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SHORT NOTE

The lower Penninic nappes in the western Alps: the link between Helvetic and Penninic

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INTRODUCTION

ONE of the most significant advances in the nappe geology of the western Alps since the precursors like Argand and Lugeon has been provided by Escher *et al.* (1993). They presented new data and interpretations concerning the middle Penninic nappes and the Helvetic nappes.

However, their discussion about nappe geometry in a profile of the Swiss western Alps, does not include a very important part of the lower Penninic: the link between the Antigorio nappe and the middle Penninic thrust. Nevertheless, recent works have considerably improved the understanding of these lower Penninic units, in France as well as in Switzerland (Burri 1967, 1979, Antoine 1971, 1972, Steck 1984, Leu 1986, Merle 1987, Jeanbourquin & Burri 1989, Ackerman *et al.* 1991, Burri *et al.* in press). Moreover, recent kinematic interpretations of the Alps place an important part of the Alpine subduction in these lower Penninic units (e.g. Ackermann *et al.* 1991, Stampfli 1993).

The aim of this Short Note is to bridge that very important gap of description between the middle Penninic and the Helvetic, and to invite Alpine geologists to an open discussion. Most of these new results concern the root zone of the Central Alps in the Brigue–Simplon area. They provide information crucial to the understanding of the interrelations between the lower Penninic units, the zone of Sion–Courmayeur, the Prealpine nappes, the 'Ultrahelvetic' and the Helvetic.

Due to the strong uplift of the Lepontine Alps (Spicher 1980), the lower Penninic units largely crop out east of the Brig, and display a complete pile of basement and cover nappes (gneiss cores/Bündnerschiefers) as established by the work of Schmidt & Preiswerk (1908) and many others. Although these rocks are highly metamorphosed (amphibolite facies) and have recorded several ductile deformations, it has been possible to recognize lithologic successions of metasediments and partly to link them with basement units. Between the middle Penninic and the Antigorio nappes, four main tectonic units, can be recognized, from top to bottom (Figs. 1 and 2).

(1) The '*zone Houillière*' is a zone of Carboniferous to Triassic sediments. It marks the thrust of the middle Penninic nappes. Hence, it is mostly chaotic and presents many characteristics of mélanges (e.g. Burri & Jemelin 1983). Parts of this zone might be the basement of the Flysch Trilogy, but this assertion remains very uncertain, due to the presence of another adjacent chaotic unit, the 'Versoyen' (see below).

(2) The '*Flysch Trilogy nappe*' comprises a mid- to upper Cretaceous (Lower Tertiary?) clastic sequence called the 'Flysch Trilogy', and a basal chaotic unit, the 'Versoyen'. The 'Flysch Trilogy' is represented in the western Swiss Alps by a very characteristic succession, from bottom to top: the 'Couches de l'Aroley', the 'C. des Marmontains', and the 'C. de Saint-Christophe' (Trümpy 1952, 1955). It crops out over 200 km, from the Simplon Pass to the Aosta Valley (Italy) and Moûtiers (France) (Antoine 1971, 1972). With a present-day thickness of up to 1 km, it represents the major unit of the zone of Sion–Courmayeur. Furthermore, due to its larger extent than other lower Penninic units (and the other units of the zone of Sion–Courmayeur), this sequence provides a clue to the understanding of the lower Penninic Flyschs and the Bündnerschiefers in the whole Alpine Chain (Trümpy 1980). The recognition of that 'Flysch Trilogy' has led to a very detailed geological map in the root area of Simplon–Brig (Burri *et al.* in press), which displays new cover–basement relationships and spectacular fold patterns (Fig. 1). Near Moûtier (France, around 200 km southwest of Brig), the 'Flysch Trilogy' lies on a chaotic complex called 'Versoyen' or 'ensemble ante-flysch' by Antoine (1971, 1972). In the Simplon–Brigue area, a similar complex zone occurs at the base of the Flysch Trilogy. It consists of a mélange of manganese-rich black schists with blocks and slivers of meta-gabbro, meta-basalts and serpentinites, and is locally accompanied by slivers of gneiss, Mesozoic breccias and conglomerates (Jeanbourquin & Burri 1991). It has been tentatively suggested that this mélange is the

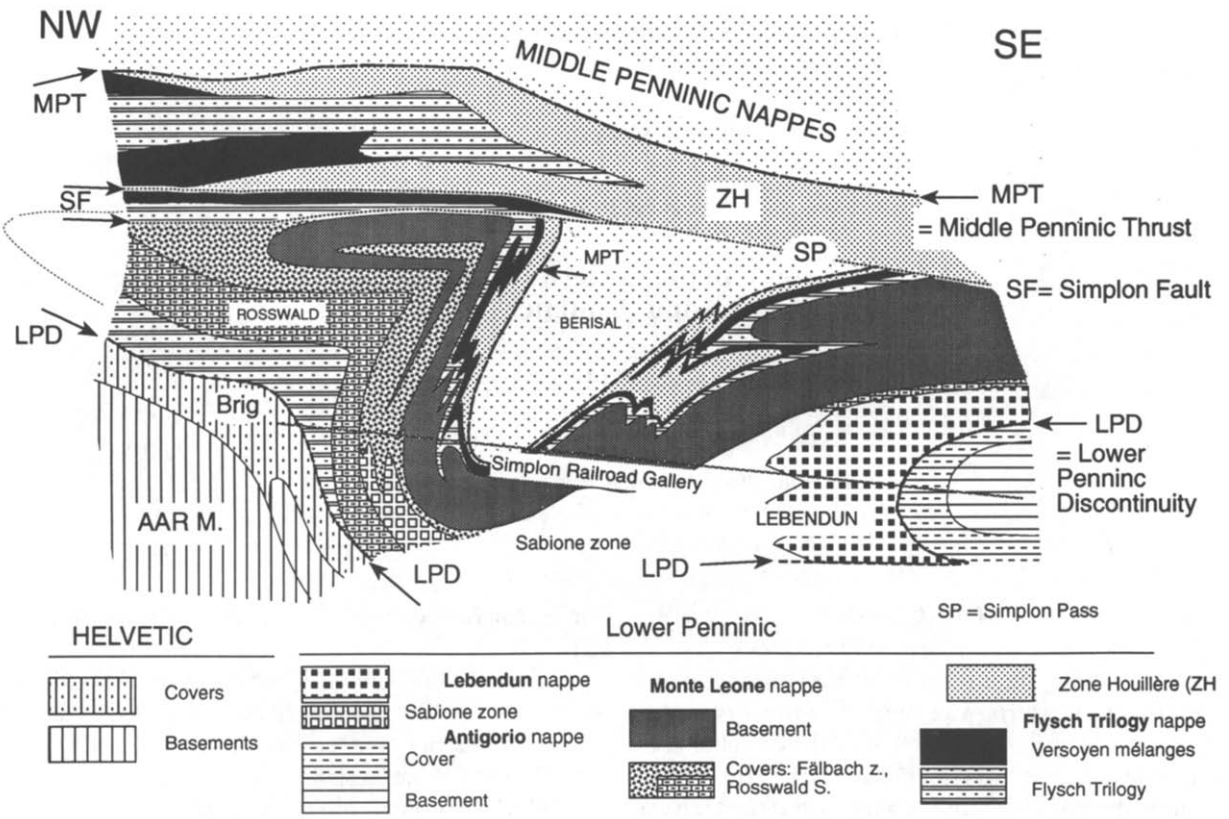

Fig. 1. Schematic profile near Brig, Switzerland, showing the lower Penninic comprised between the Antigorio nappe and the middle Penninic thrust (see deepest part of fig. 2 of Escher *et al.* 1993). The Simplon fault (SF) is a late normal/right-lateral fault evolving from a ductile shear zone to a brittle fault with the uplift of the Lepontine dome. Some units are intentionally thickened to show the geometric relations.

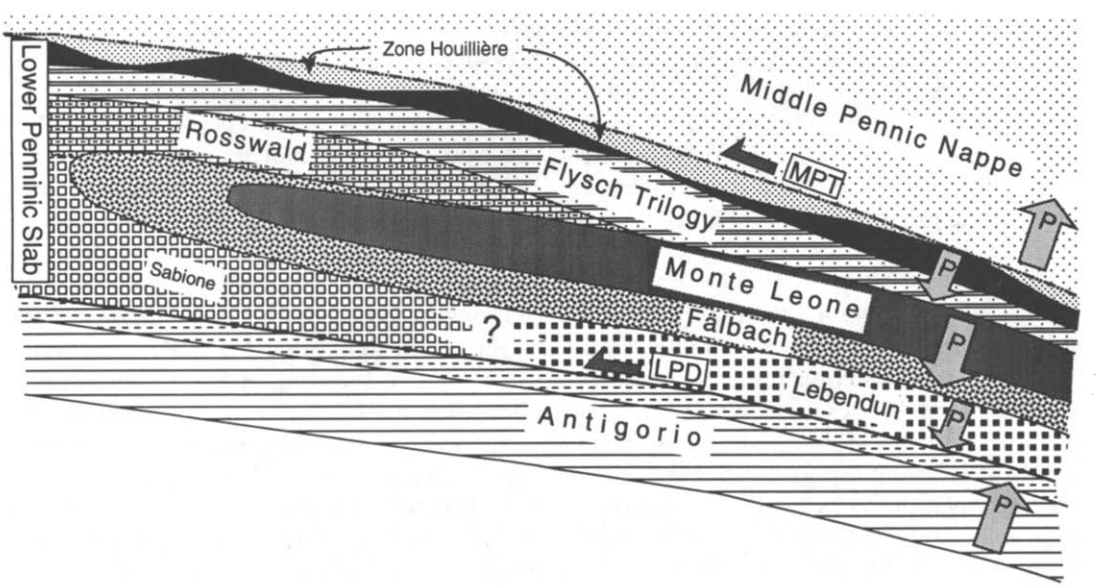

Fig. 2. A possible reconstruction of the nappe pile during the early stages of the ductile deformation. Not to scale.

'basement' of the flysch (Jeanbourquin & Burri 1991). However, as the Versoyen and the Zone Houillière form a large mélange zone due to the strong imprint of the middle Penninic thrust, it is very unreliable to allocate a precise basement to the Flysch Trilogy.

(3) *The Monte Leone nappe* presents a large ductile recumbent fold (amplitude over 30 km) of crystalline basement with a narrow Triassic cover of quartzite and dolostone. According to Leu (1986), the post-Triassic cover is represented by the Fäldbach zone (chaotic conglomerates), a thin band of greenstones and the Rosswald series (clastic sequence). These rocks are post-Triassic but they are not dated. There are still uncertainties in the allocation of these Mesozoic (Ceno-

zoic?) meta-sediments, notably below the nappe (zone of Sabbione). As depicted in Fig. 2, the interrelations between the Fäldbach zone, the Rosswald Series and the Monte Leone crystalline core are complex, and they suggest either early thrusting or different provenance, or both.

(4) *The Lebendun nappe.* According to the new interpretation of Spring *et al.* (1992), the Lebendun nappe should be a Mesozoic sequence lying over a Paleozoic basement, the Valgrande Gneiss.

The recognition of the Flysch Trilogy in the Simplon area has several practical and theoretical consequences. It indicates a Cretaceous age to the former Jurassic 'Bündnerschiefers'. It has also allowed detailed geological mapping (Burri *et al.* in press), which accurately depicts a very spectacular geometry resulting from the interference of at least three phases of ductile folding and early thrusting (see e.g. fig. 2 of Ackermann *et al.* 1991). Interference patterns of superimposed folds, close to the type III of Ramsay (1967, p 531), are observable from the outcrop-scale to the map-scale (Fig. 1). The geological mapping surprisingly reveals that the Flysch Trilogy forms a paradoxal nappe, where the stratigraphic succession Aroley–Marmontain–Saint-Christophe is consistently inverted (Figs. 1 and 2). The minimal apparent translation is over 30 km. Furthermore, a possible reconstruction of the nappe pile before the late phases of ductile folding (Fig. 2) suggests that the Monte Leone nappe and the Lebendun unit (Spring *et al.* 1992) are also inverted; these are nappes without normal limb in their present-day position! Among these three units, only the Monte Leone is a folded basement nappe; its Mesozoic cover distribution (Fig. 2) may represent either a palinspastic distribution or a cover replacement after the initial folding.

In the case of the Lebendun and Monte Leone nappes, this type of geometry can be easily explained by considering the interrelations between high-level and low-level shear zones during crustal compression as suggested by Escher *et al.* (1993, fig. 7). In the case of the 'Flysch Trilogy' nappe, the explanation is more difficult, due to the well constrained stratigraphy and the lack of basement. Hence, it is tentatively proposed to group the three units, characterized by an atypical inverted geometry, into the lower Penninic slab, which thus constitutes a paradox in the folded nappe geometry of the western Swiss Alps presented by Escher *et al.* (1993).

Models of the Alpine collision often involve a multistage subduction (see Hunziker *et al.* 1989 for a review): the classic 'eoalpine' subduction of the Piemontais–Ligure Ocean and a less typical (or simply less observable) upper Cretaceous–lower Tertiary subduction, where vanished the 'Valaisan Ocean' lithosphere. Considering these models, parts of that slab (e.g. the 'Versoyen') represent subducted lithologies of the 'Valaisan Ocean'. Together with the lower Penninic flyschs (the 'Flysch Trilogy'), these mélanges are probably the remains of a late Cretaceous to early Tertiary accretionary prism developed between the Briançonnais and the Helvetic domains (Ackerman *et al.* 1991, Jeanbourquin & Burri 1991, Stampfli 1993). New HP–BT data up to 2000 MPa in several units of the lower Penninic (at least in the 'Versoyen' and in the Monte Leone nappe, see Ackerman *et al.* 1991, Stampfli 1993) emphasize the hypothesis that the whole lower Penninic slab rose from deep in the crust. Among the two essential tectonic discontinuities limiting this slab, the upper, marked by two strongly deformed chaotic zones, the 'Zone Houillière' and the 'Versoyen', is very important. It suggests that processes similar to 'tectonic erosion' or 'subduction erosion' have been active at the boundary between middle and lower Penninic (or 'Valaisan' and 'Briançonnais'). On the other hand, the lower discontinuity could represent the boundary between the continental crust of the Helvetic domain and the thinned continental crust of the External Valaisan domain. Regarding this second subduction, the presence of the lower Penninic slab evokes many questions about Alpine kinematics. How deep and how important was this subduction? Was its vergence really south? When did the detachment of the Prealps occur (if it did)?

It is hoped that this brief presentation of the lower Penninic paradox, characterized by the importance of the Flysch Trilogy, and nappe geometry characterized by only inverted limbs, will provoke discussion and help understand the kinematics of Alpine subduction.

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