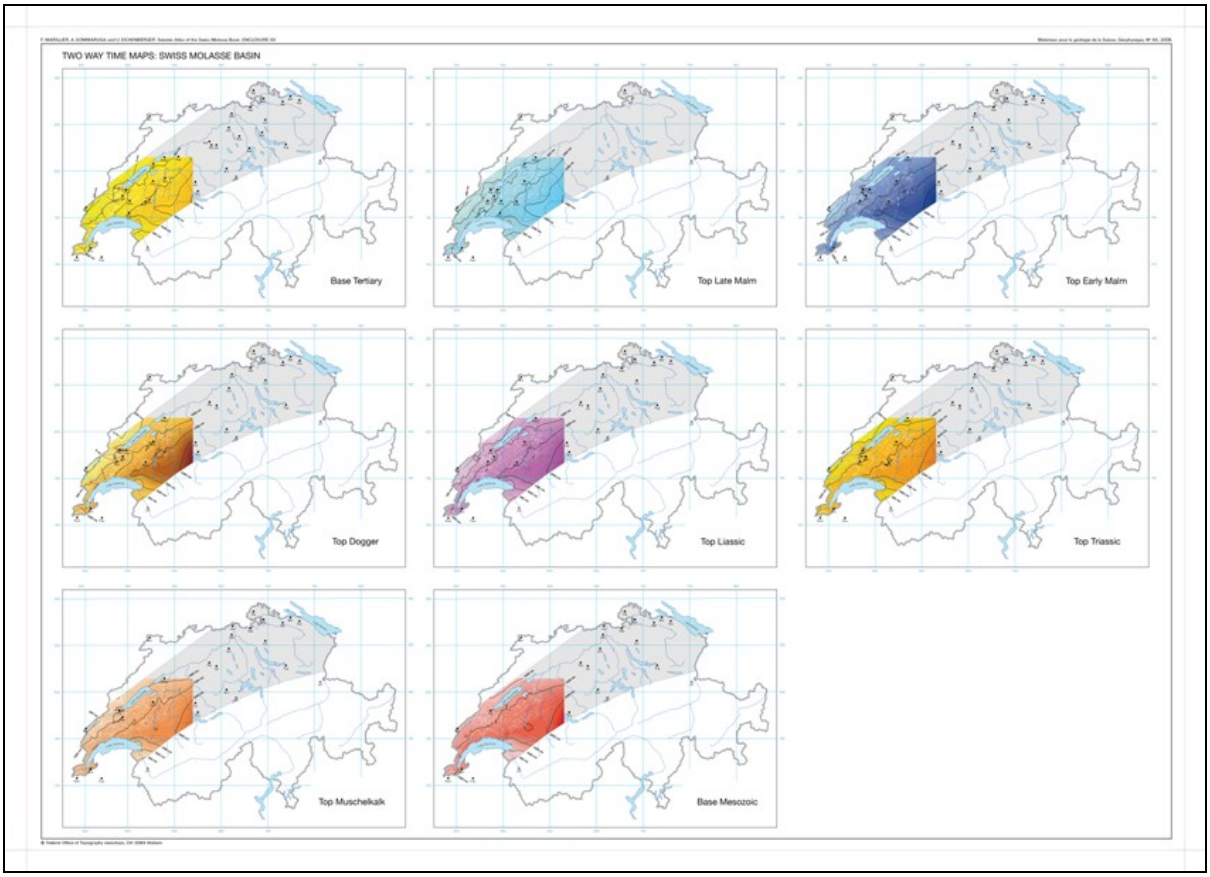


Figure 2: Plate assembling eight two-way time contour maps in the western Swiss Molasse Basin. Each single map represents an interpreted seismic horizon (see text for description of the horizons).

Velocity maps

To convert TWT maps (in seconds) into depth maps (in meters), it is necessary to have velocity information. Velocities were acquired from deep wells. Figure 3 shows velocity maps for each interval with a scale ranging from 2200 m/s to 6400 m/s (interval of 200 m/s). Details on the well used to derive velocities and on the elaboration of the maps were presented in the 2006 report. Figure 3 is an example of a large plate that will be presented in the printed version of the Atlas (see Chapter 5 of this report, Final products of the Atlas).

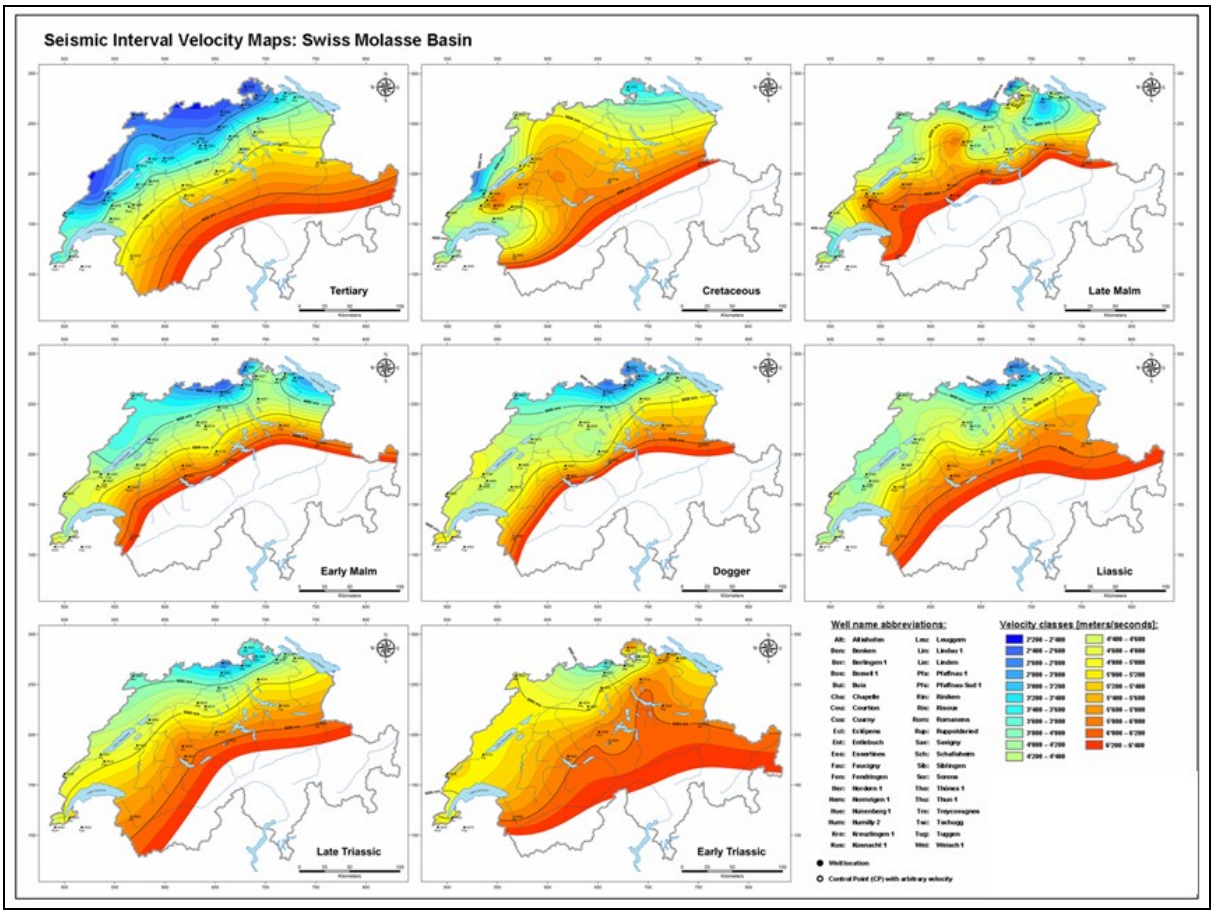


Figure 3: Plate assembling eight velocity contour maps in the western Swiss Molasse Basin. Each single map represents the velocity for an interval between two interpreted horizons.

Depth maps

Depth maps were calculated from the TWT maps using appropriate velocities. As example, figure 4 shows the Top Dogger depth map with contours from -100 m to -7000 m in the western Molasse Basin. Major faults affecting this horizon were included as barriers in the gridding and subsequent contouring.

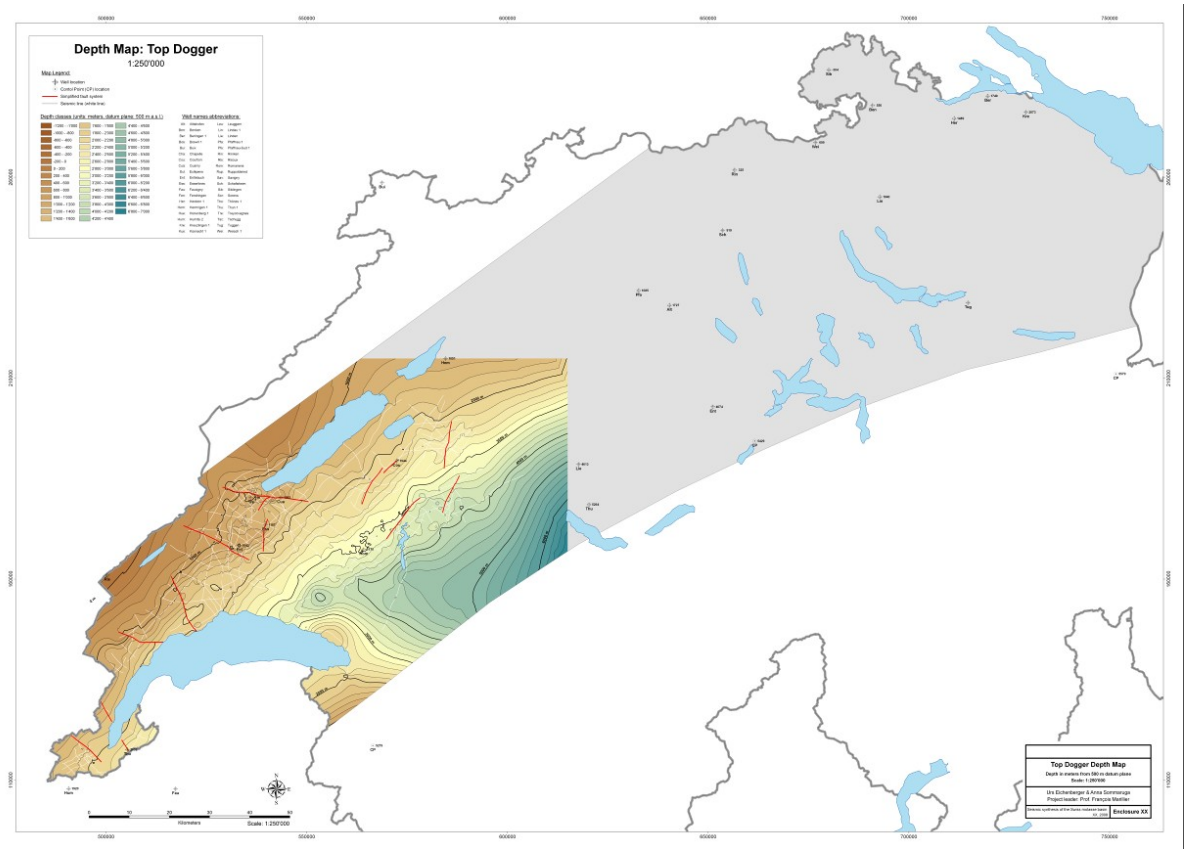


Figure 4: Depth map of Top Dogger in the Swiss western Molasse Basin. Major faults affecting this horizon are shown in red.

Isopach maps

Isopach maps display the thickness comprised between two horizons. They were calculated using the depth horizons. Figure 5 shows an example of an isopach map for the Early Triassic interval. The colour scale ranges from 0 m in the South to more than 1500 m in the Jura Mountains. In the Atlas, we will present a plate with an assemblage of isopach maps for all intervals between the interpreted horizons.

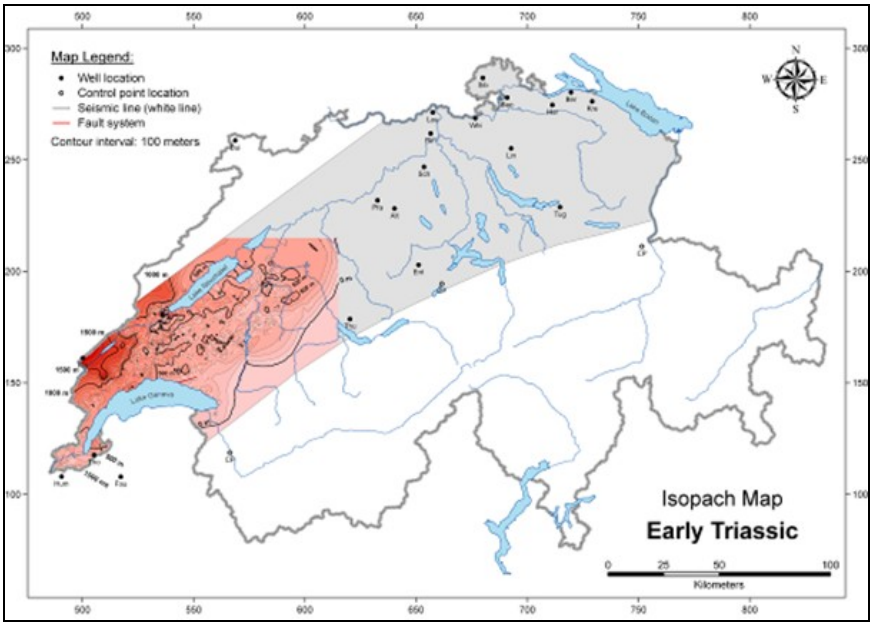


Figure 5: Isopach map of the Early Triassic interval in the western Swiss Molasse Basin.

Fault maps

Fault maps were constructed for four levels: surface, Base Tertiary, Top Dogger, and Base Mesozoic. The Permo-Carboniferous map includes also fault structures. An example is shown in figure 6 with the Base Tertiary fault map in the western Swiss Molasse Basin. The 2006 report describes how the fault maps were constructed and discusses the difficulties to correlate faults from a seismic line to another.

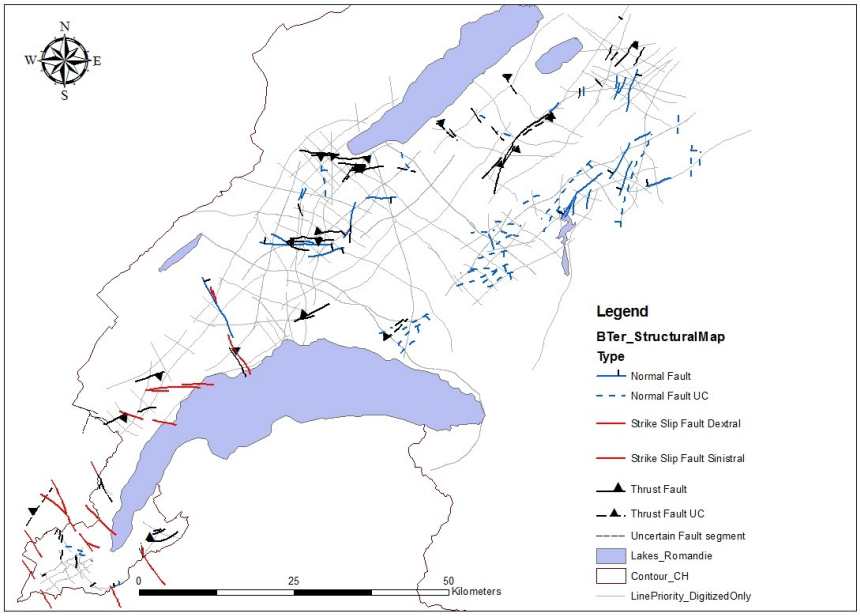
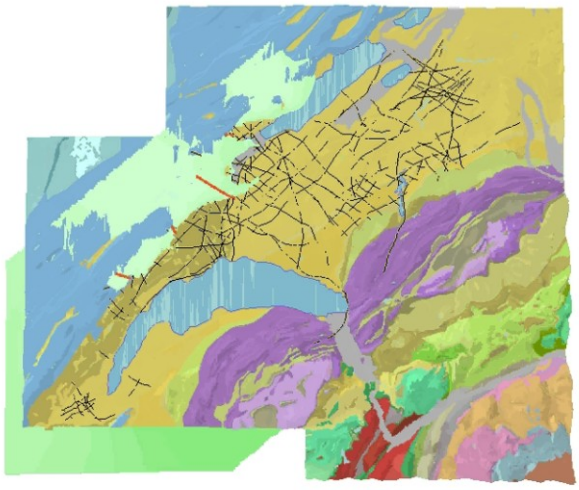


Figure 6: Base Tertiary fault map for the western Swiss Molasse Basin.

4. GEOLOGICAL MODEL

A 3D geological model of the western Swiss Molasse Basin is presented. A short movie can be viewed under «DepthGridsMovie.avi» (25 Mb). Here we describe a few snapshots extracted from the movie.

The depth grids of nine stratigraphic horizons (see chapter 3) were calculated in ArcGIS using a simple spline option.



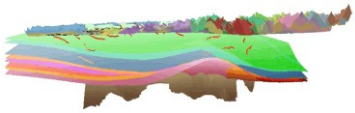
The topographic surface is taken from Swisstopo ATM 25 onto which some elements of a tectonic overview map (Swisstopo 1:500'000) were projected. The colours of this map represent the folded Jura mountains (blue), the Molasse (ochre), The Prealps (purple), the Flysch units (olive), the Helvetic nappes (green), the external massifs (red) and the Pennine units in colours ranging from light grey via light purple and brown to gray-blue. For better orientation, Lake Geneva and Lake Neuchatel are displayed. Black lines in the Molasse basin indicate the position of interpreted seismic lines (on the map view of the model only).

From base to top, we distinguish the following horizons:

Near top Cretaceous
equal "Base Tertiary" (green)
Near top Malm (turquoise)
Near top early Malm (blue)
Near top Dogger (light brown)
Near top Liassic (purple)
Near top Triassic (red)
Intra Triassic (yellow)
Base Mesozoic (dark red)
Near base Permo-Carboniferous (dark brown)

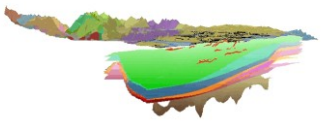
Note that in the above presentation, the Permo-Carboniferous interpretation is incomplete. Its definition is difficult and the degree of uncertainty may be very high locally. For better representation of the layer geometry, the depth model as shown in the short film is vertically exaggerated five times.

The movie starts with a map view of the surface and then the model is turned around a horizontal E-W oriented axis to show a side view from the South.



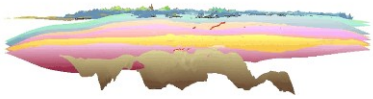
View from the South

The second scene turns the model around a nearly vertical axis in a clockwise direction. This provides an insight into the package of Mesozoic strata: the wide gap between the accentuated surface and the top of the Cretaceous (green) horizon is filled in reality by Cenozoic clastics. The red lines at the base of this volume indicate the position of the major fault systems that cut through the Mesozoic-Cenozoic boundary.



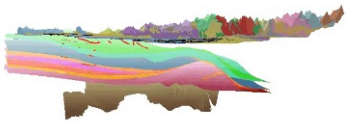
View from the East

The view from the East shows the little disturbed monocline of Mesozoic strata dipping southwards under the Alpine nappes. Under the eastern end of Lake Geneva, a saddle area stands out. There are only a few seismic lines in the area but they clearly indicate the presence of this structure.



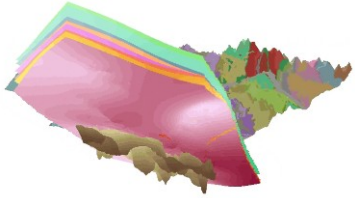
View from the North

Looking from the North there are no Cenozoic sediments left and the folded Jurassic horizons (blue) dominate the outcrop area. The Paleozoic basins show deep graben structures which seem to line up in two distinct directions.



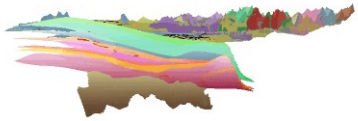
View from the South

The above mentioned saddle under Lake Geneva separates the Cenozoic basin into two parts with the Lake Geneva side showing half the thickness of the Vaud-Fribourg side. This becomes apparent when looking into the model from the South.



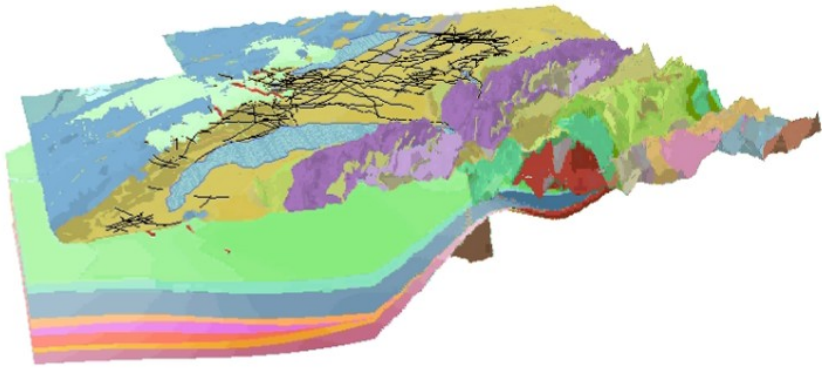
View from underneath, from South

After having completed a little more than a full circle's rotation, the model turns back in a slightly tilted position which provides insight into the Palaeozoic structures. It then comes back to a position near the starting position with an oblique northward viewing angle.



View from the South-West

Back to the view from above South



5. FINAL PRODUCTS OF THE PROJECT

The final three products of the project were specified in agreement between Swisstopo (represented by Adreas Kühni) and the Swiss Geophysical Commission (represented by Edi Kissling).

- Atlas on paper:
  - This atlas report will provide data, seismic interpretation and other results (maps, transects etc.). The report will be written in English and contends eight chapters and twenty large plates. It will be published by the Federal Office of Topography (Swiss Geological Survey) and edited by the Swiss Geophysical Commission. Examples of the large plates are given in figures 2 and 3.
- Scientific publication:
  - A paper will be published in the Swiss Journal of Geosciences. It will focus on the scientific questions that the atlas results enable to address. This publication will be prepared in 2009.
- Digital atlas:
  - This atlas version will contain all digital results of the Atlas project and will be available through the web-viewer of Swisstopo at the end of 2009.

6. SCIENTIFIC CONTACTS

In 2007, we had scientific contacts with various people from private or public offices and from universities.

We were invited to give special lectures on the project and on the Jura Mountains-Molasse Basin structures and relationships at the following places:

- Wettingen, NAGRA, April 2007
- Neuchâtel, Martin Burkhard Conference, May 2007
- Basel, Geological Institute, September 2007
- Neuchâtel, Geological Institute, October 2007
- Fribourg, Geosciences Department, November 2007.

The following private companies have asked for our expertise on the Jura Mountains and Molasse Basin:

- Celtic, London: a British private oil company, presentation of our results and exchange of data, confidential contract
- Interoil : exchange of data, discussions on specific topics as Tertiary unit or ArcGIS data base.
- AlpGeo, Geothermie (Dr. Bianchetti): presentation of the structures and seismic horizons in canton Vaud.

Two additional contracts were signed:

- with the Federal office of topography (Swisstopo) in order to receive ArcGIS digital files of geological maps
- with SEAG: extension of the previous contracts (“Anhang 3” of 2005 contract) in order to receive important well data.

7. ACKNOWLEDGEMENTS

We thank SEAG, NAGRA, FREAG, SHELL, the Geological Department of the universities of Fribourg, Neuchâtel and Geneva, the Geological Museum in Lausanne, the Geological office of Canton Geneva, the Department for environment and construction of Canton Fribourg, the BWG-Archives, Swisstopo, Geoform, Interoil (Proseis) and Prof. Emile Klingele for providing data for this work.

Several co-workers helped us during the year 2007 by providing technical support (Robin Engler, Bertrand Dumont, Dieb Hammami and Philippe Logean) and colleagues (Klaus Holliger and Pierre Gex) for interesting discussions.

We thank Andreas Küni from Swisstopo for his help in getting the support of Swisstopo to print and provide web access to the project results in the near future. Last but not least, we thank Edi Kissling, president of the Swiss Geophysical Commission, for discussions on the content of the final output of the project and for his support in our negotiations with Swisstopo.

8. REFERENCES

Marillier, F., U. Eichenberger and A. Sommaruga: Seismic synthesis of the Swiss Molasse Basin, Report for 2004, Swiss geophysical commission.

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