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Significance of latest-Variscan and Alpine deformation for the evolution of Montagne de Pormenaz (Southwestern Aiguilles Rouges massif, Western Alps)

Reply to the paper by A. Lox & J. Bellière: "Le Silésien (Carbonifère supérieur) de Pormenaz (Massif des Aiguilles-Rouges): Lithologie et tectonique."

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Key words: Western Alps, basement, Aiguilles Rouges massif, Upper Carboniferous sediments, Mesozoic cover, Alpine orogeny

ABSTRACT

The polymetamorphic basement of the Montagne de Pormenaz (including the Pormenaz granite) is covered by autochthonous and parautochthonous Upper Carboniferous and Triassic rocks and by allochthonous Morcles nappe.

Starting in the Late Westphalian, black shales were deposited in an intramontanous basin. Brittle tectonic activity probably caused the forming of conglomerates in the Latest Carboniferous.

Alpine orogeny started with a sinistral transpression which formed the N–S trending positive Pormenaz flower structure. This event was predated by affected Triassic rocks and postdated by the Oligocene overthrust of the Helvetic Morcles nappe. In all post Mid Carboniferous rocks a pervasive foliation was produced under low-grade metamorphic conditions (max. T below 290°C) during nappe emplacement (transport towards NW to W). Normal faults provide evidence for a later extension.

The Upper Carboniferous sedimentary rocks of the Pormenaz – Coupeau basin underwent a foliation producing deformation during the Alpine orogeny only.

RESUME

Le socle polymétamorphique de la Montagne de Pormenaz (comprenant le granite de Pormenaz) est recouvert par les roches autochtones et parautochtones du Carbonifère supérieur et du Trias et par la nappe de Morcles.

A partir du Westphalien supérieur, des schistes noirs se sont déposés dans un bassin en extension. Durant le Stephanien une activité tectonique cassante a probablement causé la formation des conglomérats.

L'orogenèse Alpine a débuté par une transpression sénestre, responsable de la structure en fleur positive de Pormenaz, orientée N–S. L'âge de cet événement est calé par l'existence des roches triasiques affectées par la transpression et le chevauchement d'âge Oligocène de la nappe helvétique de Morcles. Dans toutes les roches plus jeunes que le Carbonifère moyen, une foliation pénétrative a été produite sous les conditions métamorphiques de bas degré (T max en dessous de 290°C) pendant l'emplacement de la nappe vers l'NW ou l'W. Des failles normales témoignent de l'extension qui suit.

Dans les roches Silésiennes une foliation a été produite seulement pendant l'orogenèse alpine.

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Introduction

The Aiguilles Rouges Massif (ARM, Fig. 1a) is a relic of the pre-Triassic polymetamorphic basement of the Helvetic realm in the Western Alps. Migmatites, ortho- and paragneisses, micaschistes, phyllites, eclogites, metabasites and higher differentiated metavolcanics were consolidated by polyphase Variscan collision (v. Raumer et al. 1993), at high to low grade metamorphic conditions (v. Raumer 1984, Joye 1989, Schulz & v. Raumer 1993, independent investigations).

At the end of the Variscan orogeny, beginning in Westphalian D and possibly lasting up until Early Permian (Bertrand 1926, Jongmanns 1960), two intramontanous basins were formed: the Salvan–Dorenaz basin or Dorenaz–Chatelard syncline in the eastern part, and the Pormenaz–Coupeau basin or Pormenaz–Prarion zone in the western part of the ARM (Fig. 1b).

Mesozoic sedimentation started with clastic deposits in the Latest Ladinian or Carnian (Demathieu & Weidmann 1982). In the course of Alpine hypercollision the ARM was overthrusted by Helvetic nappes and later by Penninic nappes. Upper Carboniferous slates and meta-sandstones, occurring at the Prarion, are part of a tectonic slice, the Vervex unit, which was transported together with the Helvetic Morcles nappe (Épard 1990).

Contrary to the opinion that both autochthonous outcrops of Late Carboniferous rocks were strongly deformed during a late stage of the Variscan orogeny in Late

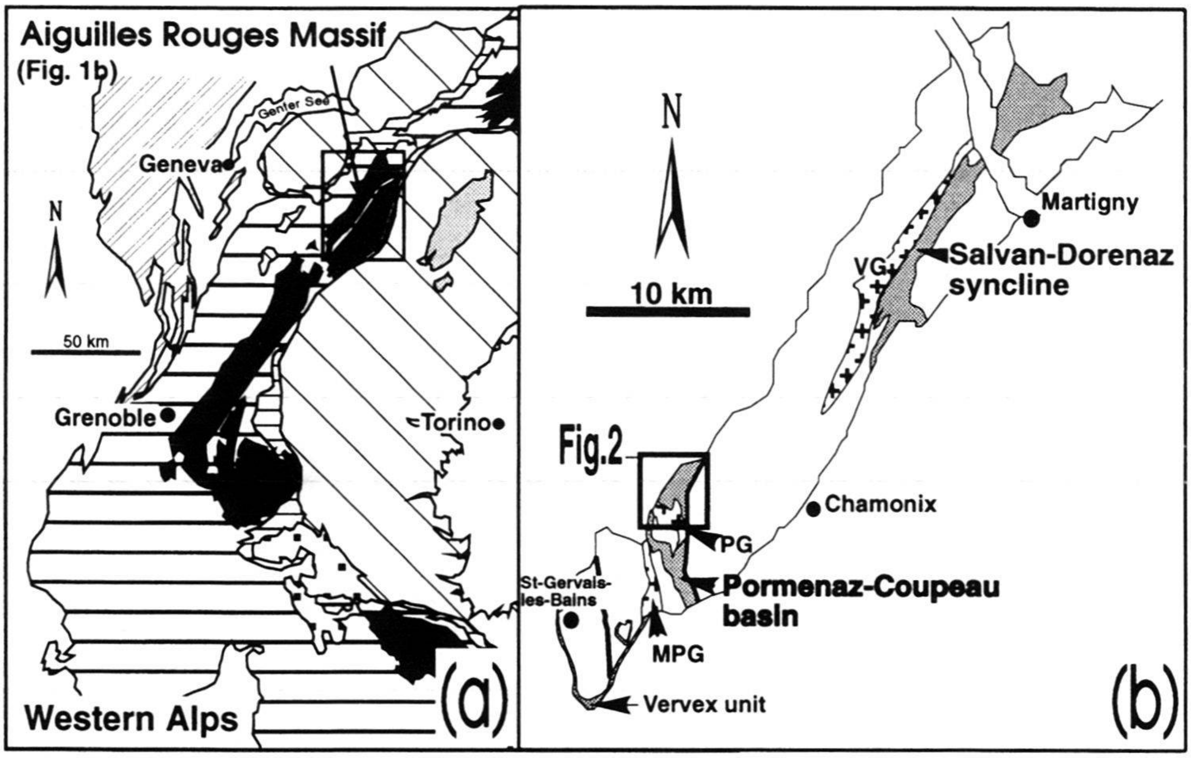

Fig. 1 a) Position of the Aiguilles Rouges Massif within the Western Alps. b) Regional geological setting of the Aiguilles Rouges Massif. VG Vallorcine granite, PG Pormenaz granite, MPG Montées-Pélissier granite, Upper Carboniferous in light grey. Unfilled box indicates figure 2.

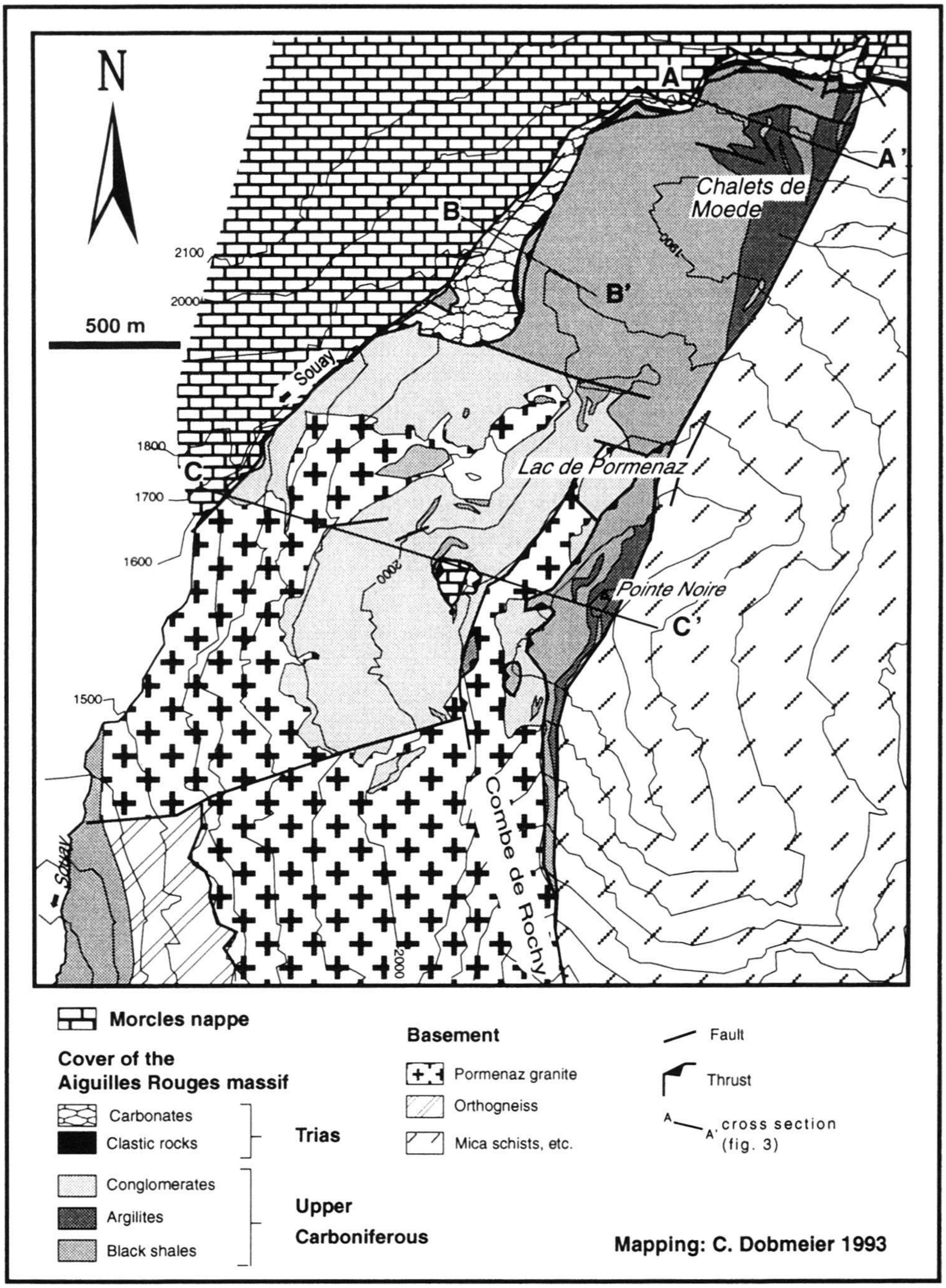

Fig. 2. Geological map of the Montagne de Pormenaz. The three cross sections are shown in figure 3.

Permian (Sublet 1962, Laurent 1967, Badoux 1971), Pilloud (1989) showed that the Salvan–Dorenaz basin is an Alpine megastructure. Lox & Bellière (1993) renewed their opinion (Bellière 1958, Lox 1983) of a Variscan deformation for the Pormenaz–Coupeau basin.

The remapping of the Montagne de Pormenaz in 1993 added important new data which indicate that the Pormenaz–Coupeau basin was deformed during Alpine orogeny only.

Lithologic units

Basement

The basement east of the Pormenaz fault (PF) comprises fine grained, partly garnet bearing muscovite-biotite- to chlorite-biotite-micaschists and intercalated biotite-plagioclase-schists, quartzites, garnet-amphibolites, amphibolites and leucocrate quartz-feldspar-gneiss layers. In the Diosaz Gorge west of PF medium grained feldspar-augengneisses, amphibolites, amphibole schists and intercalated paragneisses outcrop. Parallel to the pervasive foliation striking porphyric Pormenaz granite covers the gneiss series beginning from 1650 m altitude.

Upper Carboniferous sediments

The Upper Carboniferous clastic sediments can be divided in two lithologic units: a partly very coarse grained conglomeratic one with arkosic layers and shale lenses, and a fine grained one, which consists mainly of black shales and intercalated argilites. First palaeontologic age datings were published by Bertrand (1926), assigning plant fossils from the black shales of Coupeau and Pormenaz area to Westphalian D. Laurent (1967) and Lox (1983) confirmed the age. No fossils have been found in the conglomeratic sequence.

Lox & Bellière (1993) mentioned that the sedimentary sequence starts with conglomerates ('partie inférieure' or 'formation grossière' according to Lox 1983), which are covered by the black shales ('partie supérieure' or 'formation fine et formation arénacée). Contrary to this Laurent (1967) thougt that the conglomerates must be younger than the black shales. But as all contacts between the shales and the conglomerates are tectonic, no bottom – top succession can be established.

However, our observations indicate that the conglomerates are younger than the shales: south of Lac de Pormenaz thin, fine grained, redish layers exist in the conglomerates. We interpret such structures as small alluvial fans. The colour, arising from ferrous coating of the pebbles, indicates arid weathering. According to Krainer (1993), the change from humid to arid weathering occurred in the Latest Carboniferous or Earliest Permian. The lack of intense red coloured conglomerates, as exposed in the Salvan – Dorenaz syncline, provides evidence for the end of the sedimentation at the Carboniferous – Permian boundary.

For the general interpretation, it is important to know that besides debris of the polymetamorphic basement and the granite, fragments of black non-metamorphic shales and argilites contributed to the build up of the conglomerates. They can be derived from Late Carboniferous sediments only, as Visean schists had already suffered a medium grade metamorphism. Obviously, fine grained black Upper Carboniferous sediments were eroded and redeposited during sedimentation of the coarse grained conglomeratic sequence, which probably happened during the Stephanian. Fabre et al. (1987) describe repeated accretion of coarse grained material during the Stephanian in the Briançon Houillère Zone triggered by tectonic activities of the 'Asturian phase'.

In addition the very coarse grained conglomerate horizons are not only present in the upper part of the conglomeratic sequence, but also directly above the Pormenaz granite (north of Lac de Pormenaz).

Whether the conglomerates, intercalated in the northern and eastern part of the fine grained series, belong to the conglomeratic sequence is very questionable. North of Moëde these rocks are under- and overlain by black shales. Furthermore, arkosic layers and very coarse grained conglomerates, which are typical for the conglomeratic sequence, are absent. In consequence, we interpret these rocks as coarse grained alluvial fans in fine grained basin deposits.

We thus conclude that sedimentation started in Westphalian D with black shales and intercalated coarser grained alluvial fans in a terrigenous environment. Erosion of these sediments and deposition of a conglomeratic sequence point to brittle tectonic activity during the Latest Carboniferous.

Triassic sediments

Sedimentation started with white and light-grey conglomerates and arkoses (1–2 m thickness). The following shales (1–3 m thickness) are covered by brecciated dolomites of varying thickness. The brecciation of the dolomites is mostly caused by overthrusting of the Morcles nappe. Synsedimentary breccias (Épard 1990) are nearly not exposed in the Pormenaz area.

Morcles nappe and Klippe south of Lac de Pormenaz

The Morcles nappe is mainly built up of marly shales and limestones. The exposed sequence starts normally with Liassic dark grey marly shales and shales and ends within the Cretaceous limestones (Soley 1985). But the base of the nappe is not always formed by the same stratigraphic horizon, as can be seen where, for example, besides the shales sometimes white marbles occur.

The Klippe south of the Lac de Pormenaz consists of white marbles only. Pairis et al. (1973) could prove a Cretaceous age using micro fossils.

Nature of the contacts between the lithologic units

The contact between the Pormenaz granite and the Upper Carboniferous conglomerates is sedimentary.

The fine grained Westphalian D and the gneiss series are separated by the PF.

All contacts between the coarse grained and the fine grained Upper Carboniferous unit are tectonic.

Between the Triassic rocks and the weathered black shales a low angle unconformity of 0° to 15° can be observed. But the contact is not always a sedimentary one. Often the

Triassic conglomerates disappear along the contact (Fig. 2). In addition, the weathered part below the Trias unconformity is absent. Near to the PF, where the Carboniferous black shales and intercalated conglomerates dip nearly vertically, the first few meters below the Triassic conglomerates consist of only black shales with a nearly horizontal foliation and slickenside planes. North of the Lac de Pormenaz a lateral ramp only can explain the change of the stratigraphic level of the Triassic rocks which are in contact with the Upper Carboniferous (Soley 1985, independent observations). Therefore, all structures indicate a fault contact between the Carboniferous and the Triassic rocks. The fault must be located partly in the Triassic shales and breccias and partly in the Carboniferous shales.

We thus interpret the Triassic cover of the Pormenaz area as a parautochthonous slice at the base of the Morcles nappe. Consequently, the high angle contact between the Paleozoic and the Mesozoic units does not provide an argument for a pre-Triassic age of the folds and the foliation in the Westphalian and Stephanian rocks.

A mylonite horizon of some m thickness is located between the parautochthonous Trias and the Morcles nappe.

At the Klippe south of Lac de Pormenaz a several meter thick mylonitic granite horizon, which lays above Late Carboniferous conglomerates, appears below the marbles. Therefore the Klippe is clearly allochthonous, and, by comparison of the structures, is correlated with the white marbles at the base of Morcles nappe.

Structures

Structures of the Variscan cycle

All polymetamorphic and monometamorphic pre-Mid Carboniferous rocks have suffered a last intensive shearing event under mid- to low-grade metamorphic conditions during Mid Carboniferous (320–310 ma, Joye 1989; Dobmeier unpublished data) transpression. By this, a steeply dipping, N–S striking foliation with a subhorizontal stretching lineation has been formed. Only in the Pormenaz granite do we observe a younger foliation set, which strikes NE–SW and dips to SE. No younger foliations are seen in these rocks.

Sinistral Transpression

W of the Pointe Noire de Pormenaz several thrusts exist where granite or black shales were overthrusted above Late Carboniferous conglomerates with a NW oriented transport direction. Some of these thrusts are obviously rooted in the PF (Fig. 2, Fig. 3, cross section C–C'). In addition to palaeostress analysis results (performed with the program from Peterek 1993b) from the whole southwestern part of the ARM (Dobmeier, unpublished data), we interpret this feature as a positive flower structure. The general direction of the sinsitral oblique slip faults is N–S. The WNW–ESE to WSW–ENE striking faults are obviously the dextral X and R shear planes of this system.

The exact age of the transpression is unclear but is generally of Alpine age, as this deformation also affected the Triassic rocks in the Bon Nant valley, located to the southwest of the investigated area (independent observations). As all faults are cut off by the Morcles nappe, the sinistral transpression was active before the Oligocene.

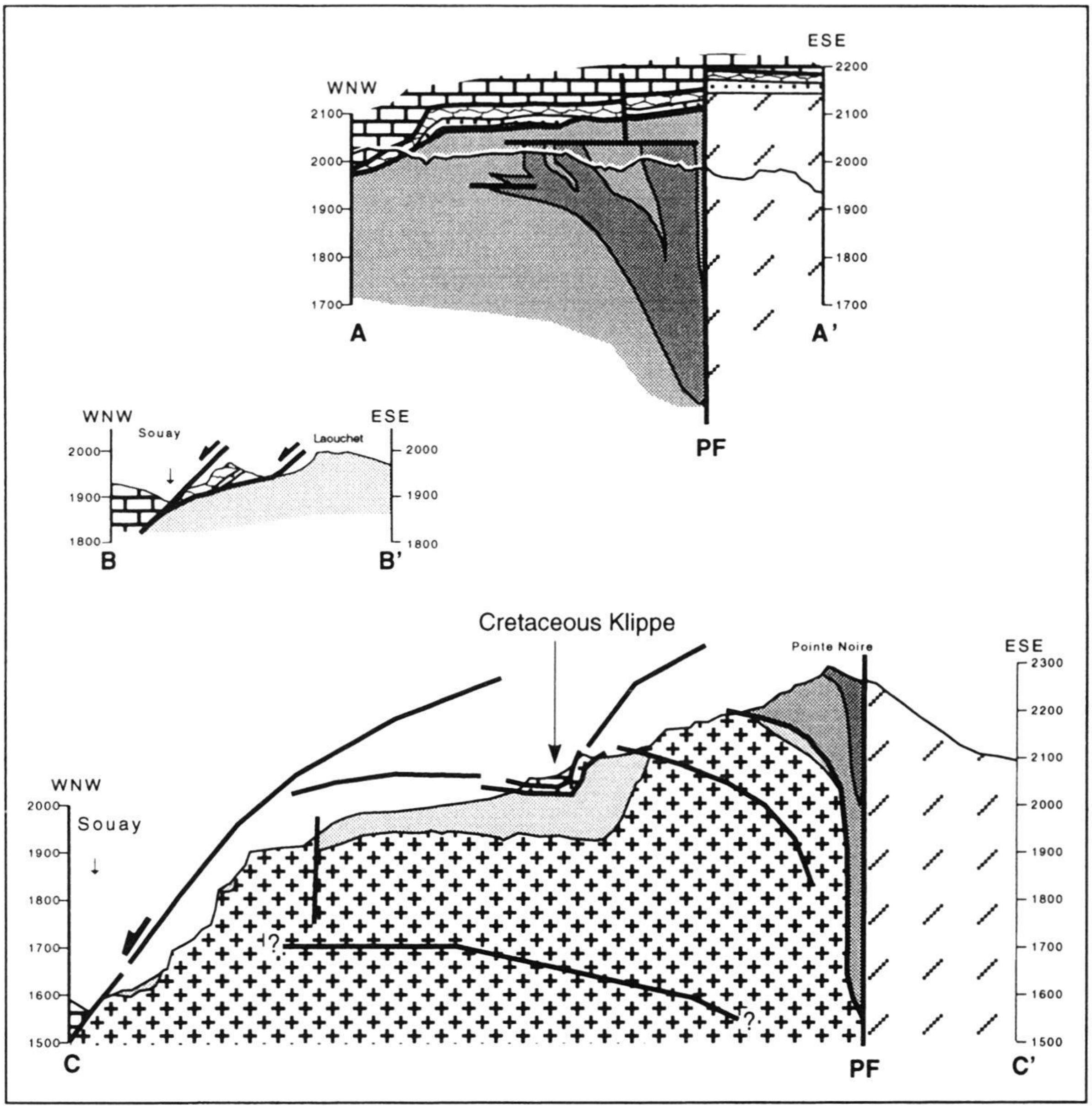

Fig. 3. Cross sections through the Montagne de Pormenaz. Postitions and symbols are indicated in figure 2.

The mysterious first folding event in the Moëde area, discussed by Lox (1983) and Lox & Bellière (1993) can be correlated with this brittle tectonic activity if the syncline is explained as an en-échelon fold structure (compare Sylvester & Smith 1976 for example). According to palaeostress analysis (Fig. 4a) the subhorizontal σ_1-axis is oriented in SE–NW.

The main foliation and related structures

All Upper Carboniferous detrital rocks have one pervasive foliation (s1) developed as pressure-solution-cleavage in the coarse grained and as slaty cleavage in the fine grained

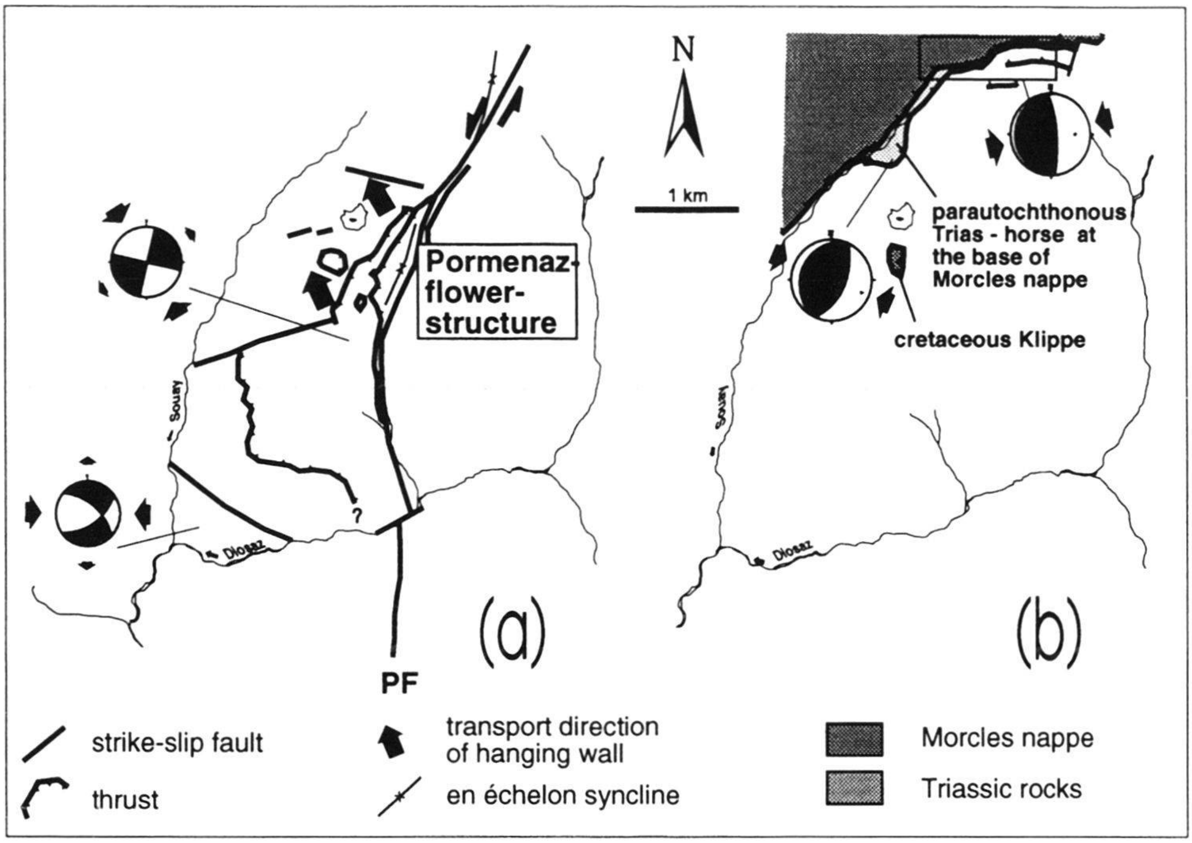

Fig. 4. Palaeostress analysis for a) pre-Oligocene transpression and b) Oligocene nappe emplacement. The different orientation of the nearly horizontal σ_1-axis gives evidence for anticlockwise rotation of the overall stress field during Tertiary deformation (see also Dobmeier 1994).

rocks. The N–S trending planes are nearly horizontal, a smoothly NE to SE dipping strechting lineation (str1) is present in fine grained slates only. In addition to the 'normal' cleavage there are slickenside surfaces (sh1) which are arranged with an angle of about 10° to s1. Hoeppener (1956) has already described such textures from slates of the Rhenish Massif as "V_{m1a}-type" texture caused by simple shear. According to his model nearly vertically oriented quartz-veins are relics of the antithetic surfaces s1a (see also Voll 1968). sh1 surfaces are important as it is possible to use them for palaeostress analysis. Performed analysis for sh1-planes of the Moëde area indicate a transport of the hanging wall to the WSW (Fig. 4b). A relic, older foliation (Lox 1983, Lox & Bellière 1993) was not seen.

N–S oriented axes of first folds (B1) are also nearly horizontal (Fig. 5). Fold parameters depend on lithology but generally there are steep W dipping short limbs and long limbs arranged nearly parallel to s1.

Microstructural investigations showed that only one pervasive foliation has been formed. Lox & Bellière (1993) interpreted this foliation to be a witness to a Late Variscan deformation event, possibly of a Mid Permian age ('Saalian phase').

Comparable structures are developed in the parautochthonous Trias, where micro- and macrostructures are identical to those of the Carboniferous (Fig. 5). Computed

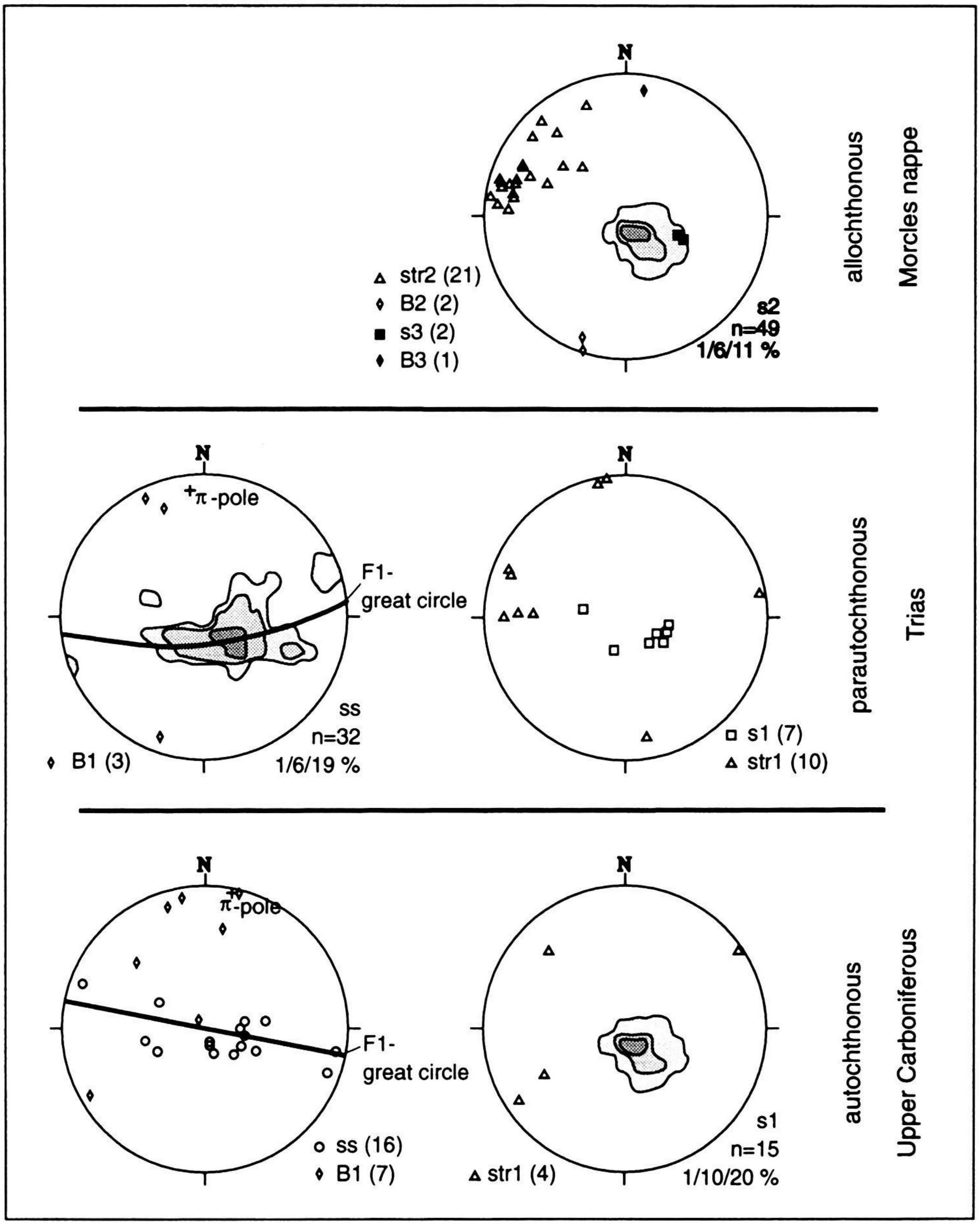

Fig. 5. Comparison of structures, formed in different tectonic units nearby the Morcles nappe sole thrust. Projection in the lower hemisphere of the Schmidt net.

eigenvektors (Wallbrecher 1986, Peterek 1993a) for s1, B1 and str1 of both stratigraphic units have comparable orientations.

Further, their orientations are similar to those of the s2 main foliation and related structures (B2, str2) in the Morcles nappe (Fig. 5). Therefore only an Alpine age is possible for the formation of these structures, as Breton (1972) has already proposed. Obviosly the main foliation in all three units was formed during the Oligocene overthrust of the Morcles nappe.

The interpretation of the unconformity between steeply dipping Carboniferous sedimentary surfaces and flat lying Triassic conglomerates as a consequence of Late Variscan deformation of the former rocks (Lox & Bellière, p. 778) is rejected, as the corresponding contact is a tectonic one. The overthrust surfaces are mostly hidden in the black shales and in the brecciated dolomites. Slickenside surfaces only sometimes appear.

Palaeostress analysis provides evidence for a WNW-ward thrusting of the parautochtonous Triassic cover and the allochthonous Morcles nappe over the autochthonous basement and Upper Carboniferous rocks (Fig. 4b).

All structures became slightly refolded by N dipping fold axes (B2 in the autochthonous and parautochthonous rocks, B3 in the Morcles nappe). A corresponding crenulation cleavage appears only locally in the Morcles nappe (s3) and in the dolomites (s2).

Extensional structures

S to SE or NW steeply dipping normal faults which cross-cut all other structures provide evidence for a late extensional event. Together with Early Miocene dextral strike-slip movements in the SW–NE striking Chamonix valley (Hubbard & Mancktelow 1992) they could be interpreted as transtensional structures with a subhorizontal σ_1-axis in ENE–WSW direction (Dobmeier 1994). But in the Diosaz valley northeast of the investigated area observed SW or NE steeply dipping late normal faults provide together with the other set of normal faults, evidence for a pure extensional regime. This could be caused by loading (overthrusting by Penninic units) and therefore increasing the absolute amount of vertical tension.

At the moment the situation remains unclear for the last observable deformation event, and further investigations are required.

Metamorphism

Illite "Crystallinity"-data, analyzed from Triassic clastic rocks (for preparation and measurement conditions see Krumm & Buggisch 1991) range from 0.254 to 0.292 $\Delta°2\delta$ for the integral breadth and 0.192 to 0.212 $\Delta°2\delta$ for the half-width. Following Kisch (1990), these "epizonal" values are very close to the limit between anchizonal and low grade metamorphism (anchizone above 0.32 $\Delta°2\delta$ for integral breadth and above 0.21 $\Delta°2\delta$ for half-width). Thin section analysis showed that only new sericite (2M1-muscovite, determined by X-ray diffraction analysis on powder samples) and chlorite were formed in the Triassic and Upper Carboniferous clastic cover of the ARM in the investigated area during the overthrust by the Morcles nappe. As quartz did not start to recrystallize, the maximum temperature could not exceed 290°C (Voll 1980). No differences in the grade of maximum metamorphic conditions between the two units was observed.

Conclusions

Contrary to the opinion of Lox & Bellière (1993), the sedimentation in the Pormenaz – Coupeau basin started with fine grained black shales and intercalated coarser grained alluvial fan deposits in a terrigenous intramontanous-type basin during the Westphalian D. A Late Variscan brittle tectonic event (? Stephanian) caused the formation of coarse grained conglomerates. This event is probably also responsible for the partly observable low angle unconformity between the Carboniferous and the Triassic rocks. The sedimentation stopped in the Latest Carboniferous in contrast to the Salvan–Dorenaz basin where the deposition of clastic material continued into Early Permian (Jongmanns 1960, Pilloud 1989).

The subhorizontal foliation in the Upper Carboniferous rocks was produced simultanously with the foliation in the overlying Triassic rocks and in the basal part of the Morcles nappe during Oligocene nappe tectonic events of the Alpine orogeny, as

- all three units show comparable structures with similiar orientations
- no metamorphic gap between the Upper Carboniferous and the Triassic rocks exists
- the structures of the Upper Carboniferous rocks of the Montagne de Pormenaz are not compatible with the Late-Variscan extensional stress field (Dobmeier, unpublished data).

No relic older foliation is observeable in the Upper Carboniferous. Thus, our results confirm the result of Breton (1972).

The steep dip of the Upper Carboniferous rocks in the area east of the Chalets de Moëde along the PF is interpreted as an en-échelon syncline of the Alpine 'Pormenaz flower structure', which was formed during pre-Oligocene sinistral transpression.

The Triassic cover north of Moede was transported as a slice at the base of the Morcles nappe and is therefore parautochthonous. Also, the Cretaceous Klippe south of the Lac de Pormenaz is an allochthonous slice, probably a remainder of the inverted lower limb transported at the base of the nappe.

Steeply dipping normal faults of different orientations provide evidence for a post-Oligocene extension.

Summarising all the observations, we conclude that the Upper Carboniferous sedimentary rocks of the Pormenaz–Coupeau basin underwent, as the Permocarboniferous rocks of the Salvan–Dorenaz basin (Pilloud 1989), foliation-producing deformation during the Alpine orogeny only.

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