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

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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.

Recent studies have combined surface field data, subsurface data from seismic surveys, earthquake analysis (especially distribution of clusters) with 3D modeling. The objective is to construct a kinematically consistant 3D-model that will help orient and constrain hydrocarbon and deep geothermal energy exploration as well as seismic hazard analysis.

Aspects of the pre-Alpine and Alpine tectonic evolution of the Gurktal Extensional Allochthon, Eastern Alps: Constraints from structural studies and $^{40}Ar/^{39}Ar$ white mica ages

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The nature and extent of Alpine thrusting of the Gurktal nappe complex represents one of the most controversial topics of Austrian geology. New structural and white mica $^{40}Ar/^{39}Ar$ ages from the Gurktal nappe complex, Eastern Alps, indicate ESE-directed distributed shear mainly leading to the present-day juxtaposition of the deeper Murau nappe overprinted in higher greenschist metamorphic conditions during the Cretaceous, to the higher, nearly unmetamorphic Stolzalpe nappe. The boundary in between represents, therefore, a ductile low-angle normal fault and the unmetamorphic Stolzalpe nappe the main body of a Late Cretaceous extensional allochthon. The distributed extensional shear system along the western margin of the Gurktal nappe complex overprinted nappe stacking structures and operated from initial ductile via semi-ductile and finally to brittle conditions within the same kinematic framework. A plateau age of 89.0 ± 0.6 Ma was found for newly grown white mica in the basal Lower Triassic Stangalm Quartzite exposed at the base of the Mesozoic cover succession on the Bundschuh basement. For the first time, a plateau age of 85.78 ± 0.33 Ma demonstrates the pervasive Late Cretaceous metamorphic overprint on the Murau nappe in the footwall of the regional, ESE-directed ductile detachment fault. This age is interpreted to date cooling after the throughout recrystallization of rocks composing the Murau nappe.

Furthermore, a post-Variscan angular unconformity below the Lower Triassic Stangalm Quartzites (PISTOTNIK, 1976) proves the preservation of style and orientation of Variscan structures in the Bundschuh basement unit. Essentially, an open N-trending fold is unconformably overlain by the above mentioned Lower Triassic Stangalm Quartzite. The basement micaschist displays three stages of deformation. Deformation stage D1 relates to the formation of a penetrative foliation within amphibolite facies conditions as pseudomorphs after staurolite testify. The second deformation stage D2 is represented by formation of E-W-trending isoclinal folds similar as in the wider surroundings. The isoclinal folds are again refolded in open, N-trending folds, representing deformation stage D3. This fold is discordantly cut and overlain by the Stangalm Quartzite. These relationships argue for a Variscan age of the dominant metamorphism within amphibolite facies conditions.

The pre-Alpine deformational structures at this angular unconformity indicate Variscan N–S shortening as the most dominant structure. This is in line with reports suggesting Variscan ca. SSW-directed SSW–NNE shortening at the famous angular unconformity between Devonian limestones and the Permian Prebichl Fm. at the structural base of the Northern Calcareous Alps (NEUBAUER, 1989). Together, these structures indicate ca. N–S resp. NNE–SSW Variscan shortening within present-day coordinates. However, this must be confirmed by further regional investigations.

NEUBAUER, F. (1989): Late Variscan structures of the Eastern Greywacke Zone (Eastern Alps). - Neues Jahrbuch für Geologie und Paläontologie Monatshefte, 1989/7: 425–432.

PISTOTNIK, J. (1976): Ein Transgressionskontakt des Stangalm-Mesozoikums (Gurktaler Alpen, Kärnten/Österreich). - Carinthia II, 166/86: 127–131.