**Zeitschrift:** Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie

**Band:** 79 (1999)

**Heft:** 3

**Artikel:** Petrological features of the Pelvas d'Abriès massif (northeastern Queyras, French-Italian Alps)

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**DOI:** https://doi.org/10.5169/seals-60217

SCHWEIZ. MINERAL. PETROGR. MITT. 79, 431–437, 1999

# Petrological features of the Pelvas d'Abriès massif (northeastern Queyras, French-Italian Alps)

by *Cécile Ambrics*[1] and *Jean Bertrand*[1]

**Abstract**

The Pelvas d'Abriès massif, on the NE side of the Guil Valley, is an ophiolitic klippe characterized by an unusual association of gabbro and peridotite. High level-type Ca–Mg gabbros and subordinate Fe–Ti gabbros are the main rock types. Associated ultrabasic rocks are feldspathic dunites. An Alpine greenschist to moderate blueschist facies imprint is recognized in the gabbros which preserve locally some signs of oceanic flaserization. The peridotites suffered from intensive oceanic serpentinization. The unusual association of high-level isotropic gabbros with cumulate-textured peridotites is interpreted as resulting from early intrusions of a peridotitic mush into the upper part of the magma chamber.

*Keywords:* ophiolite, gabbro, peridotite, intrusion, metamorphism, structure, French-Italian Alps.

## Introduction

Near Abriès, on the NE side of the Guil Valley, the Pelvas d'Abriès massif (2929 m) crops out at the French-Italian border. Between the Briançonnais zone to the west and the Dora-Maira massif to the east (Fig. 1), this ophiolitic klippe, comprising mainly gabbro and peridotite, preserves some remnants of its primary sedimentary cover. It belongs to the Upper Oceanic Unit of the Piemont-Ligurian Schistes Lustrés zone (LAGABRIELLE, 1982, 1987). The contact with the underlying Piemont calc-schists is tectonic (Fig. 1). At the Col d'Urine (Fig. 1) the reverse position of the Jurassic marbles of the supra-ophiolite sedimentary cover indicates that the klippe is overturned. This attitude was explained by LAGABRIELLE et al. (1985) and LAGABRIELLE (1987) as corresponding to part of the inverted limb of a folded megastructure.

Ultrabasic intercalations are observed in the east and southeast flanks of the massif (Fig. 1). Their genetic relationships with the gabbro are still not quite clear. Ultrabasic cumulate layers (BEARTH et al., 1975), ultrabasic intrusions, or peridotitic tectonic slices are possibilities. Petrological and structural data allow a new hypothesis concerning the magmatic origin and Alpine metamorphism of this gabbroic body to be proposed.

## Main rock types

The gabbro is typically of high level-type. Ca–Mg varieties are by far the most common; Fe–Ti gabbros are locally observed, mainly in the northeastern part of the klippe. A few troctolitic gabbros and leucotroctolites are present as rare more evolved felsic products sometimes intersecting the gabbro body. Late doleritic intrusions are rare. The associated peridotitic intercalations exhibit peculiar characteristics. Their primary composition was strongly dunitic with cumulate structures. Olivine is the dominant cumulus phase and orthopyroxene is rare or absent. Plagioclase, often including idiomorphic to subidiomorphic Cr-spinel, crystallized as minor (< 3%) to, locally, major (> 30%) intercumulus phase (Fig. 2c).

## Metamorphism

The imprints of both oceanic and Alpine regional metamorphism can be recognized. The first one is

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mainly indicated by locally flaserized gabbro. Sometimes this flaserization is crosscut by late undeformed more evolved veins having escaped any significant Alpine deformation. The ultrabasic intercalations generally do not record a well defined Alpine metamorphic imprint, having preserved their cumulate structures (Fig. 2c) and their oceanic serpentinization.

In gabbro, the imprint of Alpine metamorphism is irregular with respect to the distribution of the observed mineral associations and the degree of deformation is generally weak. Moderate blueschist facies mineral assemblages, which preferentially developed within Fe–Ti gabbros (Fig. 2b), coexist with greenschist facies parageneses (Fig. 2a), sometimes clearly as retrograde event. Still coexisting relics of primary minerals (particularly clinopyroxene) and of oceanic metamorphism (mainly greenschist, locally amphibolite facies) also testify to polyphased out of equilibrium, mineral assemblages.

Evidence of dynamo-metamorphic processes are recognizable in several places: (a) intensive tectonization of gabbro at the north-northwest contact with sedimentary country rocks (Fig. 1). This contact zone shows spectacular evidence of intensive deformation in the form of slickenslides, highly mylonitized and chloritized gabbro, and even the development of a pervasive recrystallization foliation (Fig. 5c); (b) shear zones within the massif testifying to brittle tectonic processes; (c) zones of recurrent faulting at some contacts between gabbro and ultrabasic intercalations with subsequent cataclasites, and mylonite formation; these processes could also be linked, at least partly, to the oceanic evolution.

## Mineral assemblages

The diverse mineral assemblages were investigated by microscopy and X-ray diffraction. The primary and secondary (oceanic and Alpine) parageneses are summarized in table 1.

Within the gabbro, in which the primary minerals often suffered granulation and deformation, diopsidic-augitic clinopyroxene is often replaced by amphibole: very rarely magnesio-hornblende, mostly actinolite-tremolite and/or crossite-ferroglaucophane, and sometimes by an aegyrinic

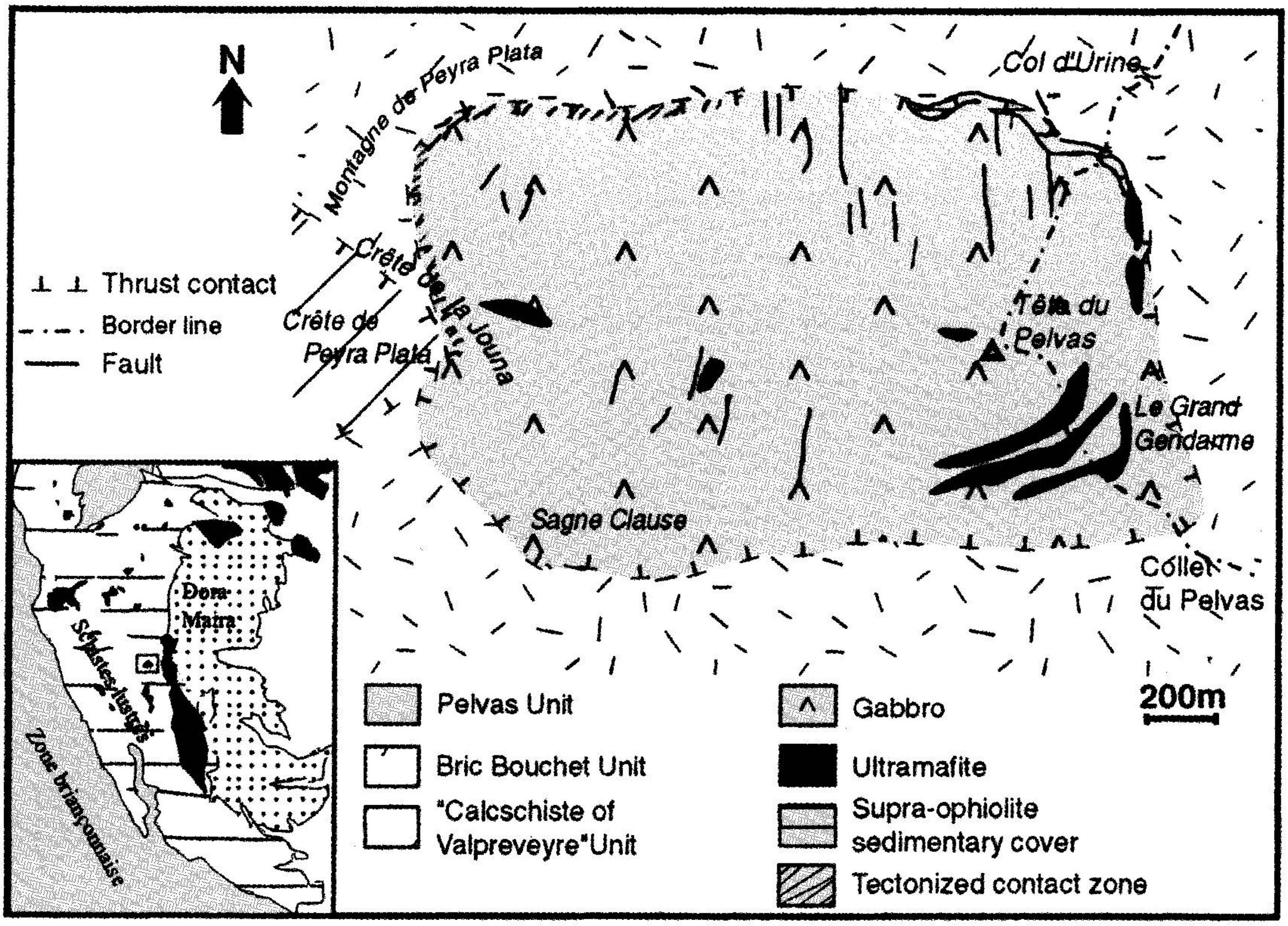



*Fig. 1* Simplified structural map of the Pelvas d'Abriès area (modified from LAGABRIELLE et al., 1985).

pyroxene. Plagioclase is generally intensely transformed to saussurite, with dominant albite and epidote. Chlorite and carbonate are frequent secondary phases (Figs 2a and 2b).

In ultrabasic intercalations, in which the primary cumulate texture is still recognizable, olivine, except rare relics, and plagioclase are respectively replaced by serpentine and chlorite minerals (Fig. 2c). Nevertheless, ghosts of previous features still may be locally recognized: polysynthetic twins and zones of fine-grained rodingitic Ca-silicates within plagioclase crystals, development of amphibole-bearing reaction rims between olivine and plagioclase. All these recrystallizations may be related to the oceanic stage. Indeed, similar recrystallizations are recognized in equivalent rock types from present-day ocean ridge environments. Moreover, comparable peridotitic rocks, reworked within ophicalcitic horizons, may appear in some places (e.g. Montgenèvre, Northern Apennines) in stratigraphic contact with overlying Jurassic to Lower Cretaceous supra-ophiolite sediments.

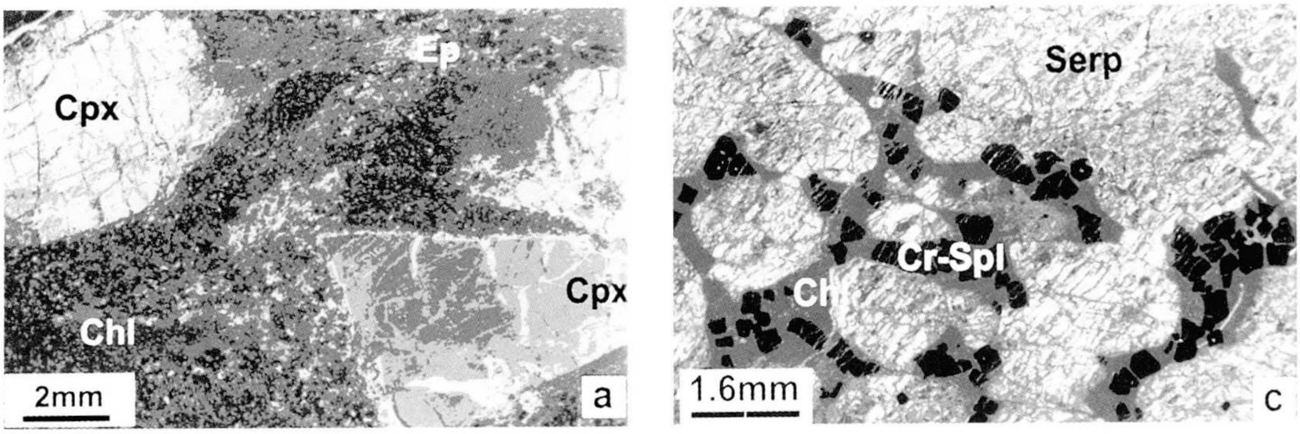
In the shear zones along the contacts between peridotite and gabbro, both rock types are often intensely carbonatized and chloritized.

**Bulk rock chemistry**

Bulk rock chemical analyses (major and trace elements by XRF, Earth Sciences laboratory, University of Lausanne), were made on gabbro and ultrabasic rocks.

The results are given in selected diagrams (Figs 3 and 4) in which data from the Montgenèvre ophiolite (MOC) (Bertrand et al., 1982, 1987) and from Rocciavre (ROC) (Pognante et al., 1982) are introduced for comparison.

For the gabbros, $TiO_2$/MgO (Fig. 3a) and Y/Zr (Fig. 3b) diagrams permit a comparison of the gabbros of the Pelvas (PL), Montgenèvre and Rocciavre localities. In figure 3a, the evolution from Ca–Mg to more evolved members is clear; the grouped distribution of Ca–Mg gabbros contrasts with the very large dispersion of Fe–Ti varieties. In figure 3b, we can notice the low concentrations of Zr and Y for most of the gabbros from PL and ROC contrasting with significantly higher concentrations of Y and/or Zr for several samples from MOC. The comparable distribution pattern of the representative points from the Pelvas (greenschist to blueschist facies), the Mongenèvre ophiolite (pumpellyite-prehnite facies) and Rocciavre (blueschist to eclogite facies) moreover shows that the Alpine metamorphism did not significantly change the global chemistry.



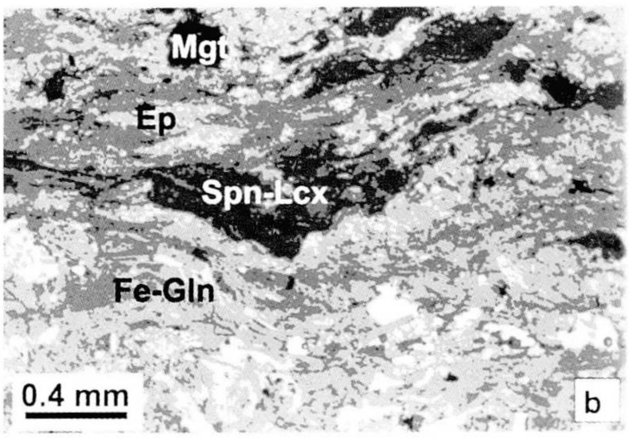




*Fig. 2* Microphotographs of representative rock types. Mineral abbreviations according to Kretz (1983). (a) Ca–Mg gabbro, plane light. Greenschist paragenesis. Clinopyroxene crystals (Cpx) are amphibolitized and chloritized (Chl); plagioclase is intensely saussuritized (Ep). Note the deformation features of clinopyroxene and saussuritic matrix. (b) Fe–Ti gabbro, plane light. Blueschist paragenesis with Alpine foliation. Fe-Gln: ferroglaucophane, Lcx: leucoxene. (c) Dunitic peridotite with cumulate texture, slightly uncrossed polars. Serpentinized olivine (Serp) and chloritized intercumulus plagioclase (Chl) including chromiferous spinel crystals (Cr-Spl).

For the serpentinized peridotites, the diagrams $Al_2O_3$/MgO, $Al_2O_3$–MgO–FeO*, and V/Cr (Figs 4 a, b and c) permit a comparison between the ultrabasic lithologies of the Pelvas and those of the Montgenèvre (BERTRAND et al., 1982). In figure 4a, a linear correlation and two distincts fields are clearly shown for the ultrabasic rocks from PL and MOC. This difference may be partly explained by the presence of chromiferous spinel and interstitial chloritized plagioclase within the Pelvas samples. Figure 4b simply underlines the chemical difference between PL and MOC peridotites. In figure 4c, good linear trends of the representative points from both localities are observed. The higher Cr contents for the PL ultrabasic intrusives are linked to the presence of the chromiferous spinel.

## Discussion

### RELATIONSHIPS BETWEEN GABBRO AND PERIDOTITE

Identifying the type of relation between gabbro and peridotite is essential to understand how the peridotites were emplaced. Two types of contacts, when preserved from later deformation, are observed: (a) intercalations displaying sharp con-

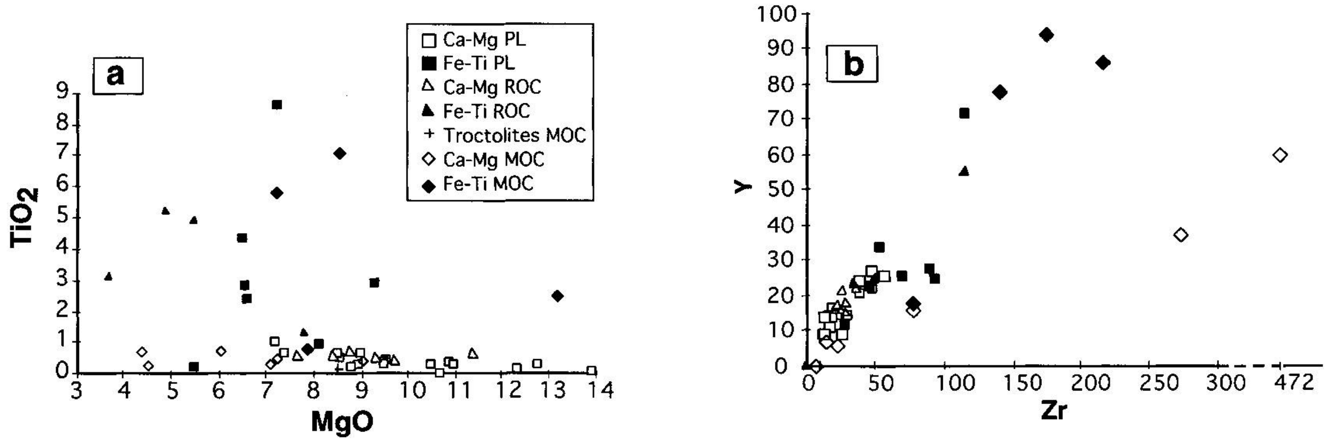



*Fig. 3* Chemical diagrams for gabbro types from Pelvas d'Abriès (PL), Montgenèvre (MOC) and Rocciavre (ROC). (a) $TiO_2$–MgO diagram. Note the large contrast in the distribution mode of the Ca–Mg and Fe–Ti gabbro representative points. (b) Y–Zr diagram. Low concentrations for most analyzed samples contrast with significantly higher concentrations of several samples from MOC.

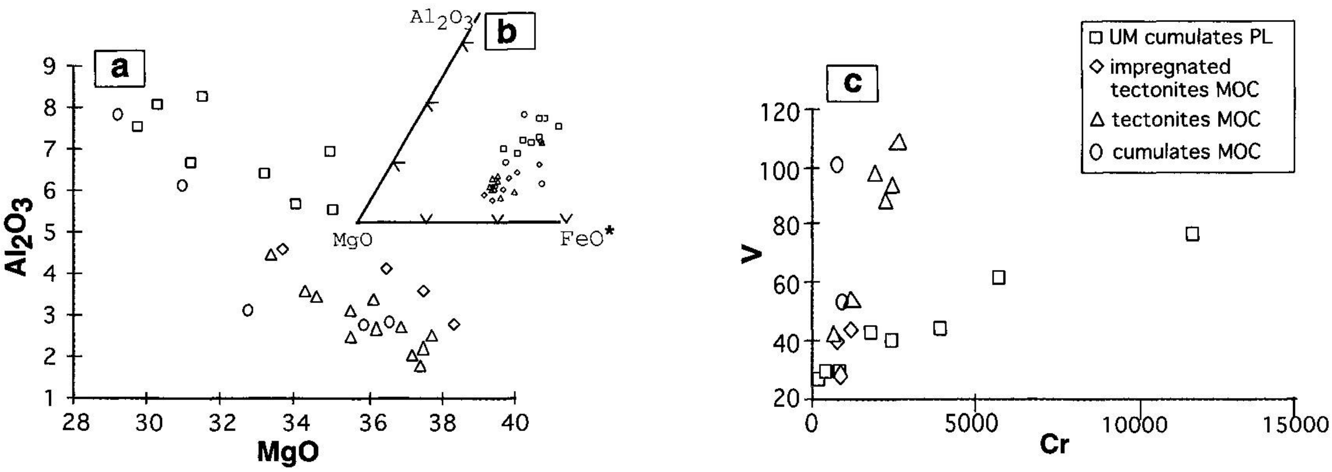



*Fig. 4* Chemical diagrams for serpentinized peridotites from Pelvas d'Abriès (PL) and Montgenèvre (MOC). (a) $Al_2O_3$–MgO diagram clearly showing a negative linear correlation and two distinct fields for the ultrabasic rocks from PL and for those from MG. This difference may be partly explained by the presence of chromiferous spinel and interstitial chloritized plagioclase within the Pelvas samples. (b) MgO–$Al_2O_3$–FeO* diagram underlying the chemical difference between PL and MOC peridotites. (c) V–Cr diagram showing good linear trends of the representative points from both localities. The higher Cr contents of the PL ultrabasic intrusive rocks are linked to the presence of the chromiferous spinel.

*Tab. 1* Primary and secondary (oceanic and Alpine) mineral assemblages of the main rock types. The abbreviations are taken from KRETZ (1983). Other abbreviations: Cpx: clinopyroxene, Px: pyroxene, Amph: amphibole, Cros: crossite, Ox: Oxide, Lcx: leucoxene, Serp: serpentine mineral, Carb: carbonate. In italics: rare minerals.

| **Rock types** | **Parageneses** | |
|---|---|---|
| | **Primary** | **Secondary** |
| Ultramafite | Ol + Pl + Px + Cr-Spl + FeOx | Serp + Chl + Tr-Act + Carb + *Tlc* + *Brc* |
| Ca–Mg gabbro | Cpx + Pl + Mag + Ilm + *MgHbl* | Ca-MgAmph + Cros-FeGln + Ab + Ep-Czo + *NaPx* + *White mica* + *Pmp* + *Lws* + Chl + Carb + *Tlc* |
| Fe–Ti gabbro | Cpx + Pl + Fe-TiOx + Ap + *Zrn* + *Tur* | Cros-Fegln + *NaPx* + Ab + Ep + Czo + Ttn-Lcx + Chl + Carb + *Tlc* |

tacts with the gabbro (Fig. 5a); (b) more complex contact relationship as observed in the lower part of the eastern flank of the massif. Ultrabasic apophyses intrude the gabbro and fragments of gabbro with evidence of assimilation process are enclosed in the peridotite. These observations are interpreted to represent an intrusive relationship which occurred under ductile conditions (Fig. 5b).

Other data are consistent with an intrusive emplacement of the peridotite: (1) the deformation which developed within the gabbro either before or during its emplacement at the ridge is never observed in the serpentinized peridotites which preserve their crystallization structures (Fig. 2c), except some high temperature plastic flow features; (2) folded and boudinaged flow structures of differentiated levels locally developed within the ultrabasic intercalations (Fig. 5b). These differentiated levels correspond to the layering mentioned by BEARTH et al. (1975). They are not observed in the most often isotropic gabbro, which never shows any rythmic layering except a very locally developed incipient one.

Such field observations, together with the microscopic textures, suggest that the ultrabasic intercalations result from injections of a dunitic, more or less feldspathic, crystal mush within the gabbroic body in the transition zone between upper mantle and lower crust probably in a ridge axis environment. These intrusions, which apparently post-date the oceanic deformation of the gabbros, seem to have been emplaced in variable temperature conditions as suggested by sharp and diffuse contacts (respectively, Fig. 5 a and b). This, probably, could be due to the long duration of the intrusive process.

## MAGMATIC HISTORY OF THE GABBRO-ULTRAMAFITE ASSOCIATION

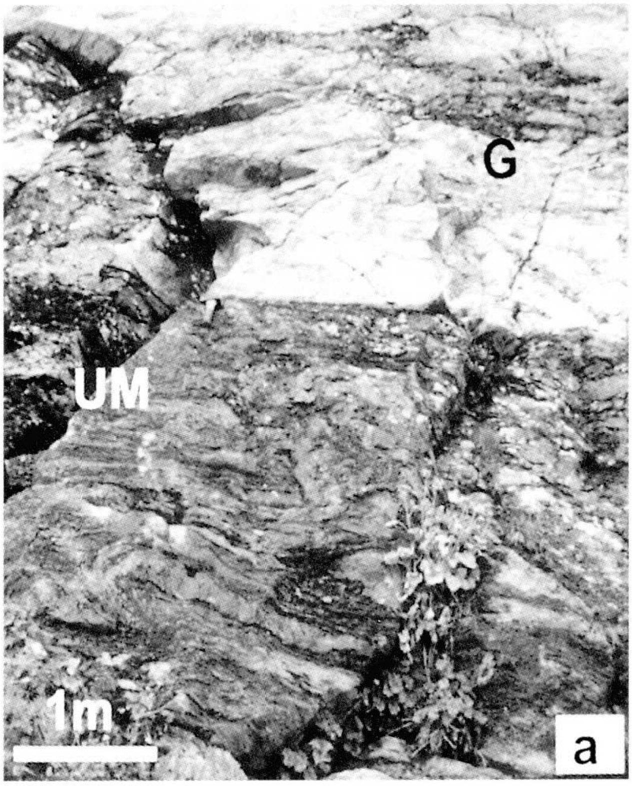
The search for the conditions prevailing for the gabbro-peridotite association is a highly speculative attempt. Indeed, as the Pelvas consists only of a small isolated portion of an ophiolitic sequence, mainly formed of isotropic gabbro, there is no observable transition nor primary relationship with a true mantle section. This makes the proposed interpretations problematic. However, (1) the intrusive character of the peridotites into high-level gabbros is clear; (2) an Atlantic type slow-spreading ridge initial environment is often proposed (LAGABRIELLE, 1982, 1987; LAGABRIELLE et al., 1985; LAGABRIELLE and LEMOINE, 1997). Particularly, features such as (1) a reduced and sporadic magmatic activity implying short-lived, ephemeral, small magma chambers not favourable for the development of an important differentiated cumulate portion, (2) a high degree of tectonic segmentation of the ridge, are typical of such environments. Classically, dunites are observed in the upper mantle-lower crust transition zone showing, in such a context, a reduced thickness of about 300 m. More precisely, this zone corresponds to the limit between an upwelling mantle and the lithospheric magma chambers (NICOLAS, 1989).

Several origins, sometimes of a controversial nature particularly due to textural convergences, are mentioned in the literature: (1) early cumulates, (2) refractory residues (BOUDIER and NICOLAS, 1977), or (3) replacement dunites in diverse contexts (CANNAT and LÉCUYER, 1991; CEULENEER and RABINOWICZ, 1992; KELEMEN et al., 1997). For the intrusive dunitic intercalations of the Pelvas, the hypothesis of an origin from early ultrabasic cumulates is favoured. Such intrusive cumulates have been described in the Shetland Ophiolite Complex (FLINN, 1996).

The gabbro and the peridodite could originate from two different parts of a same magma chamber. From the lower part of the chamber, the segregated ultrabasic crystal mush, composed of olivine with more or less spinel and plagioclase could have intruded into the differentiated, partly solidified, gabbroic upper part of the magma chamber, for instance as a consequence of a tectonic segmentation triggering hydraulic fracturing. Two different magma chambers, developed either in the same segment or in two adjacent one, could also be considered as sources, the ultrabasic crystal mush originating from one of them.

## STRUCTURE OF THE PELVAS MASSIF

Several structural, metamorphic and magmatic features mentioned above contribute to an understanding of the structure of the Pelvas. Particularly the intensely tectonized contact at the





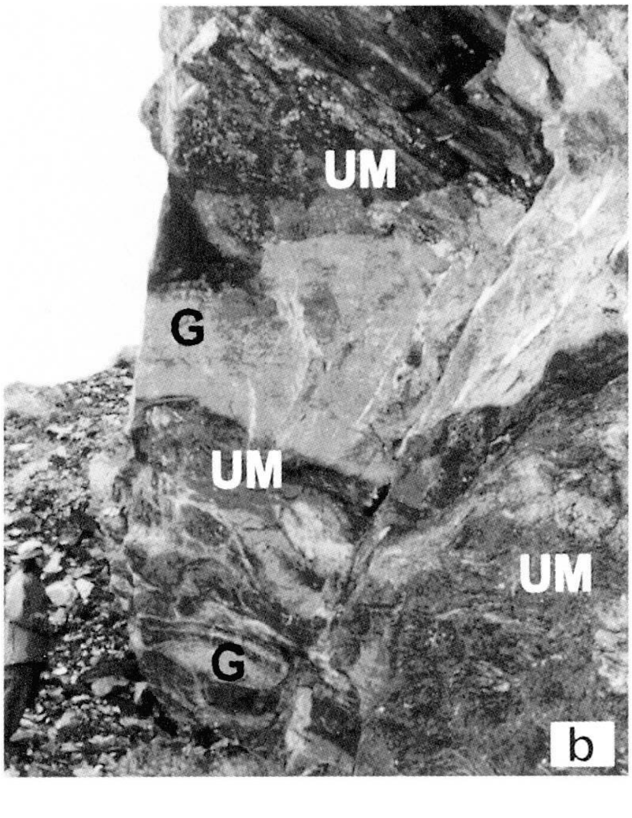



*Fig. 5* Representative field relationship. (a) Folded and boudinaged flow structures of differentiated levels within ultramafite (UM) contrasting with the sharp contact with isotropic gabbro (G). (b) "Magmatic mélange" contact peridotite-gabbro. Lenses, blocks of gabbro (G) imbedded within ultramafite (UM). Note the indications of ductile behaviour, and the sharp to diffuse contacts indicating an assimilation process. (c) Pervasive recrystallization foliation of the gabbro close to the western tectonic contact with sedimentary country rocks.

north-northwest limit of the massif (Fig. 5c), favour the interpretation of LAGABRIELLE (1982), in which the Pelvas massif is an overturned thrust-slice overlied, by fault contacts, by the calc-schist unit, and locally, by the Bric Bouchet unit (Fig. 1). The lack of evidence for Alpine folding in the gabbros and the ultrabasic intrusive rocks, as well as in associated shear zones, also makes it difficult to recognize a folded structure in the massif, as it has been proposed by LAGABRIELLE et al. (1985).

## Conclusions

The Pelvas d'Abriès massif, with its peculiar association of intrusive peridotites into a high level-type gabbro, is a good example of the diversity of the magmatic activity in environments considered as slow-spreading ridge.

Except for the probable reduced thickness of the original succession, due to the omission of certain units, the observed incomplete ophiolitic pseudostratigraphy certainly results from intensive dismembering of the corresponding segment of the Jurassic-Cretaceous Ligurian Tethys. Such events, probably initiated at an early stage of the compressive phase, continued until the closure of the oceanic basin with concomitant erosion and reworking. This is demonstrated by the numerous blocks and different types of ophiolitic detrital horizons scattered within the calc-schists.

Such conditions are not favourable for the reconstitution of the original context of emplacement of the peridotites. Some considerations are still to be developed, such as comparisons with analogous situations which should include a modelisation approach.

## Acknowledgements

We are grateful to Y. Lagabrielle for his introduction in the field and his collaboration. Our thanks are also due to M. Dungan and J. Barclay who improved the English of the manuscript and for constructive remarks. The paper has significantly benefited from the reviews of J. Desmons and M. Frey who are gratefully acknowledged. This work was undertaken in the context of the SNRF grant no 20-50634.97.

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Manuscript received February 20, 1999; revision accepted June 20, 1999.