The samples can be categorized as chlorite-muscovite-quartz schist, chloritoid-chlorite-quartz-muscovite schist, chlorite-muscovite-quartz-chloritoid schist and interbeds of marble. Accessory minerals in chloritoid schist are tourmaline, zircon and rutil. Microstructural features show two deformational events, the sinmetamorphic and postmetamorphic events. The latter deformational event is recorded in the development of flazer structure, where the mineral grains in cleavages are translated, fractured and rotated.

The whole-rock chemical analyses show high concentrations of SiO_2 (74.79 wt. %), K_2O (2.5 wt. %), Al_2O_3 (13.22 wt. %), and low values of MgO (0.99 wt. %) and CaO (0.08 wt. %).These results indicate that acid rocks could be a possible protolith. The REE distribution normalized to chondrite shows higher LREE to HREE concentrations ((La/Yb)N=5.68, (La/Sm)N=3.05, (Gd/Yb)N=1.21), while the Eu anomaly has a low value (Eu/Eu*=0.7).
Such metamorphic mineral assemblage is characteristic for low-grade metamorphism. The chlorite-chloritoid geothermometer gives metamorphic temperature values of approximately 450°C.

The source rocks of the chloritoid schist are argillaceous sandstones, derived from acid magmatic rocks, interbeded with carbonates. Carbonate interbeds indicate deposition in a marine environment. The morphology of zircons shows that the source for protolith is of granitoid composition, while their weak roundness indicates a short transport.

The role of rift-inherited hyper-extension in Alpine-type orogens

Mohn, G.[1,2], Manatschal, G.[2], Beltrando, M.[3] & Haupert, I.[2]

[1] GEC, Université Cergy-Pontoise, F-95 000 Cergy, France
(gmohn@unistra.fr)
[2] CNRS-EOST, Université Strasbourg, Strasbourg, France
[3] Dipartimento di Scienze della Terra, Università di Torino, Italy

The Alpine orogen is commonly interpreted as the imbrication of rifted margins and intervening “oceanic” domains. Notably, the understanding of the architecture and evolution of rifted margins underwent a paradigm shift thanks to new high-resolution refraction and reflection seismic imaging method developments combined with the Ocean Drilling Program. Indeed most continental rifted margins show evidence for hyper-extension prior to lithospheric breakup. Hyper-extended domains are characterized by: 1) extremely thin continental crust and exhumed subcontinental mantle extending over hundreds of kilometers, 2) necking zones marking sharp boundaries between little extended crust and hyper-extended < 10km thick crust.

The discovery of hyper-extended domains and necking zones in rifted margins still awaits to be fully integrated in conceptual and numerical models of collisional orogen evolution. This study aims to constrain the extent to which rift-inherited hyper-extension may control the architecture and evolution of Alpine-type orogens.
Based on the available geological and geophysical datasets, the Alpine orogen can be subdivided into external and internal domains. Notably, the external domains formed at the expense of the former proximal rifted margin associated with a poorly extended crust. In contrast, diagnostic elements for hyper-extended domains are being increasingly recognized in the internal domain of the Alpine orogen while the identification of former necking zone remains more problematic. However, based on the available data, we suggest that the transition between the external and the internal domains still preserves the evidence of a former necking zone.

As a result, we propose that the evolution of the Alpine orogen is strongly controlled by rift inheritance. We suggest that subduction is initiated within the hyper-extended domain rather than the oceanic crust. Subduction processes are enhanced by partial serpentinization due to rifting processes. The continental collision is then triggered by the arrival of necking zones at convergent plate margins. Since they mark the boundary between little extended proximal and hyper-extended domains, necking zones act as buttresses initiating the transition from a subduction to a collisional stage. The continental collision, controlled by the necking zone, will create a major boundary in the orogen delimiting (1) the highly deformed and overthickened internal domain preserving the relics of rift related hyper-extension from (2) the weakly deformed external domain which neither suffered significant rift-related crustal thinning nor orogeny-related thickening.

Eventually, adopting a more realistic pre-orogenic margin architecture may significantly modify our view on mountain building formation of Alpine type orogens. Besides, results of this work should be seen in the light of recent discoveries from present-day deep-water rifted margins questioning the nature of the Alpine Tethys as either related to a true Atlantic-type ocean or to hyper-extended rift basins showing hyper-extended continental crust and local mantle exhumation but failing to create a stable plate boundary.

Tectonics in the Swiss Molasse Basin

Mosar, J., Abednego, M., Gruber, M., Ibele, T., Sommaruga, A. & Vouillamoz, N.

Department of Geosciences, Earth Sciences, University of Fribourg, Chemin du Musée 6, CH-1700 Fribourg, Switzerland
(jon.mosar@unifr.ch)

The Swiss Molasse Basin is located to the North of the Subalpine Molasse and the Prealpes Klippen belt, and is forming along its northern edge an erosive limit with the first fault-related folds of the Jura fold-and-thrust belt (JFTB). Originally the Molasse Basin extended farther north into the JFTB as documented by the numerous Molasse occurrences in the box-shaped synclines. Towards the W-SW the Molasse Basin grades into the fault-related fold structures of the Subalpine Chains in France. In its wester portion the Molasse Basin forms a wedge-top foreland basin, whereas in its oriental part, east of the eastern tip of the JFTB, it forms a classic flexural foreland basin. This transition – where the alpine orogenic front jumps from the frontal Jura thrust (including the Mandach thrust) to the Alpine front s.str. – occurs along a series of major NW-SE trending faults such as the Neuhausen and Randen faults and the Hegau-Bodensee graben faults, as well as the St. Gallen fault system farther SE. The transition between the tip of the JFTB belt and these faults is formed by the Permo-Carboniferous Graben of N Switzerland.

Strain partitioning inside the Swiss Molasse Basin develops a complex pattern of evaporite-cored structures (folds and grabens, fault-related folds laterally terminated by steep oblique ramps, extensional structures (grabens), inversion features above Permo-Carboniferous basins, triangular structures (mostly at the transition with the Subalpine Molasse thrust zone), and strike-slip fault systems. The latter such as the Vuache fault system or the La Lance Fault and the Pontarlier Fault in the JFTB regionally form a conjugate fault system with left-lateral faults striking N-S and dextral faults striking NW-SE. They cut from the JFTB into the Molasse basin. Locally former normal faults are reactivated in a strike-slip mode such as in the N-S trending Fribourg Zone.

Strain partitioning also occurs in a vertical profile; thus the whole area, including the JFTB, is detached above a layer of Triassic evaporites. In the southern part of the Molasse Basin the Tertiary Molasse series s.str. are detached from the Mesozoic substratum. The basement also bears major tectonic faults that form a series of Permo-Carboniferous grabens, the extent and direction of which remains elusive, except in a few rare cases such as the graben of N Switzerland. The thrust faults and strike-slip faults are restrained to the cover series and root in the basal Triassic detachment and do not extend into the basement.

The structural development of the foreland basin is classically associated with the formation of the JFTB. Recent sedimentology studies from Molasse series in the Jura synclines show distinct facies pointing to syndepositional topographic barriers which we interpret to be embryonic folds. Combined with other information such as onlaps (from seismic studies) we suggest that the onset of folding in the Molasse Basin and the JFTB is much earlier as hitherto suggested – probably as early as Oligocene.