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# POST-NAPPE FOLDING VERSUS BACKTHRUSTING IN THE WESTERN ALPS

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The main schistosity along the ECORS-CROP profile changes from a SE-dip in the external part of the Briançonnais (Front Briançonnais) to a dominant NW-dip in the southeastern part (Gran Paradiso). This change in dip is directly linked to the overturning of the entire nappe pile. Metamorphic grade also changes from subgreenschist facies in the more external Zone Houillère to eclogite conditions in the more internal Schistes Lustrés and the Gran Paradiso "massif". In the west metamorphic grade increases towards tectonically higher units, while in the east a decrease in the metamorphic grade towards tectonically higher units is observed. Classically the change in dip, the so-called fan-structure of the Briançonnais, was explained by outward directed thrusting followed by inward directed backthrusting (e.g. BUTLER and FREEMAN, 1996).

New structural investigations carried out in the Zone Houillère form the Petit Saint Bernard Pass to the Gran Paradiso allow us to distinguish the following three deformation phases. The first deformation phase is only preserved as relicts such as microlithons of chloritoid or as an old schistosity formed by chloritoid and phengite in garnets. D1 is associated with peak pressure conditions in terms of metamorphism. The second phase of deformation is characterised by isoclinal folds and a strong W to NW oriented stretching lineation L2. D2 fold axes are sub-parallel to L2 and the strong axial planar cleavage of D2 folds forms the main foliation. In the internal parts the D2 schistosity is outlined by the orientation of white mica, epidote and chlorite, which replace high-pressure mineral assemblages. Therefore D2 corresponds to the decompression part of the P-T path. Over the entire area shear senses associated with L2 consistently indicate top-to-the W to NW movement. D3 is characterised by open folds on all scales with gently SE dipping (5°–20°) axial planes and, in general, by NE-SW oriented fold axes. Towards higher structural levels F3 folds become tighter.

D3 mega folds overprint a pre-existing nappe stack formed during D1 and D2. In particular the overturning of tectonic contacts such as (i) the contact between the Zone Houillère and the Ruitor massif in the external part and (ii) the contact between the Schistes Lustrés and the internal Brianconnais in the internal part can be directly observed in the field. Retrodeformation of the D3 post-nappe folds suggests that these contacts (including the so-called Entrelor shear zone which was erroneously attributed to backthrusting by BUTLER and FREEMAN, 1996) originally represented top-to-the northwest thrusts, which formed during the final stages of nappe stacking (D2).

Based on structural mapping the axial traces of two such large-scale D3 folds could be identified. In the external part the change of dip of the main foliation from a SE-dip in the Valaisan and the external parts of the Zone Houillère over a subvertical dip within the Zone Houillère, to a predominant NW dip within the Ruitor massif is due to the large-scale Ruitor antiform. In the internal part the Valsavaranche synform was evidenced in the upper parts of Val Grisenche and Val di Rhêmes. This second and structurally higher D3-megafold turns the nappe stack back

into an upright position such as observed in the uppermost part of Valgrisenche (i.e. the Grande Sassière area).

These observations show that the third phase of deformation refolds the entire nappe stack on a large scale such as first described by Argand (1911). While similar large scale post-nappe refolding with subhorizontal axial planes has also been described by modern workers in the Swiss-Italian Alps (for example in the form of the Mischabel backfold or the backfolds of the Suretta nappe (MÜLLER, 1982; SCHMID et al., 1996) this old idea has not yet been revived in the French-Italian Alps.

These structural data show the so-called fan-structure of the Briançonnais as well as the overturning of the whole nappe stack are due to large scale post-nappe folding (Ruitor antiform and Valsavaranche synform). However, no evidence for backthrusting, frequently reported in the literature (e.g. BUTLER & FREEMAN, 1996), was found. Hence we purpose that post-nappe folding rather than backthrusting along the ECORS-CROP profile is responsible for the present day geometry of the nappe stack. The syn-D3 wedging of the Gran Paradiso massif into the nappe pile might be responsible for this refolding which is associated with vertical shortening, following Argand (1912) who wrote: "*Le rétroplissement par sous-charriage (Rückfaltung durch Unterschiebung) est une fonction normale des grandes chaînes en mouvement*" which we freely translate as following: "backfolding by underthrusting is a common feature of growing mountain chains".

## References


ARGAND, E., (1911): Bull. Soc. Vaud. Sc. Nat., t. **XLVII**, procès-verbal de la Séance du 17 Mai.

ARGAND, E., (1912): Bull. Soc. Vaud. Sc. Nat., t. **XLVIII**, procès-verbal de la Séance du 20 Mars.

BUTLER, R.W.H. & FREEMAN, ST. (1996): Can crustal extension be distinguished from thrusting in the internal parts of mountain belts? A case history of the Entrelor shear zone, Western Alps. – Journal of Structural Geology, Vol. **18**, 7, 909–923.

MÜLLER, R., (1982): Die tektonische Erforschung der penninischen Alpen. – Eclogae Geol. Helv., **75/3**, 447–449.

SCHMID, S.M., PFIFFNER, O.A., FROITZHEIM, N., SCHÖNBORN, G. & KISSLING, E., (1996): Geophysical-geological transect and tectonic evolution of the Swiss-Italian Alps. – Tectonics, **15**, 5, 1036–1064.



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