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Dedicated to Daniel Bernoulli

Ophiolites and other (ultra)basic rocks from the West-Central Alps: new data for a puzzle

by

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Abstract.–MASSON H., 2002. Ophiolites and other (ultra)basic rocks from the West-Central Alps: new data for a puzzle. *Bull. Soc. vaud. Sc. nat. 88.2*: 263-276.
This paper is a summary of a communication presented at the Davos meeting of the SGS and SSMP on "Birth and Early Evolution of Alpine Ocean Basins" (Sept. 2002). It presents new data on the age, tectonic position and geodynamic significance of all the (ultra)basic rocks of the West-Central Alps that are generally considered in the recent literature as ophiolites of Mesozoic age (see Figure 1). These data require in several cases a serious reconsideration of their geological interpretation:
– Some are genuine Mesozoic ophiolites. Recent age determinations provide new insights on the kinematics of continental break-up and inherent complications.
– Others are Mesozoic but not ophiolites.
– Others may be ophiolites but are not Mesozoic. This is the case of the metabasites ascribed to a so-called "Valais ocean" in the Versoyen and Visp areas.
The new data favour the concept of a slowly propagating and "punctuated" opening of the Alpine Tethys, complicated by aborted attempts and jumps of the spreading ridge.

Keywords: Ophiolites, Alps, Penninic, Tethys.

Résumé.–MASSON H., 2002. Ophiolites et autres roches (ultra)basiques des Alpes Centre-Occidentales: nouvelles données pour une énigme. *Bull. Soc. vaud. Sc. nat. 88.2* : 263-276.
Ce texte résume une communication présentée au colloque «Birth and Early Evolution of Alpine Ocean Basins» de la SGS et de la SSMP à Davos (sept. 2002). Il présente de nouvelles données sur l'âge, la position tectonique et la signification géodynamique des roches (ultra)basiques des Alpes de Suisse W et régions voisines de France et d'Italie qui ont été généralement considérées dans la littérature récente comme des ophiolites d'âge mésozoïque (voir figure 1). Ces données obligent parfois à modifier considérablement l'interprétation géologique de ces roches:
– Certaines sont d'authentiques ophiolites mésozoïques. De récentes déterminations d'âge précisent la cinématique de l'ouverture de la Téthys Alpine et mettent en lumière des complications insoupçonnées.

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– D'autres sont bien mésozoïques mais ne sont pas des ophiolites.
– D'autres encore peuvent être des ophiolites mais ne sont pas mésozoïques. C'est le cas des métabasites du Versoyen et de Viège (Visp) attribuées jusqu'ici à un océan dit «Valaisan».
Ces nouvelles données conduisent à l'idée d'une propagation lente et «hésitante» de l'ouverture océanique, compliquée par des tentatives avortées et des sauts du centre d'expansion.

Mots clés: Ophiolites, Alpes, Pennique, Téthys.

1. Introduction

A tantalizing aspect of the Alpine geological puzzle lies in the presence of (ultra)basic rocks of (possible) ophiolitic affinity in a number of different zones of the orogen. Their tectonic position, age and geodynamic significance may differ and are often controversial.

Figure 1 shows all the (ultra)basic rocks known in the West-Central Alps that have generally been considered in the recent literature as ophiolites of Mesozoic age (in green and dark blue). We have also drawn all the outcrops of basalts of Jurassic and Cretaceous age intruded as dykes or extruded as volcanic flows through continental crust (red "V"). Several localities are new and mentioned here for the first time.

Recent research has produced a wealth of new field and analytical data on these rocks. In some cases they fix more accurately their age and position in the broad framework of classical models, but in other cases they require a complete reconsideration of their geological interpretation:

– Some are genuine ophiolites and are the remnants of Mesozoic oceanic crust and underlying mantle. They bear witness to the former existence of the Piemont ocean, the main branch of the Alpine Tethys.

– Others are Mesozoic but not ophiolites. This is the case of basic volcanites in continental rifts: they may represent early stages of the evolution leading to the ocean, or they may also result, as suggested here, from complications of the opening mechanism, such as aborted attempts of ocean opening in a competition between several rift zones towards the final break-up of the continent, or jumps in the development of the ridge system.

– Others may be ophiolites but are not Mesozoic.

2. Ophiolites from the Piemont ocean: age of the earliest crust and consequences

Most authors agree on the existence of a *Piemont ocean* in the South-Penninic domain. Based on detailed geological and modern geochemical investigations, fundamental advances have been made in recent years towards

a better understanding of the opening mechanism of this ocean, mainly in Eastern Switzerland (*e.g.* MANATSCHAL and BERNOULLI 1999, MÜNTENER and HERMANN 2001) and Liguria (*e.g.* PICCARDO *et al.* 2001). In the region of Figure 1, the Piemont ophiolites are presently distributed between three main tectonic units, each of which is characterized by a specific metamorphic and structural evolution determined by its original position in the ocean (from NW to SE): *Zermatt-Saas*, *Tsaté* (a subdivision of the former Combin zone) and *Gets*. The special case of the *Antrona* ophiolites will be treated below. Moreover it is very probable that several flysch nappes in the Prealps (Gurnigel, Sarine and Dranses) are the detached sedimentary cover of parts of this ocean.

An important progress has been the successful dating of ophiolitic gabbros, settling a longstanding argument over the age of Alpine Tethys. In Western Switzerland they are 166 ± 1 Ma in the Gets nappe (BILL *et al.* 1997) and around 164 Ma in the Zermatt-Saas zone (RUBATTO *et al.* 1998), while they are slightly younger (161 ± 1 Ma) in Eastern Switzerland (SCHALTEGGER *et al.* 2002). We think that this age pattern may be significant:

– Several lines of evidence (BILL *et al.* 2000) support the idea that the Gets gabbros date a very early, embryonic stage of ocean opening. The Zermatt-Saas ophiolites belong to a younger stage.

– There are suggestions of a progressive northeastwards opening of the Alpine Tethys, the lithospheric detachment propagating like scissors in the direction of the pole of rotation.

Here we will only insist on the intimate association in the Gets nappe of the ophiolites with elements of continental crust. The main constituent of this nappe is an *ophiolitic mélange* (in the sense of GANSSER 1974) where blocks and slices of serpentinites, basalts, radiolarites and more rarely gabbros are mixed within a wildflysch matrix with blocks derived from the continent (granites and shallow water sediments). This association may even be observed in individual blocks, *e.g.* basaltic dykes in blocks of granite, or pebbles of granite and crinoidal limestone in basaltic breccias. This clearly points to an origin of the rocks of the Gets mélange in the transition zone between continent and ocean, where we can expect to find remnants of the oldest oceanic crust. This scenario is compatible with the chemical compositions and the isotopic signatures of the basalts (BILL *et al.* 2000).

As the Platta nappe in Eastern Switzerland also represents an ocean-continent transition, it seems reasonable to suppose that the 161 ± 1 Ma old gabbros (SCHALTEGGER *et al.* 2002) date on the Eastern Swiss traverse the same type of event as the 166 ± 1 Ma Gets gabbros do on the Western Swiss one. We suggest that this age difference may give the propagation rate of the spreading center from West to East. Such considerations would be a first step towards 3D-reconstitutions of the opening of the Alpine Tethys. A propagation rate of the order of 50 mm/year is consistent with presently observed values (*e.g.* TAYLOR *et al.* 1999).

The Western Swiss Alps demonstrate a remarkable time coincidence between: (1) the age of the oldest ophiolites; (2) the end of tensile fracturing in the marginal continental crust; and (3) the beginning of its thermal subsidence (well dated from latest Bajocian, SEPTFONTAINE 1983) following a 20 Ma long phase of thermal uplift. A peak of extensional fracturing of the continental crust before the break-up is documented both by:

– The bottom-up filling of fissures in Paleozoic granites by basaltic dykes (in the Gets nappe);

– The top-down filling of fissures in Triassic limestones by continental or shelf sediments (in the Briançonnais s.s. domain of some Middle Penninic nappes, *e.g.* BAUD *et al.* 1979). These fissures are genetically linked to a prominent system of conjugate normal faults.

The Gets nappe also contains the oldest radiolarites reported from oceanic crust in the Alps (middle Bathonian; BILL *et al.* 2001). These rocks reveal a very well preserved radiolarian fauna including 190 species, among which 18 are new (O'DOGHERTY *et al.*, submitted).

3. THE CASE OF THE ANTRONA OPHIOLITES

The ophiolitic *Antrona* zone is specific to the West-Central segment of the Alps. Its ophiolites and associated sediments look at first sight similar to those of the Zermatt-Saas zone, but its tectonic position is different and remains unexplained (*e.g.* PFEIFER *et al.* 1989). Recent research shows that:

– The sedimentary component of the Antrona zone is similar to the Cretaceous part of the Zermatt-Saas zone but Jurassic equivalents are missing.

– The internal structure of the Antrona zone is fundamentally overturned below the overturned limb of the Monte Rosa nappe. This suggests that it originally lay in a normal position over it.

– Structural, stratigraphic and metamorphic relations suggest that the Antrona zone was originally the external part of a unique and coherent Zermatt-Portjengrat-Antrona nappe (see dashed contour in Figure1).

We tentatively explain the origin of this unusual disposition by inferring a northwards jump of the oceanic ridge in the Central Alps at the Jurassic-Cretaceous limit (while spreading would have continued unchanged in the French-Italian segment). This suggestion also explains other peculiarities of the Swiss Alps, such as the late Jurassic uplift of the Briançonnais (s.s.) domain (*e.g.* HÜRLIMANN *et al.* 1996), conspicuously absent in the French Briançonnais, and the synchronous reactivation of its internal border faults (giving rise to the Upper Breccia of the Middle Penninic Brèche and Mont Fort nappes). These facts are consistent with a sedimentary record of the thermal uplift linked to this second phase of continental break-up in the Swiss-Italian Alps.

4. Volcanism on the margins

Absence or scarcity of volcanic dykes of Jurassic age in the margins of Alpine Tethys has earned them the justified reputation of being "non-volcanic" or "magma poor". However abundant *basaltic dykes* exist in the *Furgg* (Jaboyedoff *et al.* 1996) and *Portjengrat* (Carrupt et Schlup 1998) zones (Fig. 1).

Recent lithostratigraphic reinvestigation points to a latest Jurassic to early Cretaceous age for this volcanism, which is consistent with a magmatic record of this second phase of continental break-up in both the Northern (Furgg) and Southern (Portjengrat) margins of the incipient Antrona ocean.

The paradox of this localized but conspicuous volcanism in a non-volcanic margin may be explained by a different break-up mechanism, due to a different thermal state of the lithosphere at the end of Jurassic.

5. The case of the Versoyen zone

The *Versoyen* (ultra)basites, in the Lower Penninic of the French-Italian Alps, are considered since 40 years by nearly all authors as Cretaceous and as the stratigraphic substratum of at least a part of the Tarentaise-Valais flysch series. These interpretations are the basis of highly fashionable models of Alpine paleogeography that ascribe an important role to a so-called "Valais" ocean.

But recent research reveals that:

– The Versoyen (ultra)basites and associated sediments ("black schists") are separated from the Tarentaise-Valais series by a major thrust.

– They are the stratigraphic basement of the Triassic-Jurassic Petit St-Bernard series.

Consequently:

1. The Versoyen (ultra)basites and associated sediments have a Paleozoic age. This conclusion, based on structural and sedimentological observations, is in good agreement with U-Pb dates by Schärer *et al.* (2000).

2. They belong to a distinct tectonic unit that we define as the *Versoyen-Petit St-Bernard nappe* (very similar to the Petit St-Bernard zone in the sense of Schoeller 1929).

3. The Tarentaise-Valais series is nowhere in stratigraphic relation with ophiolites. The "Valais ocean" exists in the literature, not in the field.


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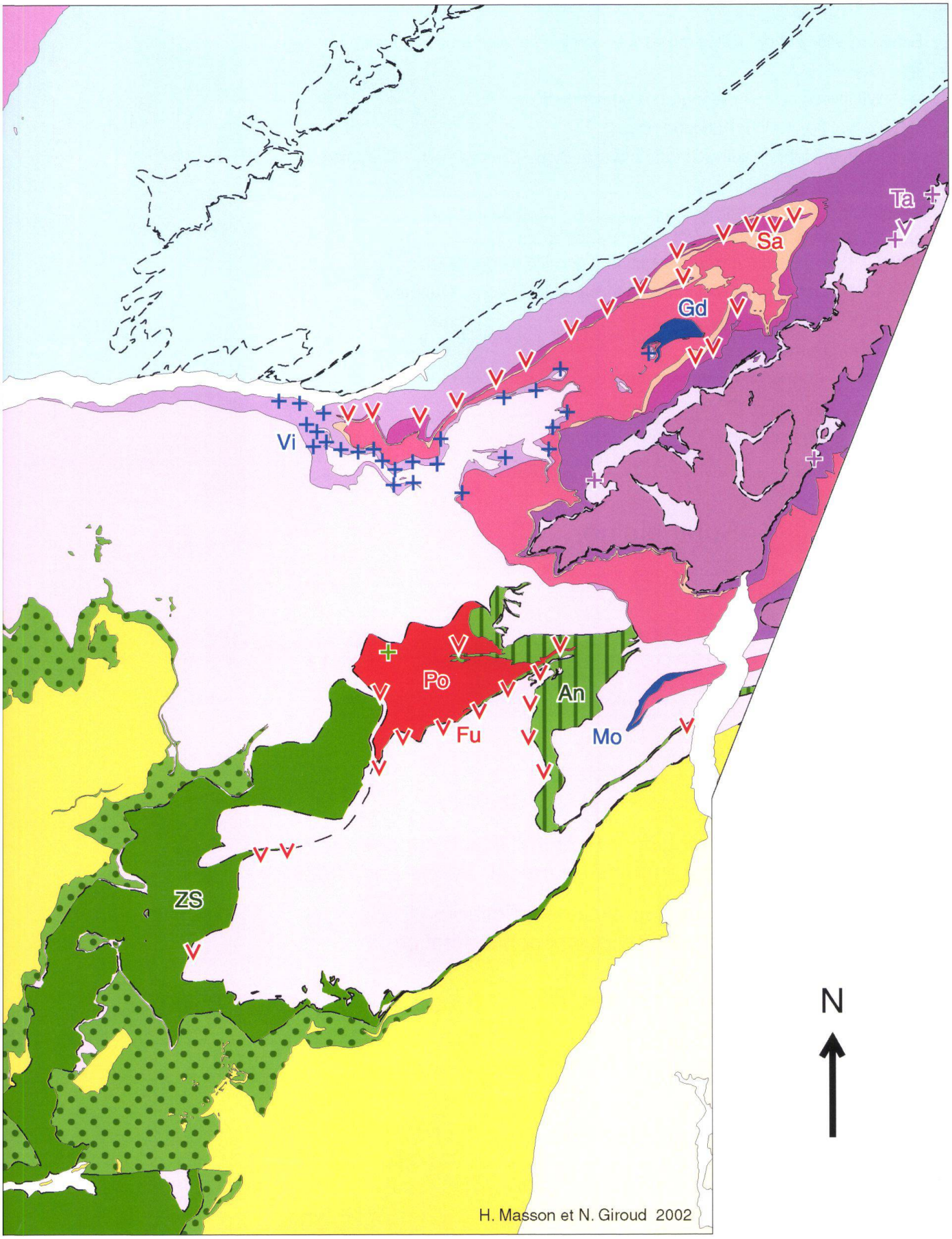


Ophiolites and other (ultra)basic rocks from the West-Central Alps

Blocks or slices of ophiolites mixed with continental elements in a mélange:

- Gets
- Wildflysch in the Portjengrat sedimentary cover
- Robièi Formation (Antigorio nappe)
- Visp and other wildflysch formations in Sion - Courmayeur - Tarentaise

Intracontinental basic volcanism of Jurassic - Cretaceous age:
basaltic dykes and flows in or on continental crust;
volcanic breccias with mixed basaltic and granitic elements

- V **Ge** Gets (from SW to NE: La Rosière, Le Plenay, Jaunpass)
- V **Po** Portjengrat
- V **Fu** Furgg
- V **Tr** Trom (Zone Submédiane)
- V **Sa** Sabbione (P. Vallone nappe)
- V **Ta** Tamier (Robièi Formation, Antigorio nappe)

Southalpine

Austroalpine including Simme

Gets (**Ge**), including
Hundsrück and Pte. Chésery

Other Upper Penninic flysch nappes
in the Prealps (Gurnigel, Sarine and Dranses)

Tsaté (**Ts**), including Frilihorn
and other slices of continental crust

Upper

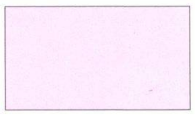
Zermatt - Saas (**ZS**)

Penninic

Portjengrat (**Po**): basement and cover

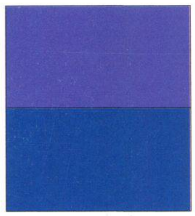
Antrona (**An**)

Figure 1.- Ophiolites and other (ultra)basic rocks from the West-Central Alps.
Geological limits mainly based on the tectonic map of Steck et al. (1999) (GIS version by courtesy of CREALP, Bovier et al. 2001) and on Antoine et al. (1993), Badoux (1965) and Plancherel et al. (1998), modified according to new data from the geologists mentioned in the acknowledgment and from personal work.
Ao: Aosta; La: Lausanne; Si: Sion.



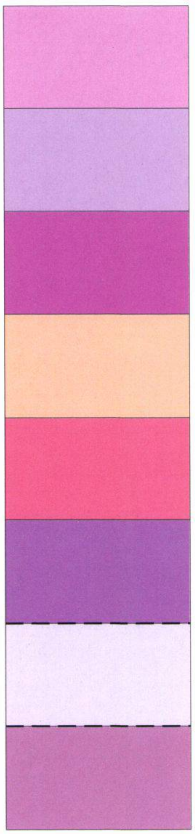
Middle Penninic

including Gros Plané, Laubhorn, Höchst, Zone Submédiane, Cimes Blanches, etc, but without Frilihorn and Portjengrat



Petit St.-Bernard (PSB)

Versoyen (Ve), Geisspfad (Gd) and Moncucco (Mo)



Infra-Niesen and Niesen

Sion - Courmayeur - Tarentaise
including the Visp mélange (Vi)

P. Vallone: basement (Eisten) and cover

Mt. Leone: cover (Holzerspitz)

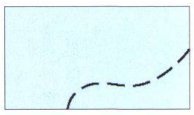
Mt. Leone: basement

Lebendun, Bosco and other nappes

Verampio and Antigorio: cover
including the Robièi Formation

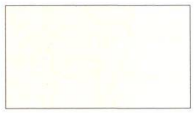
Verampio and Antigorio: basement

Lower Penninic



Helvetic

including Subalpine Flysch and Ultrahelveti
Dashed contour: cover / basement contact



Subalpine Molasse

Plateau Molasse and Quaternary

6. (Ultra)basic rocks from the Visp–Simplon–Geisspfad area

In the *Visp-Simplon* area (Lower Penninic, Valais), metabasalts and serpentinites form blocks and slices (up to 2,5 km wide) imbedded in a mélange of wildflysch type with blocks of various rocks of mainly Triassic and Paleozoic age. They are not dated but most authors correlate them with the Versoyen (ultra)basites (*e.g.* Burri 1979, Burri *et al.* 1994). These two localities are 100 km apart but the occurrence of lenses of ophiolites along the same tectonic contact NW of Aosta (Zulauf 1963) supports the idea of a link between them (Fig. 1).

Recent research shows that:

– In the surrounding sediments it is necessary to distinguish two types of so-called "black schists" that have been confused until now: some are originally associated with the metabasites in the same slices, others belong to the matrix of the mélange. The first ones show analogies with the Versoyen "black schists", confirming the possibility of a correlation.

– However it is improper to apply (as is usually done) the name Versoyen to the Visp rocks because their tectonic position is different: they form blocks in a chaotic formation which is part of the Sion-Courmayeur zone, while the Versoyen rocks belong to the basement of a distinct coherent nappe. We define this ophiolite-bearing chaotic formation as the *Visp mélange*. It is the source of these (ultra)basic blocks that can be tentatively correlated with the basement of the Versoyen-Petit St-Bernard nappe.

– We interpret the Visp mélange as forming the top (and not the base as usually considered) of the Sion-Courmayeur tectonic unit, thus stratigraphically overlying the Valais flysch series.

– The above-mentioned correlation implies that the Visp ophiolites have a Paleozoic age.

– While the "Valais ocean" vanishes, the recent discoveries open a way to the birth of a new "*Versoyen-Visp (VV)*" *ocean* of Paleozoic age. Although unforeseen by the existing models of Paleozoic paleogeography, the VV ocean does not seem to contradict them; *e.g.* it could be incorporated as a large pull-apart basin on an E-W transcurrent mega-fault system.

Farther East, the *Geisspfad* peridotite-serpentinite is one of the largest ultramafic bodies of the Central Alps (Pastorelli *et al.* 1995). It is generally considered as belonging to the Monte Leone nappe. However work in progress suggests that it could be a slice analogous to those of the Visp mélange, infolded into the Monte Leone basement by a complex pattern of superimposed deformations.

7. The case of the Sabbione metabasites

These basic volcanites can be followed nearly continuously for 40 km along the Northern border of the Monte Leone nappe (Lower Penninic, Valais and Val Formazza) with a maximal thickness of 200 m in the *Sabbione* area. They are not ophiolites: recent stratigraphic and structural research shows that these metabasalts form dykes, sills and volcanic flows within metasediments of probable Dogger age that were deposited on a continental crust in a rift environment (Carrupt 2002). This series is continuously separated from the sedimentary cover of the Monte Leone nappe by a tectonic contact and belongs to the newly defined Pizzo del Vallone nappe (Carrupt 2002). Work in progress suggests that the Eisten gneiss may represent its basement.

Thus these metabasalts record an intracontinental volcanic event of Middle Jurassic age. We tentatively interpret this rifting event as an aborted attempt of ocean opening, contemporaneous with the successful Piemont break-up but in a more external position. Alternative solutions are also worth of consideration, *e.g.* a fragment of the Piemont margin transported to its present external position by large transcurrent faults (Carrupt 2002).

To the West the Pizzo del Vallone nappe arrives very near the Visp mélange of the Sion-Courmayeur zone. This proximity has been the source of much confusion.

8. (Ultra)basic rocks in the cover of the Antigorio nappe

Still farther East (Val Formazza and Ticino), and in a much lower tectonic position, (ultra)basic rocks have been newly discovered in the sedimentary cover of the Antigorio nappe.

The Antigorio cover is reinterpreted as mainly formed by detrital sediments of Late Cretaceous-Tertiary (?) age. It is capped by a calcschist formation that contains blocks and slices of gneiss, marble and (ultra)basites. We define it as the *Robiei* Formation and interpret it as a meta-wildflysch. (Ultra)basites are present in it as:

– blocks of amphibolites, some of them very mafic and with a chemical composition corresponding to meta-pyroxenites;

– basic dykes in blocks of gneiss. These dykes show an ultra-potassic trend.

We define the set of these rocks as the *Tamier* metabasites. They are not dated but indirect evidence suggests a post-Triassic age.

We interpret the Robiei meta-wildflysch and its (ultra)basic blocks and dykes as evidence for a major tectonic suture between the Antigorio and Maggia nappes, maybe inherited from a deep intracontinental rift.

9. Conclusion

An important task for the future will be the redefinition of the paleogeographical relations of the above mentioned (ultra)basic zones of the West-Central Alps with those of the Graubünden (Eastern Switzerland), particularly in the Lower Penninic nappes where most authors (*e.g.* Steinmann and Stille 1999) agree on the existence of a narrow oceanic domain of Cretaceous age (that can no more be called "Valais"). We tentatively suggest that the link with the Western segment could be a transcurrent fault transecting the whole Middle Penninic domain and transferring the Cretaceous component of opening from Antrona to the North Penninic. This suggestion has the advantage of opening a new approach of the very mysterious tectonic correlations between Valais and Graubünden over the Lepontine Alps.

Considered as a whole, these facts favour the concept of a progressive, punctuated and nearly "hesitating" opening of the Tethys ocean, complicated by aborted attempts and jumps of the spreading system. These complications were probably conditioned by the proximity of the rotation pole, and strongly influenced by marked pre-exiting heterogeneities inherited from its complex Paleozoic history and by the gradual thermal evolution of the underlying mantle.

Acknowledgments

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