Zeitschrift: Swiss bulletin für angewandte Geologie = Swiss bulletin pour la géologie appliquée = Swiss bulletin per la geologia applicata = Swiss bulletin for applied geology

Herausgeber: Schweizerische Vereinigung von Energie-Geowissenschaftern; Schweizerische Fachgruppe für Ingenieurgeologie

Band: 16 (2011)

Heft: 2

Artikel: From the central Jura Mountains to the Molasse Basin (France and Switzerland)

Autor: Sommaruga, Anna

DOI: https://doi.org/10.5169/seals-327746

Swiss Bull. angew. Geol. Vol. 16/2, 2011 S. 63-75

From the central Jura Mountains to the Molasse Basin (France and Switzerland)

Anna Sommaruga[1]

Summary of a presentation given at the VSP/ASP annual convention, Yverdon-les-Bains, Switzerland, June 2011.

Keywords: Jura Mountains, Swiss Molasse Basin, foreland fold-and-thrust belt, décollement zone.

1. Geological setting

The Jura Mountains represent a small, arcuate fold-and-thrust belt in a frontal position of the northwestern Alpine arc. The Jura arc is surrounded by Tertiary basins of different types: to the north the Rhine Graben, to the west the Bresse Graben and to the south-southeast, the Molasse Basin (Fig. 1). The Rhine and Bresse Grabens are associated with the Eocene and younger West European rift system, whereas the Molasse Basin corresponds to an Oligo-Miocene foredeep, which developed in front of the Alpine orogeny. The Jura and the Molasse Basin represent the most external foreland fold-and-thrust belt and the youngest (from Middle Miocene onward) external deformation zone of the northwestern Alps. At its southern termination, the Jura belt merges with the Subalpine Chains which were folded during the same period. Along its western border, the Jura overthrusts the Bresse Graben, whereas to the north it overrides the Tabular Jura. At its external eastern end the most remote Jura fold (Lägeren) dies out within the Molasse Basin. The Jura Mountains and the Molasse Basin consist of a folded cover of Mesozoic and Cenozoic beds, which is detached over a basement sensu lato. Basement s. l. includes all the units below the Late-Middle Triassic evaporite décollement zone, i.e. Pre-Mesozoic crystalline or sedimentary rocks (Permo-Carboniferous sediments) and Early Triassic beds where present (e.g. Buntsandstein unit). According to Laubscher (1961), Burkhard (1990) and Burkhard & Sommaruga (1998) tectonics of the Jura belt and the Molasse Basin are intimately linked.

The Jura Mountains

The Jura is divided into an external and an internal part based on different tectonic styles. The external Jura consists of flat areas, Plateaux, limited to the north and separated from each other by so called «Faisceaux», narrow corridors consisting of numerous small imbricates and tear faults (Fig. 1). The internal Jura, also referred to as the Haute Chaîne or Folded Jura, consists of a well-developed fold train. At a large scale deformation is characterized by major folds, the trend of which turns from east to south. Major tear faults oriented at a high angle to fold axes cut the Haute Chaîne Jura at regular intervals.

The Swiss Molasse Basin

The clastic wedge of the Cenozoic Molasse Basin develops in a foreland basin (Sinclair

[1] Institut de Géophysique, Université de Lausanne, Bât. Amphipôle, CH-1015 Lausanne, Suisse.

et al. 1991, Homewood et al. 1986, Schlunegger et al. 2007), and is subdivided into four geological units (Fig. 1): the Jura Molasse, the Plateau Molasse, the Folded Molasse and the Subalpine Molasse (Homewood et al. 1989, swisstopo 2005). Classically the Jura Molasse represents the northern peripheral edge of the Molasse Basin that has been «passively» involved in the Jura folding and thrusting. Isolated patches of Tertiary Molasse sediments are preserved within major synclines of the internal Jura. The Plateau Molasse represents the major part of the Molasse Basin. The structures consist of broad anticlines oriented NE-SW and tear faults trending N-S, NW-SE and WNW-ESE. The northern limit of the Plateau Molasse corresponds to an erosional limit along the most internal high amplitude folds of the Jura belt. The Folded Molasse is a narrow zone that follows the thrust of the Subalpine Molasse. It is dominated by folds with steep limbs dipping toward the north. The Subalpine Molasse is a narrow zone along the southern border of the Molasse Basin. This zone is characterized by a stack of thrust sheets of Tertiary sediments detached along a décollement zone located within these Cenozoic layers (Trümpy 1980). In the central and eastern area, the structures within the Folded Molasse and the Subalpine Molasse form a triangle zone. The southern limit of this zone is buried below the Alpine nappes and corresponds to the

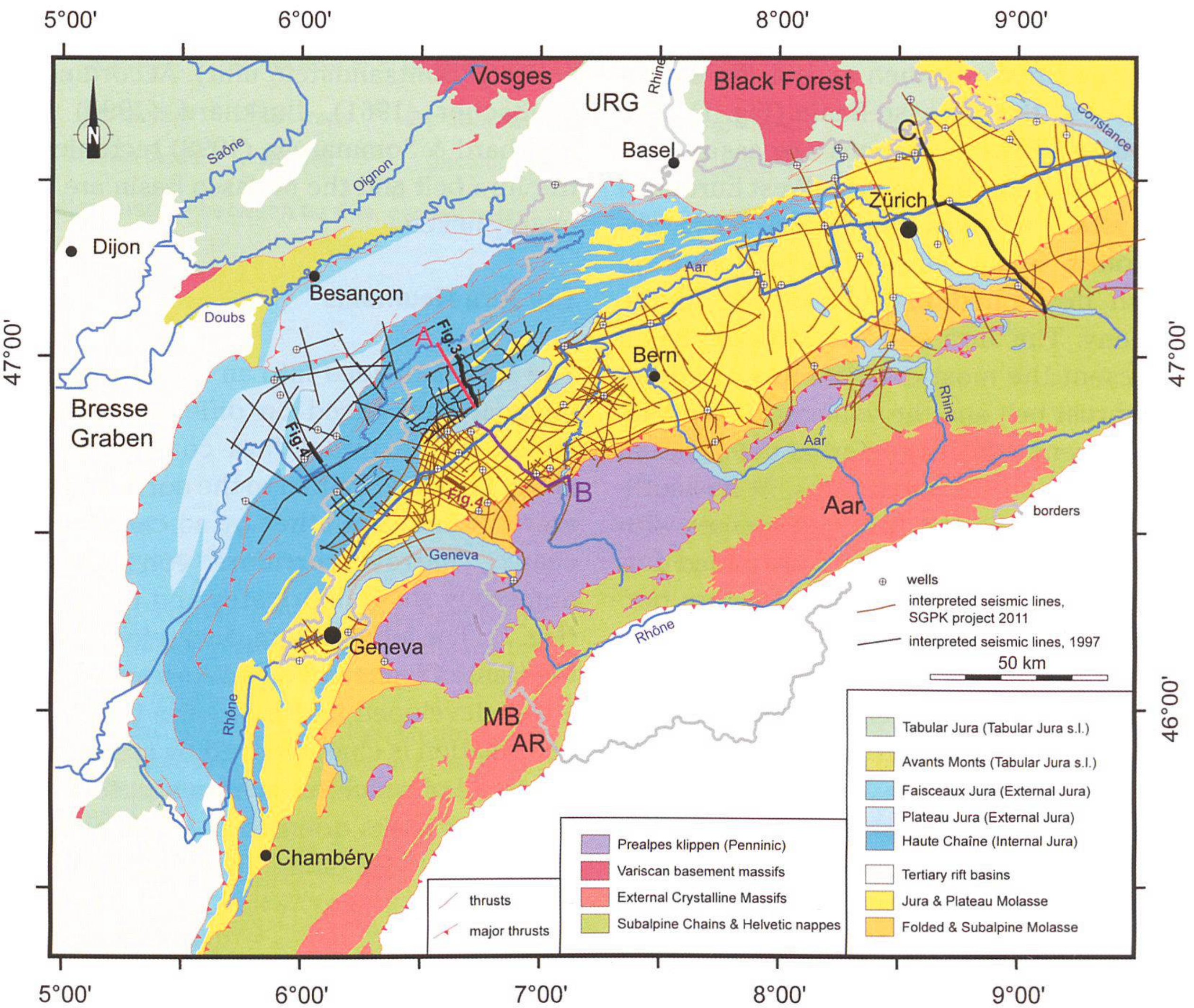

Fig. 1: Tectonic map of the Jura arc and the Swiss Molasse Basin with seismic interpreted lines. MB: Mont-Blanc Massif; AR: Aiguilles Rouges Massif. A, B, C, D correspond to the location of profiles shown in Figs. 5 and 6. Tectonic map modified from Sommaruga (1997) and Bonnet (2007).

Oligocene Alpine front represented by the frontal Penninic thrust of the Préalpes Klippen, the Helvetic nappes, etc. which overthrust the Molasse sediments.

Rock units

The main rocks units within the Jura and the Swiss Molasse Basin are from bottom to top:

a) Crystalline rocks of Precambrian to Paleozoic age. Grabens of Permo-Carboniferous age are present within the basement, but their precise location is difficult to establish (exception Weiach graben, Sprecher & Müller 1986, Nagra 1989). Crystalline rocks and detrital Permo-Carboniferous sediments are penetrated by few drill holes. The top basement is formed by an erosional surface that gently dips by few degrees toward the SW.
b) Rocks of Mesozoic age composed of Triassic, Jurassic and Cretaceous sediments. Triassic units consist of continental clastics, carbonates and evaporitic rocks deposited in an epicontinental shallow water sea. On top, alternations of limestone, marls and clays represent shelf and slope deposits from Jurassic to Upper Cretaceous age.
c) Tertiary clastic rocks form a prism which increases from NE to SW (Oligocene to Miocene age) covering the Mesozoic series. The discordance surface at the base of the Tertiary unit represents the foreland unconformity linked to piling of the nappes in the South.

2. Data

The data presented here summarize some of the results from two research projects on the interpretation of paper seismic data from industry exploration in Switzerland, calibrated by well data and depth-conversion of interpreted seismic horizons.
The first one, conducted at Neuchâtel University, concerns the central Jura and western Swiss Molasse Basin area and has been published mainly in 1997 (Sommaruga 1997, 1999). More than 1,500 km of industry seismic reflection lines in the Neuchâtel and Vaud Jura of Switzerland, the French Jura and the Swiss western Molasse Basin have been interpreted. Seismic lines are from surveys between 1970 and 1988 (BP survey in the Neuchâtel Jura).
The second project has been realized at Lausanne University with Urs Eichenberger and François Marillier for the Swiss Geophysical Commission (SGPK). It consists in a major study of the whole Swiss Molasse Basin from Lake Geneva to Lake Constance (published by swisstopo, Sommaruga et al. in press). More than 4,350 km of industry seismic lines acquired from 1960 to 1990 in the Swiss Molasse Basin have been interpreted. In addition about 30 deep wells were used for calibrating the seismic lines. In both projects, few seismic lines and well data were in the public domain, most of them were confidential. However, in the frame of the second project many seismic data along selected profiles will be published.
In this paper, the profile A located in the Jura fold and thrust belt (Fig. 5) represents a geological cross-section based on surface data and completed at depth with information from neighbouring seismic sections. The other profiles (B, C and D in Figs. 5 and 6) represent interpreted seismic sections which are converted to depth using seismic velocities calculated from well data, and follow the trace of seismic lines. Additional geological information (conceptual faults) based on geological maps, well reports, scientific papers and confidential reports have been added on the seismic interpretation. These three profiles are a selection among 15 transects which were combined to all other seismic lines interpreted in the frame of the Molasse Basin project in Lausanne and the derived horizon depth maps, to obtain for the first time a 3D view of the whole Swiss Molasse Basin.

3. Seismic horizons and units

The interpretation of the seismic lines concentrated on the Mesozoic units and on the related faults or thrusts including the major structures within the Tertiary unit. Cover-basement relations have also been studied and within the Molasse Basin only, seismic reflective zones have been interpreted as possible Permo-Carboniferous sediments pertaining to the basement. Eight seismic horizons were interpreted in the Swiss Molasse Basin: near Base Tertiary, near Base Cretaceous/Top Late Malm, intra Early Malm, near Top Dogger, near Top Liassic, near Top Late Triassic, near Top Middle Triassic and near Base Mesozoic. In the Jura Mountains, one more horizon is added (Top Aalenian) and a different labelling was used (see Sommaruga 1997 and Fig. 4). Two-way travel time, velocity and depth contour maps have been calculated for each interpreted seismic horizon and vertical thickness maps for each unit between two horizons.

Within the Tertiary units, the seismic reflections are either discontinuous or absent. It is almost impossible to follow them from one seismic line to another. The four profiles included here (Figs. 5 and 6) show the prism of Tertiary sediments which increases from N to S. In the Jura Mountains the Tertiary sediments are preserved only in the synclines (few hundred meters), whereas in the Molasse Basin the thickness increases from 0 m (erosional limit at the foot of the Jura Mountains) to more than 5,000 m to the South in the Subalpine Molasse (e. g. Thun-1 well). The Tertiary unit rests in discordance on the Cretaceous beds in the western part of the basin and on the Late Jurassic beds in the central and eastern areas where no Cretaceous beds are present (Fig. 2). The maximal thickness of the Cretaceous series has been identified in the wells around Geneva (350 m). In the central Jura, especially the Neuchâtel Jura, Cretaceous beds are well renowned because the Neocomian, Valanginian and Hauterivian stages (Early Cretaceous) were defined in this area (Remane 1982). In the upper Urgonian formation (Barremian, Early Cretaceous), asphalt deposits have been mined (Mines de La Presta) in the Val de Travers from 1713 to 1986 (Meia 1987). All Cretaceous formations thin towards N or NE and disappear totally eastward of the region north of Lake Biel (Trümpy 1980). The complete Mesozoic cover is thicker in the western part (more than 3,000 m) than in the eastern part (less than 800 m). This concerns the Swiss Molasse Basin (Profile D, Fig. 6) and the Jura fold-and-thrust belt.

4. Structures

The analysis of the geometry of structures within the central Jura and the western Swiss Molasse Basin has shown various types of folds and faults:

- Thrust-related folds, located within the Haute Chaîne Jura (Fig. 3 and Profile A in Fig. 5). These high amplitude folds are related to NW- or SW-vergent thrusts of at least kilometric dip-slip displacement that results in a duplication of the entire Mesozoic sequence. These thrusts step up from the main décollement zone (Early Triassic evaporites) through the entire Mesozoic and Cenozoic cover series.
- Evaporite-cored detachement folds, located in the external Jura (Plateau Jura) (Fig. 4) and in the western Molasse Basin (Fig. 4 and Profile B in Fig. 5). The development of these low amplitude folds is related to evaporite stacks within the Early Triassic Unit layer. The axis of these folds are oriented NW-SE, parallel to the general trend of the Jura belt structures.

These two types of folds are respectively interpreted as embryonic and evolved stages of the Late Miocene cover defor-

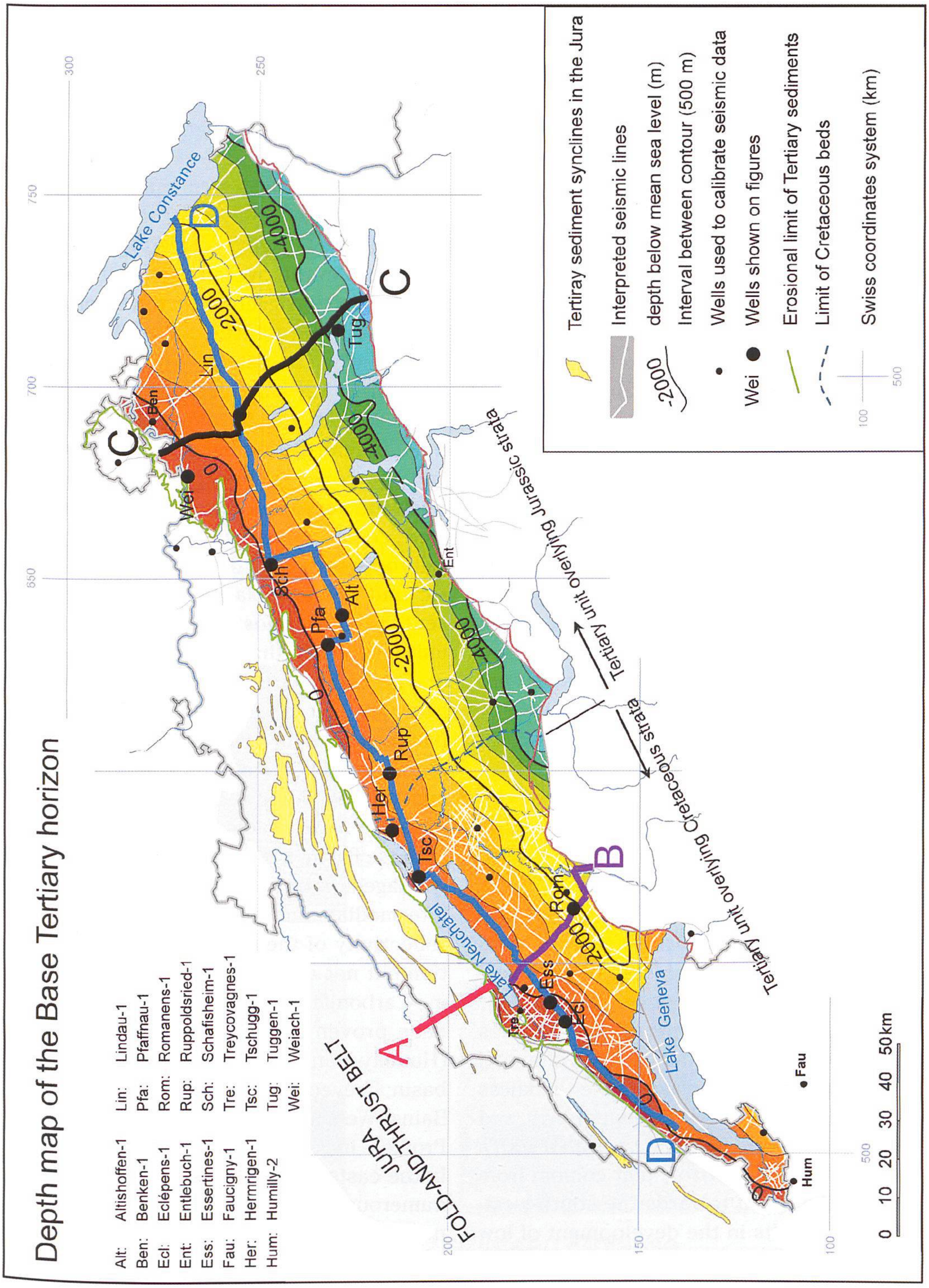

Fig. 2: Contour map in depth of the Base Tertiary horizon within the Swiss Molasse Basin. The map is a depth conversion of a TWT map obtained from the interpreted seismic lines. Location of profile A, B, C and D shown on figures 5 and 6. Modified from Sommaruga et al. (2011).

mation. The Haute Chaîne Jura folds began as buckle folds and evolved subsequently into the present thrust-related folds. In the western Swiss Molasse Basin, however, low amplitude folds represent an early stage which did not evolve because of loading by the overlying thick Tertiary sedimentary wedge. The eroded Tertiary sediments are estimated to circa 0.8 - 1.6 km (Cederbom et al. 2011). Both types of folds show that the Early Triassic evaporites are clearly involved in the development of fold and thrust structures in the cover of the Jura and controlled their formation.

- Faults oriented N-S, NW-SE and WNW-ESE with a normal, reverse or lateral offset have been interpreted on the seismic lines in the western Jura and Molasse Basin area. These faults, within the limit of seismic resolution, do not show any significant offset of the Base Mesozoic horizon and Pre-Mesozoic units from one side of the fault to the other side and are therefore restricted to the cover. Major tear faults e. g. Pontarlier, La Lance-Font-Fétigny located in the western Swiss Molasse Basin (Profile D, Fig. 5) extend from the Molasse Basin into the folded Jura where they have an important morphological expression (Heim 1915, Aubert 1959, Meia 1969, Sommaruga 1997). Within the Molasse Basin, the structural style of these faults is dominated by fault segments of hundred meter length.

For the Jura Mountains, the cover structures are also influenced by the mechanical stratigraphy. The decrease of the thickness ratio between weak (incompetent) and strong (competent layers), associated with a decrease of the Mesozoic unit column from the north-eastern towards the south-western Jura, results in the development of low relief box-folds or detachment folds in the eastern Jura and high relief thrust-related folds in the western Jura (Figs. 1 and 3, Profile A in Fig. 5). The Jura cover has been deformed over a relatively smooth Pre-Mesozoic surface dipping 1 - 3° to the S-SE, within the limited constraints of seismic resolution. The basement s. l. (crystalline basement, Permo-Carboniferous grabens or Buntsandstein beds) beneath the central Jura Mountains is not significantly affected by the deformation of structures such as the folds, the thrust faults and the tear faults observed in the cover. Small topographic variations in the overall smooth basement top may have triggered the development of major ramp structures. Shortening within the cover in the central Jura is estimated between 20 - 25 km (Burkhard 1990, Philippe et al. 1996, Affolter & Gratier 2004). The contrast in deformation between the basement and the cover is due to an unexpectedly thick and very weak décollement zone. This zone, composed essentially of evaporite and salt rocks belonging to seismic Middle Triassic unit (Muschelkalk evaporites), represents the lowermost seismic stratigraphic unit involved in the deformation of the cover. The regional thickness of this unit ranges from 200 m at the NW periphery of the Jura belt to more than 1,000 m in the central part of the Jura, due to tectonic thickening (Sommaruga 1997, Affolter & Gratier 2004).

In the Pre-Mesozoic units, beneath the Molasse Basin, the seismic reflections, poorly imaged, have been classified in reflective, intermediate and non-reflective zones. The reflectivity of these zones gives an indication but not a proof of the presence of Permo-Carboniferous throughs. However, wells have proven the presence of these rocks (Humilly-2 and Faucigny-1, south of Geneva basin; Treycovagnes-1 around Yverdon-les-Bains; Weiach-1 in North-East Switzerland, Profile C in Fig. 6).

In the eastern Molasse Basin, faults are not numerous and are oriented WSW-ENE with a normal offset north down. South of Lake Constance (Romanshorn area), some faults cut the entire Mesozoic cover and the Base Mesozoic horizon showing an offset of the crystalline basement.

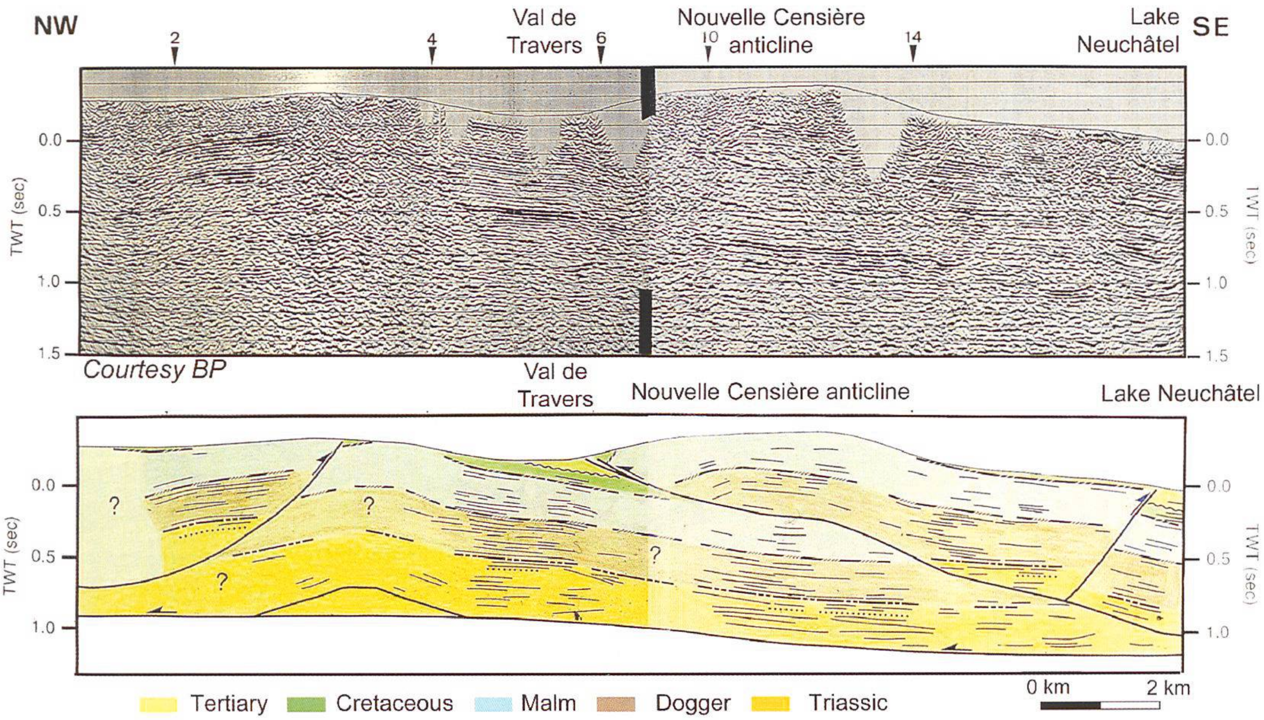

Fig. 3: Example of thrust-related fold in the Neuchâtel Haute Chaîne Jura. This seismic section is located parallel to the cross-section (profile A) of Fig. 5. For location see Fig. 1. Modified from Sommaruga (1997).

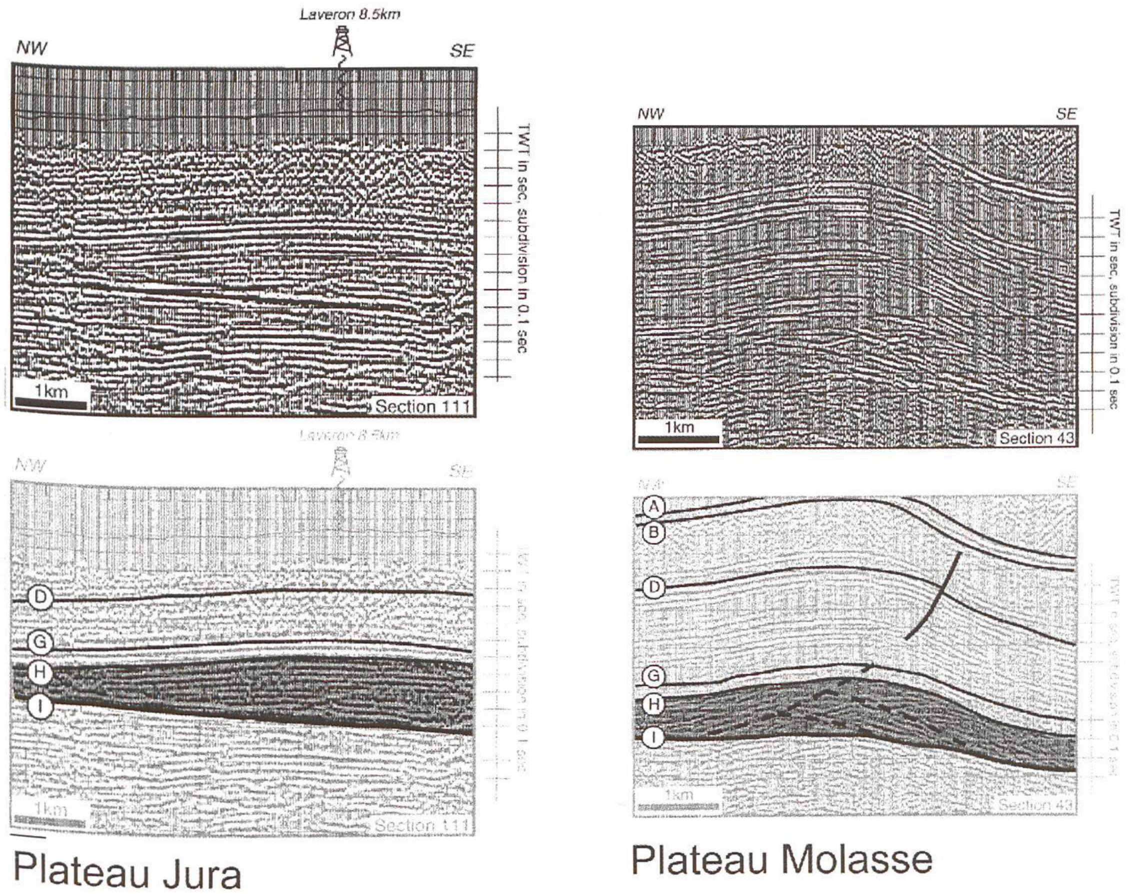

Fig. 4: Examples of evaporite-cored detachement folds. On the left, Laveron anticline located in the external Jura (Plateau Jura) and on the right, Essertines anticline, located in the Plateau Molasse. Middle-Early Triassic unit is highlighted in dark grey. D: Top Dogger (near Top Dogger), G: Top Triassic Unit 1 (near Top Late Triassic), H: Top Triassic Unit 2 (near Top Middle Triassic), I: Top Basement (near Base Mesozoic). For location see Fig. 1. Modified from Sommaruga (1999).

5. Discussion and conclusions

Along the axis of the Swiss Molasse Basin, the style of the structures is influenced by the presence or absence of a décollement zone within the Middle Triassic evaporites (Trümpy 1980, Sommaruga 1997) (see Profile D, Fig. 6). In the western and central areas of the Molasse Basin, the cover is detached above mainly Pre-Mesozoic units

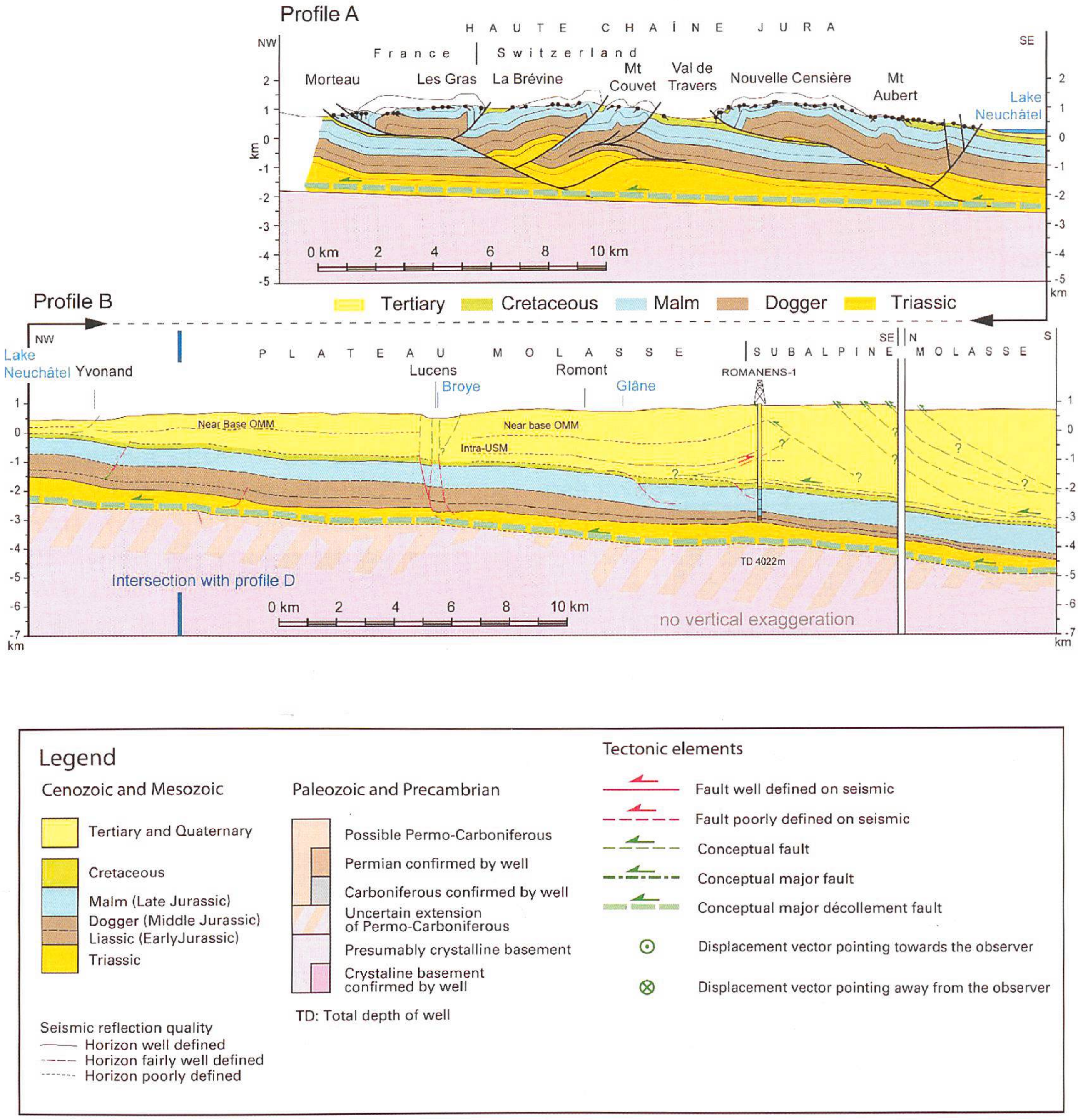

Fig. 5: Profiles A and B represent at the same scale a transverse section from the Haute Chaîne Jura to the front of the Alps. Lake Neuchâtel is located between the two profiles. Profile A: geological cross-section based on surface data and completed at depth with information from neighbouring seismic sections (e. g. Figs. 1 and 2). No indication of seismic reflection quality of the horizon is shown on this profile. Modified from Sommaruga (1997). Profile B: depth conversion of several seismic lines crossing the western part of the Swiss Molasse Basin. Intersection with Profile D (Fig. 6) is highlighted. OMM: Obere Meeresmolasse (Upper Marine Molasse). USM: Untere Süsswassermolasse (Lower Freshwater Molasse). Modified from Sommaruga et al. (2011).

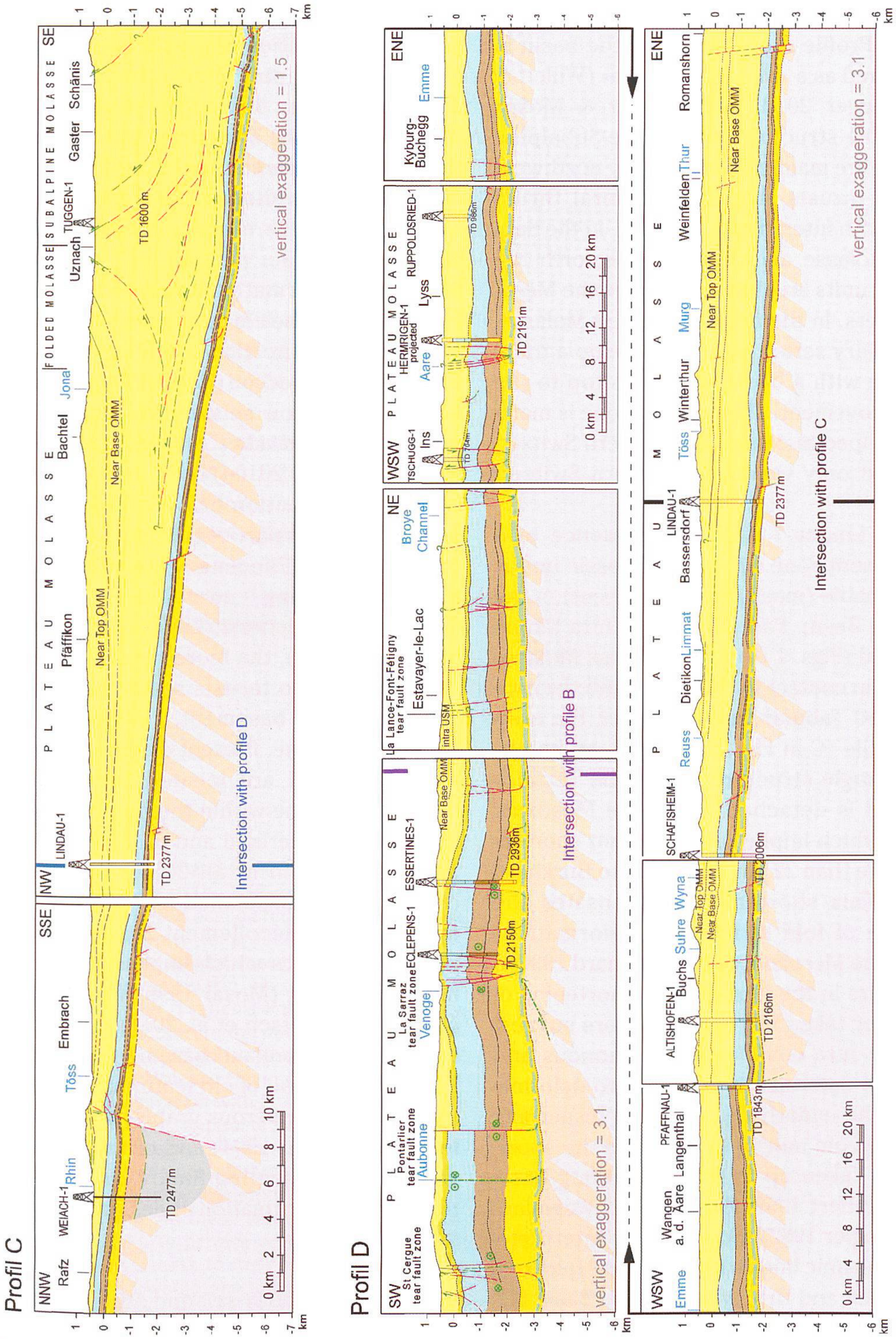

Fig. 6: Profiles B and C: depth conversion of several seismic lines within the Swiss Molasse Basin. For location see Fig. 4. Both modified from Sommaruga et al. (2011). Profile C is perpendicular to the dip direction of the strata and is located in the eastern part of the basin. Intersection with profile D is highlighted. Profile D is parallel to the basin axis. The apparent increase in thickness of the Tertiary unit around Altishofen-1 well is due to the more southerly location of this local section in the basin (see Fig. 4). Legend see Fig. 5.

(see location of conceptual décollement zone in Profile D of Fig. 6) and the basin is considered as a «wedge top basin» (Willett & Schlunegger 2010, Schlunegger & Mosar 2010). The structures within the Subalpine Molasse are mainly dominated by northwest vergent thrusts that stack several thrust sheets with internal deformation. In the Subalpine Molasse, and slightly to the north, the Tertiary units are detached above the Mesozoic layers. In the adjacent Folded Molasse, the Tertiary series typically develop a triangle zone with a backthrust with top to the South movement. This triangle zone is mainly developed in central and eastern Switzerland and only weakly in western Switzerland.

East of Lindau-1 well, the presence of a décollement zone within the Triassic unit is questionable (most probably absent) in the Molasse Basin. East of the last Jura Mountains fold (Figs. 1 and 2), the Swiss Molasse Basin is in contact to the north with the non-deformed Tabular Jura. However, the eastern profile (C in Fig. 6) presents an important triangle structure within the Tertiary unit and is detached above the Mesozoic layers, which implies an important shortening (more than 22 km according to Burkhard 1990). This shortening compensates the absence of fold structures (deformation) within the Mesozoic units (Burkhard 1990).

But where in the basement is shortening of the cover taken up? Some authors suggest that the Jura cover is autochthonous and has been deformed in response to deformation in the underlying basement (especially Pre-Mesozoic unit) and therefore the shortening is taken up in this underlying basement (Aubert 1959, Pavoni 1961, Wegmann 1963, Ziegler 1982). However, the interpretation of seismic lines within the Jura fold-and-thrust belt and the Swiss Molasse Basin has not shown examples where major fold structures are intimately linked with deformation in the Pre-Mesozoic basement. This, amongst other arguments, leads to the conclusion that the Jura and the western and central Molasse Basin cover is allochtonous and its deformation results from a distant push («Fernschub theory» from Buxtorf 1907, Laubscher 1961). The basal thrust located within the Triassic evaporites roots below and inside the External Crystalline Massifs and the shortening of the cover is taken up in these massifs (Boyer & Elliot 1982).

The main deformation phase of the Jura fold-and-thrust belt is supposed to be short, between the Late Pliocene (Serravallian) and the Early Pliocene (Becker 2000). Recent studies based on seismic lines and field work (Ustaszewski & Schmid 2007; Madritsch et al. 2010a) have demonstrated that the deformation has continued in the northern frontal part of the Jura Mountains after the Early Pliocene up to the Quaternary. According to Becker (2000), Ustaszewski & Schmid (2007), Madritsch et al. (2008, 2010a), the more recent deformation is related to thrusts seated within the Pre-Mesozoic basement, beneath the décollement zone. Present day earthquakes in the foreland are located beneath the décollement zone within the basement only in eastern Switzerland and in the Besançon area (Deichmann et al. 2011). There is a change from thin-skinned tectonics (deformation over a décollement zone) to thick-skinned tectonics which implies structures in the basement (Mosar 1999, Madritsch et al. 2010b, Madritsch et al. 2011). A shortening within the foreland basement may have led to reactivation of old features (inversion of Permo-Carboniferous graben faults, Guellec 1990, Pfiffner 1994) and of thin-skinned structures, presenting finally a superposition of both deformation styles on the same structure.

In conclusion, both seismic studies based on interpretation of seismic lines within the Alpine foreland have confirmed that the Jura is a typical foreland fold-and-thrust-belt detached over a basal décollement zone located within the Middle Triassic unit. The

Triassic evaporites control the development of the structures within the allochtonous Mesozoic cover of the Jura and the western Molasse Basin during the Late Miocene-Early Pliocene deformation time. The eastern Swiss Molasse Basin does not present a décollement zone which means that the cover is autochthonous; normal faults offset the basement. The Tertiary units are detached above the Mesozoic layers to the south and in triangular zones (Subalpine Molasse) along the northern edge of the Alps. Faults are confirmed mainly in the Mesozoic layers in the central Jura and in the western Molasse Basin. Beneath the Plateau Molasse, the Pre-Mesozoic units present reflective zones which are interpreted as possible Permo-Carboniferous sediments. New studies suggest a possible recent inversion of Permo-Carboniferous troughs or basement features (especially in frontal and East Jura tip).

Acknowledgments

I thank the VSP/ASP and Peter Burri for the invitation to participate to the VSP meeting in Yverdon-les-Bains and to the associated field trips. It gave me the opportunity to present these research works at the conference session and also during the Val de Travers field trip, which was co-guided by Jean-Paul Schaer, François Pasquier and Thierry Adatte. The results from the Jura Mountains come from works conducted at Neuchâtel University. Those from the Molasse Basin come from a group project in collaboration with Urs Eichenberger and François Marillier, supported by the Swiss Geophysical Commission (SGPK) and the University of Lausanne. The results will be published by swisstopo under the title: «Seismic Atlas of the Swiss Molasse Basin». All these works have been made possible thanks to private or public companies, which gave us access to their archives of seismic and well data. I would like to thank them for their confidence. Many thanks to Jon Mosar for constructive comments.
The Neuchâtel Jura and the Val de Travers (Creux du Van, Gorges de l'Areuse) was the favorite excursion area of Martin Burkhard, former Prof. at Neuchâtel University. I dedicate this paper to his memory.

References

Affolter, T. & Gratier, J. P. 2004: Map view retrodeformation of an arcuate fold-and-thrust belt: The Jura case. Journal of Geophysical research, v. 109. doi:10.1029/2002JB002270.

Aubert, D. 1959: Le décrochement de Pontarlier et l'orogenèse du Jura. Mémoire de la société vaudoise des sciences naturelles, 12, 93–152.

Becker, A. 2000: The Jura Mountains – an active foreland fold-and-thrust belt? Tectonophysics v. 321, 381–406.

Bonnet, C. 2007: Interactions between tectonics and surface processes in the Alpine foreland: Insights from analogue model and analysis of recent faulting [Ph.D. thesis]. Université de Fribourg.

Boyer, S. E. & Elliott, D. 1982: The geometry of thrust systems. American Association of Petroleum Geologists Bulletin, 66, 1196–1230.

Burkhard, M. 1990: Aspects of the large-scale Miocene deformation in the most external part of the Swiss Alps (Subalpine Molasse to Jura fold belt). Eclogae geol. Helv. 83, 559–583.

Burkhard, M. & Sommaruga, A. 1998: Evolution of the Swiss Molasse basin: structural relations with the Alps and the Jura belt, in Mascle, A., Puigdeffabregas, C., Luterbacher, H. & Fernandez, M. (eds.): Cenozoic Foreland Basins of Western Europe, Volume 134, London, Geological Society Special Publications, 279–298.

Buxtorf, A. 1907: Zur Tektonik des Kettenjura. Ber. Vers. oberrh. geol. Vers., 30/40, 79–111.

Cederbom, C. E., van der Beek, P., Schlunegger, F., Sinclair, H. D., & Oncken, O. 2011: Rapid extensive erosion of the North Alpine foreland basin at 5–4 Ma. Basin Research, 23, 528–550.

Deichmann, N., Sellami, S. & Giardini, D. 2011: La Suisse tremble. Sismotectonique des Alpes et du Plateau suisse: Géochronique, 117, 57–60.

Guellec, S., Mugnier, J. L., Tardy, M. & Roure, F. 1990: Neogene evolution of the western Alpine foreland in the light of ECORS data and balanced cross sections. In: Roure, F., Heitzmann, P. & Polino, R., eds.: Deep structure of the Alps, Volume 1: Zürich, Mém. Soc. géol. suisse. 165–184.

Heim, A. 1915: Die horizontalen Transversalverschiebungen im Juragebirge. Geol. Nachlese Nr. 22; V. Natf. Ges. Zürich, 60, 597–610.

Homewood, P., Allen, P. A., & Williams, G. D. 1986: Dynamics of the Molasse Basin of western Switzerland. Spec. Publs. int. Ass. Sediment. 8, 199–217.

Homewood, P., Rigassi, D., & Weidmann, M. 1989 : Le bassin molassique Suisse, in Assoc. Sédim. Française, ed. Dynamique et méthodes d'étude des bassins sédimentaires. Paris, Technip. 299–314.

Laubscher, H. 1961: Die Fernschubhypothese der Jurafaltung. Eclogae geol. Helv. 54, 221–280.

Madritsch, H., Fabbri, O. & Schmid, S. M. 2011: La chaîne plissée du Jura: évidences morphologiques en faveur d'une activité postpliocène et discussion du contexte géodynamique actuel. Géochronique, 117, 41–44.

Madritsch, H., Preusser, F., Fabbri, O., Bichet, V., Schlunegger, F. & Schmid, S. M. 2010b: Late Quaternary folding in the Jura Mountains: evidence from syn-erosional deformation of fluvial meanders. Terra Nova, 22, 147–154.

Madritsch, H., Fabbri, O., Hagedorn, E. M., Preusser, F., Schmid, S. M. & Ziegler, P. A. 2010a: Feedback between erosion and active deformation: Geomorphic constraints from the frontal Jura fold-and-thrust belt (eastern France). International Journal Earth Science, 99, 103–122.

Madritsch, H., Schmid, S. M. & Fabbri, O. 2008: Interactions between thin- and thick-skinned tectonics at the northwestern front of the Jura fold-and-thrust-belt (eastern France). Tectonics, 27.

Meia, J. 1969: Géologie du Mont Aubert et de l'anticlinal Soliat-Montagne de Boudry au Nord du lac de Neuchâtel (Jura vaudois sud-oriental et Jura neuchâtelois méridional, Suisse) [PhD thesis], Université de Neuchâtel.

Meia, J. 1987 : Derniers regards sur la Mine d'asphalte de La Presta (Val-de-Travers, Jura neuchâtelois, Suisse). Bulletin der Vereinigung Schweizerischer Petroleum-Geologen und - Ingenieure, 53. 47–56.

Mosar, J. 1999: Present-day and future tectonic underplating in the western Swiss Alps: reconciliation of basement/wrench-faulting and decollement folding of the Jura and Molasse Basin in the Alpine foreland. Earth and Planetary science letters, 173, 143–155.

Nagra, 1989: Sondierbohrung Weiach – Untersuchungsbericht, Nagra Technischer Bericht, NTB 88-08. Baden.

Pavoni, N. 1961: Faltung durch Horizontalverschiebung: Eclogae geol. Helv. 54(2), 515–534.

Pfiffner, O. A. 1994: Structure and evolution of the Swiss Molasse Basin in the transect Aar Massif-Bern-Central Jura: Géologie Alpine, v. 4, p. 85.

Philippe, Y., Coletta, B., Deville, E. & Mascle, A. 1996: The Jura fold-and-thrust belt: a kinematic model based on map-balancing. In: Ziegler, P. A., & Horvath, F., eds., Peri-Tethys Memoir 2: Structure and Prospects of Alpine Basins and Forelands, Volume 170, Paris, Mémoire du Muséum national d'Histoire naturelle. 235–261.

Remane, J. 1982: Die Kreide des Neuenburger Juras (Exkursion D am 15. April 1982). Jahresbericht und Mitteilungen des oberrheinischen geologischen Vereins, Neue Folge 64, 47–59.

Schlunegger, F. & Mosar, J. 2010: The last erosional stage of the Molasse Basin and the Alps. International Journal of Earth Sciences, v. DOI 10.1007/s00531-010-0607-1.

Schlunegger, F., Ramseyer, K., & Rieke-Zapp, D. 2007: Possible environmental effects on the evolution of the Alps-Molasse Basin system. Swiss Journal of Geosciences, 100, 383–406.

Sinclair, H. D., Coakley, B. J., Allan, P. A. & Watts, A. B. 1991: Simulation of foreland basin stratigraphy using a diffusion model of mountain belt uplift and erosion: an example from the Central Alps, Switzerland. Tectonics, 10, 599–620.

Sommaruga, A. 1997, Geology of the Central Jura and the Molasse Basin: new insight into an evaporite-based foreland fold and thrust belt. Mémoire de la société neuchâteloise des sciences naturelles, v. 12, 176 p.

Sommaruga, A. 1999: Décollement tectonics in the Jura foreland fold-and-thrust belt. Marine and Petroleum Geology, v. 16, 111–134.

Sommaruga, A., Eichenberger, U., & Marillier, F. 2011: Vision 3D du Bassin molassique en Suisse à partir de la sismique réflexion. Géochronique, 117, 44–47, 73.

Sommaruga, A., Eichenberger, U. & Marillier, F. in press: Seismic Atlas of the Swiss Molasse Basin. Matériaux pour la géologie de la Suisse, Géophysique, N° 44.

Sprecher, C., & Müller, W. 1986: Geophysikalisches Untersuchungsprogramm Nordschweiz: reflexionsseismische Messungen 82, Nagra, NTB 84-15.

Swisstopo 2005: Tectonic map of Switzerland. Bern.

Trümpy, R. 1980: Geology of Switzerland – a guidebook. Part A: An outline of the geology of Switzerland. Part B: Geological excursions: Basel, New York, Wepf, 334 p.

Ustaszewski, K. & Schmid, S. H. 2007: Latest Pliocene to recent thick-skinned tectonics at the Upper Rhine Graben – Jura Mountains junction. Eclogae geol. Helv. 100, 293–312.

Wegmann, E. 1963: Le Jura plissé dans la perspective des études sur le comportement des socles, in France. S. g., ed., Livre Mém. Prof. P. Fallot, Volume Mém. hors-série 1, Paris, 99–104.

Willett, S. D. & Schlunegger, F. 2010: The last phase of deposition in the Swiss Molasse Basin: from foredeep to negative-alpha basin. Basin Research, 22, 623–639.

Ziegler, P. A. 1982: Geological Atlas of Western and Central Europe, The Hague, Shell Internationale Petroleum Maatschappij B.V. 130 p.