



## **Extraction faulting and out-of-sequence thrusting in collisional orogeny - An example from the Swiss-Italian Western Alps**

F. Kirst (1), N. Froitzheim (1), T. Nagel (1), B. Leiss (2), and J. Pleuger (3)

(1) Steinmann-Institut, Universität Bonn, Germany (fredster@uni-bonn.de), (2) Geowissenschaftliches Zentrum, Universität Göttingen, Germany, (3) Geologisches Institut, ETH Zürich, Switzerland

In the Pennine Alps of Switzerland and Italy a stack of nappes derived from oceanic and continental units of the Piemonte-Ligurian paleogeographic domain is exposed. From bottom to top these are the oceanic Zermatt-Saas and Combin zones and the continental Sesia/Dent Blanche nappe. Different Alpine peak pressures have been estimated for these units with the highest pressures of ca. 3.2 GPa in the Zermatt-Saas zone (Groppo et al., 2009), lower pressures of ca. 1.3 GPa in the Combin zone (Bousquet et al, 2008) and intermediate pressures of up to 2.0 GPa in the Sesia/Dent Blanche nappe (Lardeaux & Spalla, 1991). Therefore, a pressure gap of 1.9 GPa exists along the Combin Fault, the contact between the Zermatt-Saas and Combin zones, and a gap of 0.7 GPa along the Dent Blanche Basal Thrust which separates the Sesia/Dent Blanche nappe from the underlying Combin zone. Due to the difference in peak pressures, the Combin Fault has often been interpreted as a large top-SE normal fault accommodating exhumation of the underlying (ultra)high-pressure rocks (e.g. Reddy et al., 1999). However, there is structural evidence that the Combin Fault is in fact an extraction fault (Froitzheim et al., 2006) and that exhumation of Zermatt-Saas (ultra)high-pressure rocks was due to SE-directed extraction of the Sesia/Dent Blanche block originally located between the Zermatt-Saas and Combin zones. Therefore, the Dent Blanche Basal Thrust would represent a top-NW out-of-sequence thrust along which high-pressure rocks of the Sesia/Dent Blanche nappe were thrust over greenschist-facies rocks of the Combin zone. On the basis of the above-mentioned peak pressure estimates and our own structural observations we propose the following tectonic scenario:

Initial nappe stacking resulted in a configuration with the Zermatt-Saas zone in the footwall of the Sesia/Dent Blanche nappe and the Combin zone as the structurally highest unit which was thrust over the Sesia/Dent Blanche nappe in the SE and the Zermatt-Saas zone in the NW. Subsequently, the Sesia/Dent Blanche block was extracted to the (S)E which is indicated by high-pressure top-(S)E shear bands within eclogites and metasediments of the Zermatt-Saas zone. At the trailing edge of the extracting block the Zermatt-Saas and Combin zones came into direct contact. Ongoing NW-directed thrusting of the Combin zone led to formation of a greenschist-facies shear zone with a top-NW shear sense in the uppermost part of the Zermatt-Saas zone. In a last step the Sesia/Dent Blanche nappe was thrust out-of-sequence over the Combin zone resulting in formation of top-NW mylonites along the Dent Blanche Basal Thrust.

The proposed model and sequence of thrusting is able to explain the pressure gaps and is consistent with the observed shear senses. Therefore, the recognition of extraction faults and out-of-sequence thrusts has implications for the structural restoration of a nappe stack. Additionally, extraction faulting provides a mechanism for the exhumation of (ultra)high-pressure rocks.

### References:

- Bousquet, R., Oberhänsli, R., Goffé, B., Wiederkehr, M., Koller, F., Schmid, S.M., Schuster, R., Engi, M., Berger, A. & Martinotti, G. (2008): Metamorphism of metasediments at the scale of an orogen: a key to the Tertiary geodynamic evolution of the Alps. In: Siegesmund, S., Fügenschuh, B. & Froitzheim, N. (eds.): *Tectonic Aspects of the Alpine-Dinaride-Carpathian System*. Geological Society, London, Special Publications, 298, 393–411.
- Froitzheim, N., Pleuger, J. & Nagel, T.J. (2006): Extraction faults. *J. Struct. Geol.*, 28, 1388-1395.
- Groppo, C., Beltrando, M. & Compagnoni, R. (2009): The P-T path of the ultra-high pressure Lago Di Cignana and adjoining high-pressure meta-ophiolitic units: insights into the evolution of the subducting Tethyan slab. *J. Met. Geol.*, 27, 207-231.
- Lardeaux, J.M. & Spalla, M.I. (1991): From granulites to eclogites in the Sesia Zone (Italian Western Alps), a record of opening and closure of the Piedmont ocean. *J. Met. Geol.*, 9, 35-59.
- Reddy, S.M., Wheeler, J. & Cliff, R.A. (1999): The geometry and timing of orogenic extension: an example from the Western Italian Alps. *J. Met. Geol.*, 17, 573-589.