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

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In their discussion, Cannic *et al.* compare two profiles of the Western Alps separated by around 100km, presenting very similar tectonic units (the Lower Celtides, Hsü 1994) with a different thermal evolution (rocks in the Tarentaise profile evolved in colder and more brittle conditions). Their discussion encompasses a wide span of problems and it enlightens puzzling problems of the present day Alpine geology such as the integration of a multitude of data from many disciplines of Earth Sciences. What is the significance of one set of data, and what priority must be favored for interpreting data?

The nappe geometry in the profile of the Western Alps in Switzerland (Escher *et al.* 1993, with NFP20) presents important features which are less clear (or absent) in the French Alps cross section (Cannic *et al.*, with Ecors-Crop), for instance: the opportunity to clearly distinguish at least two main phases of deformation D_1 and D_2 (Steck 1984, Merle 1987). Particularly in the Simplon area, the remarkable D_2, evolving from ductile to brittle conditions (Mancktelow 1985), testifies to the existence of a late (younger than 20–22Ma) normal/dextral fault coeval with backfolding (the Simplon Fault). Most of the related structures cut across the older fabrics at high angle (fig. 1 of Jeanbourquin 1994b). Therefore, the region east of the Simplon–Visp line displayed on the geological map Brig 1289, provides very good outcrops to describe D_1 and the older deformation ($D_{\emptyset i}$) in the Lower Penninic units. The D_1 is a very ductile deformation featuring the crystalline nappes (Steck 1984), and it does subsist even older phases of deformation as attested by folded thrusts ($D_{\emptyset i}$ folded by D_1). Hence, the lower Penninic nappes below the Simplon fault are a key for understanding the link

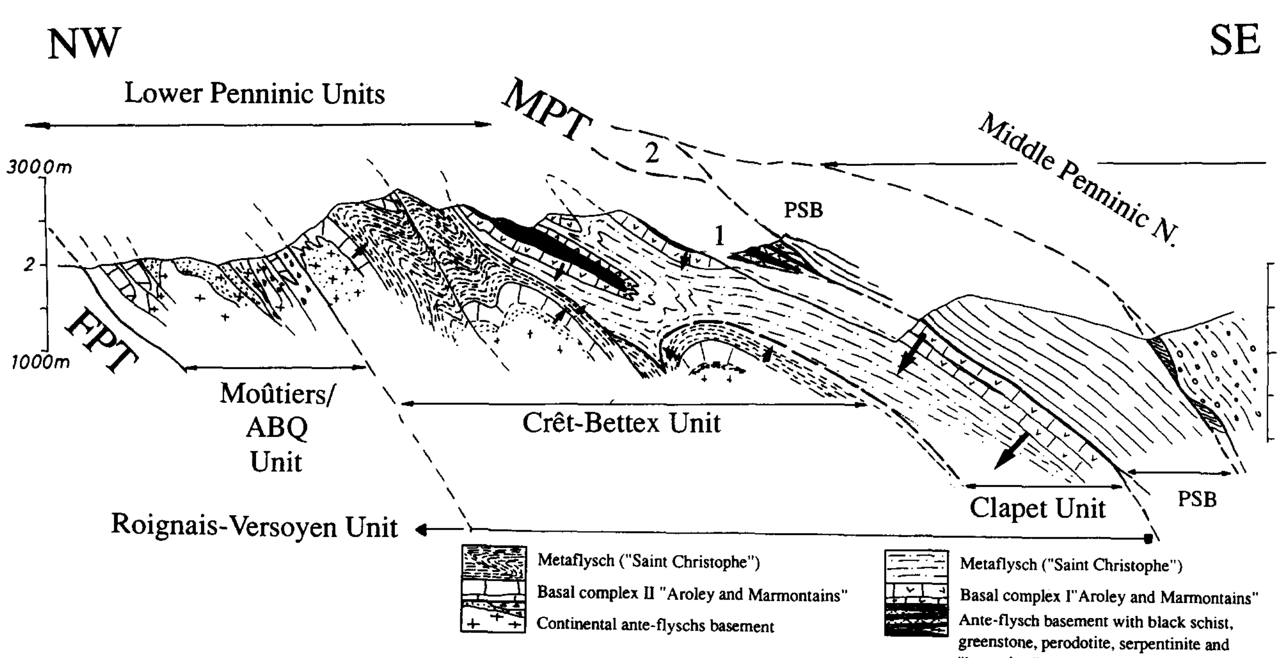

Fig. 1. WNW–ESE cross-section of the lower Penninic units located North of Bourg-St-Maurice (compare with fig. 2 of Cannic *et al.*). It is redrawn from fig. 7 of Antoine *et al.* (1992) and reinterpreted in regards of anteflysch-basement, the absence of a visible synformal hinge filled with flysch, and anastomosing thrust surfaces of the Middle Penninic Thrust (MPT). 1–Projected Versoyen unit of fig. 2 of Cannic *et al.*); 2–lens of Pierre Avoi type unit located behind of the Petit-St-Bernard pass (Laityre, Italy); PSB–Petit-St-Bernard unit.

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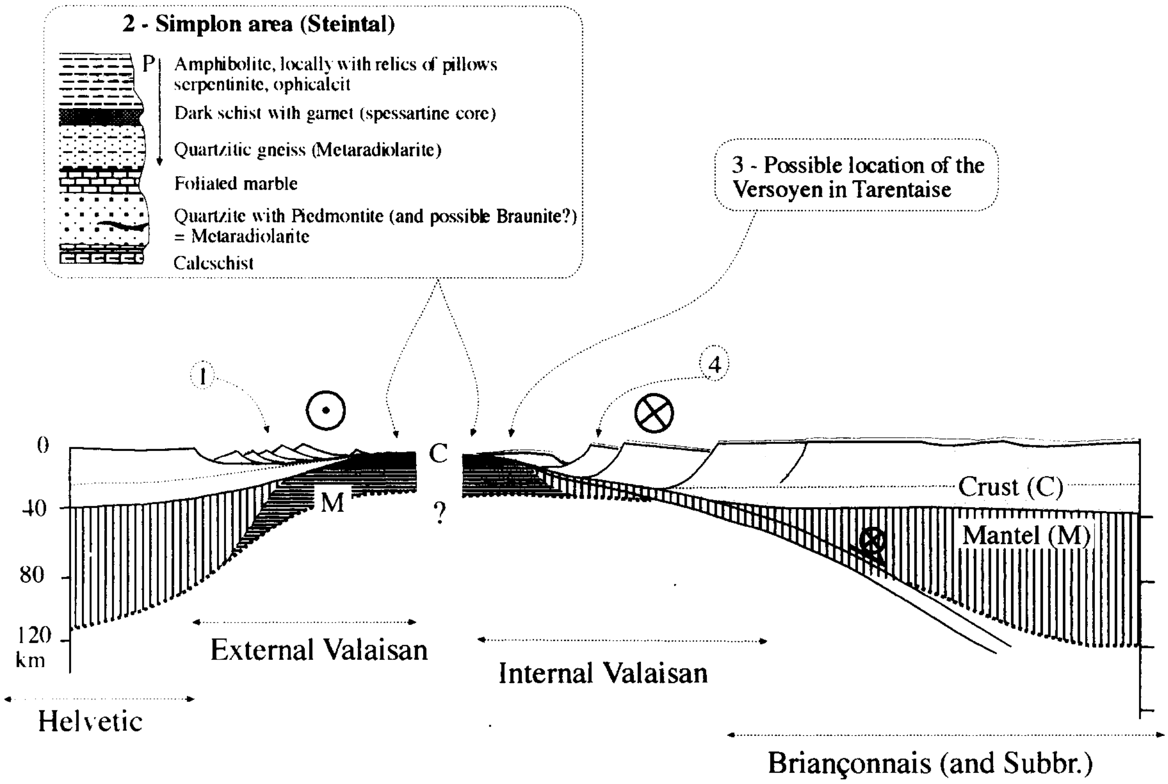

Fig. 2. Tentative reconstruction of the Valaisan Ocean in the Upper Jurassic or Lower Cretaceous ? 1–Parts of the future granitic nappes with ante-flysch sequences (e.g. Monte-Leone, Valgrande, Antigorio or Moûtiers/Crêt-Bettex/Quermoz and Ultrahelvetics mélanges Jeanbourquin 1994b); 2–Oceanic domain as recorded in the Versoyen of the Simplon area (Ophiolitic sequence piedmontite and possible braunite (?)-rich quartzite described by Frank 1975), 3–'Versoyen' of Cannic *et al.*, with leptynite intruded by basalts, 4–location of the future Pierre-Avoi type units and zone Houillère.

between the Helvetic and Penninic units. In western Valais or in the western French Alps, the geometry of the tectonic units also results from several superposed phases of deformation, but (i) the deformation was 'less ductile', and (ii) it is harder to separate the deformation events and to hypothesize about their significance. In response to Cannic *et al.* 1995, I will begin with the more recent deformations, and then will go back in time up to the speculated Valaisan Ocean.

The Neogene–Quaternary reactivation by late normal-fault components of older structures, such as the Frontal Penninic Thrust, has been pointed out recently south of the Mont-Blanc by Seward & Mancktelow (1994). Together with small-scale shear zones, this appears to be an important feature affecting the whole Lower Penninic between Switzerland and France. But, as there are little structural data already published about these late shear zones in France and Italy, Cannic *et al.* would need to describe these very interesting fabrics in detail for understanding (i) their relationships with the older structures in the Tarentaise area, and (ii) the extent in time and space of these lineations within the Lower and Middle Penninic pile. In regard to the Simplon profile (figs. 1 and 2 of Jeanbourquin 1994b), it follows that the Frontal Penninic Thrust (fig. 2 of Cannic *et al.* 1995) may correspond to the Lower Penninic Discontinuity (PF=LPD) plus probably superimposed later movements. The Middle Penninic thrust (MPT) has probably the same characteristics of reactivation. Both structures present a highly reflecting pattern in deep seismic profiles (Nicolas *et al.* 1990) which could be *very tentatively* related to the late structures.

This assumption brings us to the problem of the significance of older structures in regard to the recent ones. I will focus on field and map aspects of the zone limiting the Lower Penninic Flysch (Flysch Trilogy Nappe) and the Middle Penninic nappes. One can reasonably postulate that the MPT does not present a single surface but a sum of anastomosing surfaces. In turn, the MPT can be considered as a volume made of blocks and slices tectonically mixed within a dark pelitic matrix made of either Carboniferous schists or various black schists (originated from many units). This zone combines several tectonic and sedimentary mélanges (e.g. Jeanbourquin 1991, 1994a). Using the term mélange as a tectono-stratigraphic unit (Hsü 1968) is appropriate for describing the units related to the MPT (MPT mélange). Although some big slices may still present a coherent sequence, chaotic fabrics are common, notably at map scale or outcrop scale. Indeed, the 'Versoyen' shows remarkable chaotic fabrics not only in the Simplon area, but also close to Cannic's cross-section where it contains blocks of acidic rocks in granulite facies (?) called leptynite by Antoine (1971, figs. 5 and 6), these blocks being intruded by basalts. The lower Zone Houillère also shows a remarkable chaotic fabric (with blocks of Triassic evaporites, quartzite, dolostone blocks and coherent or chaotic slices, e.g. Pierre Avoi) from the Simplon area in Switzerland up to Italy (e.g. Burri & Jemelin 1983, Burri *et al.* 1992, Antoine *et al.*

1978); the Sapey unit next to Bourg-St-Maurice presents a similar map aspect (e.g. Antoine *et al.* 1992). Therefore, one must consider the MPT as an amalgam of mélanges (at least two) resulting from several tectonic movements, possibly overprinting sedimentary chaotic processes (notably the Pierre Avoi type Units) and some mélanges containing HP/LT assemblages. As these mélanges and the associated thrusts are folded by D_1 in the Simplon area, below the dominant surface of the Simplon Fault, they must necessarily have been formed at an early stage, preceding the strongly ductile deformation (see fig. 2 Ackerman *et al.* 1991).

Northwards, these mélanges are in contact with the Flysch Trilogy Nappe (FTN) which exhibits an important upside-down limb also in the Tarentaise area as recognized by Antoine (1971). Figure 1 presents a cross-section constructed from the map Bourg-St-Maurice (fig. 7 of Antoine *et al.* 1992). Based on (i) the absence of any visible synformal hinge, (ii) important differences within the ante-flysch basements, and (iii) disparities of the lithology of Aroley–Marmontains (NNE-facies and SSW-facies, P. Antoine, oral communication), one can postulate a separation of the Roignais–Versoyen (fig. 2 of Cannic *et al.*) into two tectonic units: the Crêt-Bettex Unit (FTN + black schists on a continental basement) and the Clapet Unit (FTN + Versoyen made of schists with greenstones, serpentinite and peridotite and auxiliary granitic blocks, presence of HP-paragenesis). Therefore, the flysch trilogy nappe marked by a reversed trend defined in the Simplon area, might be followed, despite some complications, into France, where it vanishes together with the whole Lower Penninic. Conversely, the exact correlation of the 'normal' Lower Penninic units between Tarentaise (e.g. Crêt-Bettex, Moûtiers, Quermoz) with the Eastern Alps via the Central Alps (e.g. Monte–Leone–Lebendun–frontal flysch trilogy) remains controversial; it would necessitate a long discussion which should involve also the Prealpine units (Jeanbourquin 1994a and Jeanbourquin & Burri 1991 for preliminary statements). Nevertheless, an important fact must be considered for correlating units between Western and Central Alps: the limits of tectonic units seem oblique in regards to the Mesozoic and Cenozoic trends (fig. 3 of Escher 1988 of the Briançonnais domain or fig. 2 of Jeanbourquin *et al.* 1992 for the Helvetic domain). Consequently, for instance, the equivalent of the Crêt-Bettex flysch could be deeply buried or simply absent in the Simplon area. In turn, one can reasonably postulate that a lot of material of the Valaisan domain might be missing within the MPT mélange zone. Consequently, a suture including at least the Flysch Trilogy Nappe and the MPT is not completely absurd, especially since this zone displays a very large extent (from Moûtiers and possibly up to the eastern Alps), many HP–LT data and scattered ophiolitic suites.

Finally, is it subjective or speculative to consider a Valaisan Ocean subducted within a MPT suture as stated by Cannic *et al.* (1995)? I have focussed Fig. 2 on a tentative reconstruction of the Valaisan Ocean and the main litho-stratigraphic evidence supporting the existence of ophiolitic-suites in the Simplon area. Indeed, in the Binntal–Simplon–Viège region, the Versoyen Unit presents much evidence of Alpine ophiolites (Frank 1975, Kuensen 1972), as well as mafic rocks and metasediments. Therefore, regarding the Valaisan Ocean, I favorably adhere to the paleogeographic views of Trümpy (1980), Kelts (1981), Weissert & Bernoulli (1985) or Gealey (1988) which open the Valaisan Ocean from the Valais towards east. This appears to be reasonable in terms of field observations and geological maps of eastern and central Alps. In Switzerland, it forms a suture in between the Monte–Leone crystalline core and the Berisal Gneiss (Brançonnais basement). Extending the Valaisan Ocean towards the west and south during the early Cretaceous is speculative (Stampfli 1993). This new idea might have interesting developments for considering large scale geodynamics in regard to geophysical data and tomographic images of the mantle (Spackman 1990); but it is important to recall that there is no field evidence supporting a Valaisan Ocean in France beyond the Tarentaise. Therefore, considering the geodynamics, I would prefer to link the Valaisan Ocean with a large transform zone (e.g. Kelts 1981, Debelmas & Sanduslescu 1987), which could bridge the Piemont/Valaisan Ocean of the eastern Alps to the Gascogne Gulf. Otherwise, this transform zone explains many geological characteristics of the Valaisan domain (e.g. Jeanbourquin & Burri 1991).

In conclusion, there are some zones in the Alps where the geological record is very incomplete due to early tectonic phases obliterated by several superimposed ductile and brittle deformations. This is particularly the case of the units located between the Helvetic nappes and the Middle Penninic nappes. Hence, it is important to find units presenting a large extent, such as the Flysch Trilogy Nappe and its associated parts. This approach, constrained by a large-scale synthesis of field and map data, should prepare the ground for any systematic studies of rock geochemistry or deep seismic profile. It is important to provide sound dates of the magmatism and the Alpine metamorphic events.

REFERENCES

Ackermann, T., Burri, M., Jeanbourquin, P. & Mancktelow, N. 1991. La zone Sion-Courmayeur en Haut-Valais et comparaison avec les flyschs valaisans dans les Alpes occidentales. *Eclogae Geologicae Helvetiae* **84**, 255–263.

Antoine, P. 1971. La zone des Brèches de Tarentaise entre Bourg-St-Maurice (Vallée de l'Isère) et La frontière Italo–Suisse. *Trav. Lab. Géol. Fac. Sci., Grenoble, Mém.* **9**.

Antoine, P., Barféty, J. C., Vivier, G., Debelmas, J., Desmons, J., Fabre, J., Loubat, H. & Vautrelle, C. 1992. Carte géologique de la France à 1:50000—Bourg-St-Maurice, avec notice. **727**, BRGM.

Antoine, P., Féraud, J. & Poulain, P.-A. 1978. Carte géologique de la France à 1:50000, feuille 704, Mont-Blanc, avec notice, *BRGM*.

Badoux, H., Bonnard, E. G., Burri, M. & Vischer, A. 1959. Atlas géologique de la Suisse au 1:25000, feuille 35, 1286 St. Léonard et notice. *Comm. géol. Suisse*

Badoux, H., Burri, M., Gabus, J. H., Krummenacher, D., Loup, G. & Sublet, P. 1971. Atlas géologique de la Suisse à 1:25000, feuille 58, 1305 Morcles. *Commission géologique suisse*, Bâle.

Bearth, P. 1972. Atlas géologique de la Suisse à 1:25000, feuille 61, 1309 Simplon. *Service géologique suisse*.

Burri, M. & Jemelin, L. 1983. Atlas géologique de la Suisse à 1:25000, feuille 77, 1325 Sembrancher—carte et notice.

Burri, M., Frank, E., Jeanbourquin P., Labhart, T., Liszkay, M. & Streckeisen, A. 1993. Atlas géologique de la Suisse à 1:25000, feuille 93, 1289 Brigue. *Service géologique Suisse.*

Burri, M., Fricker, P., Grasmück, K., Marro, C. & Oulianoff, N. 1992. Atlas géologique de la Suisse à 1:25000, feuille 91, 1345 Orsière. *Service hydrologique et géologique suisse.*

Debelmas, J. & Sandulescu, M. 1987. North-Penninic transform zone and problems of palinspastic correlations between the Alps and the Carpathians. *Bull. Soc. geol. France* **3/2**, 403–408.

Escher, A. 1988. Structure de la nappe du Grand Saint-Bernard entre le val de Bagnes et les Mischabel. *Rapp. géol. Serv. hydrol. et géol. natl.* **7**, 26 pp.

Escher, A., Masson, H. & Steck, A. 1993. Nappe geometry in the western Swiss Alps. *J. Struct. Geol.* **15**, 501–509.

Frank, E. 1975. Mineralogisch-petrographische und geochemische Untersuchung en der Berisal Augengneise und der Büdnerschiefer im östlichen Simplonpassgebiet. *Lizentiatsarbeit Univ. Bern.*

Gealey, W. K. 1988. Plate tectonic evolution of the Mediterranean–Middle East region. *Tectonophysics* **155**, 285–306.

Hsü, Kenneth J. 1968. Principles of Mélanges and their bearing on the Franciscan–Knoxville paradox. *Bull. Soc. geol. Amer.* **79**, 1063–1074.

Hsü, Kenneth J. 1994. Tectonic facies in an archipelago model of intra-plate orogenesis. *GSA Today* **4**, 289–293.

Jeanbourquin, P. 1991. L'Ultrahelvétique' de Derborence (Valais, Suisse). *Bull. Murithienne, Soc. valais. Sci. nat.* **109**.

Jeanbourquin, P. 1994a. Early deformation of Ultrahelvetic mélanges in the Helvetic nappes (Western Swiss Alps). *J. Struct. Geol.* **16**, 1367–1383.

Jeanbourquin, P. 1994b. The lower Penninic nappes in the western Alps: the link between Helvetic and Penninic. *J. Struct. Geol.* **16**, 895–898.

Jeanbourquin, P. & Burri, M. 1991. Les métasediments du Pennique inférieur dans la région Brigue-Simplon–Lithostratigraphie, structure et contexte géodynamique dans le bassin valaisan. *Eclogae geologicae Helvetiae* **84**, 463–481.

Jeanbourquin, P., Kindler, P. & Dall'Agnolo, S. 1992. Les mélanges des Préalpes internes entre Arve et Rhône (Alpes occidentales franco–Suisses). *Eclogae geologicae Helvetiae* **85**, 59–83.

Kelts, K. 1981. A comparison of some aspects of sedimentation and translational tectonics from the Gulf of California and the Mesozoic Tethys, Northern Penninic Margin. *Eclogae geol. Helv.* **74**, 317–338.

Merle, O. 1987. Histoire de la déformation dans les Alpes lépontines occidentales. *Bulletin de la Société géologique de France.* **11/1**, 183–190.

Nicolas, A., Polino, R., Hirn, A., Niccolich, R. & Ecors-Crop Working Group, 1990. Ecors-Crop traverse and deep structure of the western Alps. A synthesis. In: *Deep structures of the Alps* (edited by Roure, F., Heitzmann, P. & Polino, R.). *Mémoire Société géoloqigue de France* **156**, 15–28.

Seward, D. & Mancktelow, N. 1994. Neogene kinematics of the central and western Alps: evidence from fission-track dating. *Geology* 803–806.

Spackman, W. 1990. Tomographic images of the upper mantle below central Europe and the Mediterranean. *Terra Nova* **2**, 542–553.

Stampfli, G. 1993. Le Briançonnais, terrain exotique dans les Alpes. *Eclogae Geologicae Helvetiae* **86**, 1–45.

Steck, A. 1984. Structures de déformations tertiaires dans les Alpes Centrales. *Eclogae Geologicae Helvetiae* **77**, 55–100.

Trümpy, R. 1980. *Geology of Switzerland: a guide-book*, Park A. Wepf and Co., Basel.

Weissert, H. J. & Bernoulli, D. 1985. A transform margin in the Mesozoic Thethys: evidence from the Swiss Alps. *Geol. Rdsch.* **74**, 665–679.