Zeitschrift: Eclogae Geologicae Helvetiae

Herausgeber: Schweizerische Geologische Gesellschaft

Band: 92 (1999)

Heft: 2

Artikel: The Late Cretaceous-Eocene sedimentation in the internal Briançonnais units of Vanoise (French Alps) : witnesses of early alpine movements

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DOI: https://doi.org/10.5169/seals-168662

0012-9402/99/020211-10 $1.50 + 0.20/0
Birkhäuser Verlag, Basel, 1999

Eclogae geol. Helv. 92 (1999) 211–220

The Late Cretaceous – Eocene sedimentation in the internal Briançonnais units of Vanoise (French Alps): Witnesses of early alpine movements

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Key-words: Internal Briançonnais zone, Vanoise, resedimentation, synsedimentary tectonics, Senonian-Paleocene

RESUME

Dans la zone briançonnaise externe de Vanoise, les marbres chloriteux comprennent deux formations respectivement d'âge crétacé supérieur et éocène inférieur, et sont surmontés de calcschistes détritiques d'âge éocène moyen à supérieur. Dans les zones briançonnaises internes, les marbres chloriteux du Crétacé supérieur comprennent localement d'abondantes lentilles détritiques siliceuses mimant des faciès paléozoïques (Brèches de la Tsanteleina) et sont surmontés par des schistes à olistolites d'âge Paléocène (moyen?) à Éocène basal. La série semble se terminer par des marbres chloriteux d'âge Éocène inférieur probable.

Les resédimentations siliceuses du Crétacé supérieur (≈ 90–75 Ma) sont interprétées comme des coulées de débris issues de l'érosion des zones penniques internes affectées par des déformations compressives ou transpressives. Les schistes à olistolites d'âge paléocène moyen(?)–éocène basal (≈ 60–52 Ma) indiqueraient un événement tectonique. L'évolution tectonique et sédimentaire de ces zones internes parait donc différente de celle des zones briançonnaises externes, qui ne sont déformées et métamorphisées qu'après le dépôt de schistes d'âge Eocène moyen à supérieur (≈ 40–35 Ma).

ABSTRACT

In the external Briançonnais zones of Vanoise, the Chloritic Marbles include two units of Late Cretaceous and Early Eocene age, respectively, and are overlain by detrital calcschists of Middle to Late Eocene age. In the internal zones of Vanoise, the Late Cretaceous Chloritic Marbles contain abundant siliceous detrital lenses mimicking Paleozoic facies (Tsanteleina Breccia) and are overlain by olistolith-bearing schists of middle(?) Paleocene-earliest Eocene age. The succession seems to end up with Upper Chloritic Marbles of Early Eocene age.

These Late Cretaceous detrital deposits (≈ 90–75 Ma) are interpreted as debris-flows proceeding from the erosion of internal penninic units affected by compressional or transpressional deformations. The olistolith-bearing shales express a significant tectonic event of middle(?) Paleocene-earliest Eocene age (≈ 60–52 Ma). Therefore, the tectonic and sedimentary evolutions of these internal zones might differ from those of the external Briançonnais zones, which are deformed only after the deposition of Middle to Late Eocene schists (≈ 40–35 Ma).

1. Introduction

Between Triassic and Early Cretaceous times, the European margin of the Western Alps underwent a passive margin type evolution related to the opening of the liguro-tethyan ocean (Lemoine & De Graciansky 1988) (Fig. 1). During the Early and Middle Jurassic rifting phase, the Briançonnais zone underwent a marked tilted-block tectonics and became emergent. Subsequently, it subsided rapidly and received a pelagic sedimentation during Late Jurassic and Cretaceous times. In spite of local and/or sporadic compressional deformations (Septfontaine 1995), extensional conditions seem to have prevailed until Turonian times (Bourbon 1980; Claudel et al. 1997). From Late Cretaceous onwards, the closure of the Liguro-Tethyan ocean led to the progressive appearance of a compressional regime in the European margin (Lemoine & De Graciansky 1988; Le Pichon et al. 1988). Late Cretaceous and Paleogene breccias deposited in the internal areas of the Briançonnais Zone (Ellenberger 1958; Lemoine 1967; Lefèvre 1982) are interpreted as results of this compressional tectonic activity (Bourbon 1980; Jaillard 1987; Lemoine & De Graciansky 1988; Chaulieu 1992).

Alternatively, the Briançonnais zone has been interpreted as an "exotic" continental terrane, the kinematics of which is controlled by the migration of the Iberic Plate (Stampfli 1993). In this interpretation, the separation of the Iberic and North American plates during the Early Cretaceous (Olivet 1996) triggered the opening of the Ocean Valais Ocean and the sepa-

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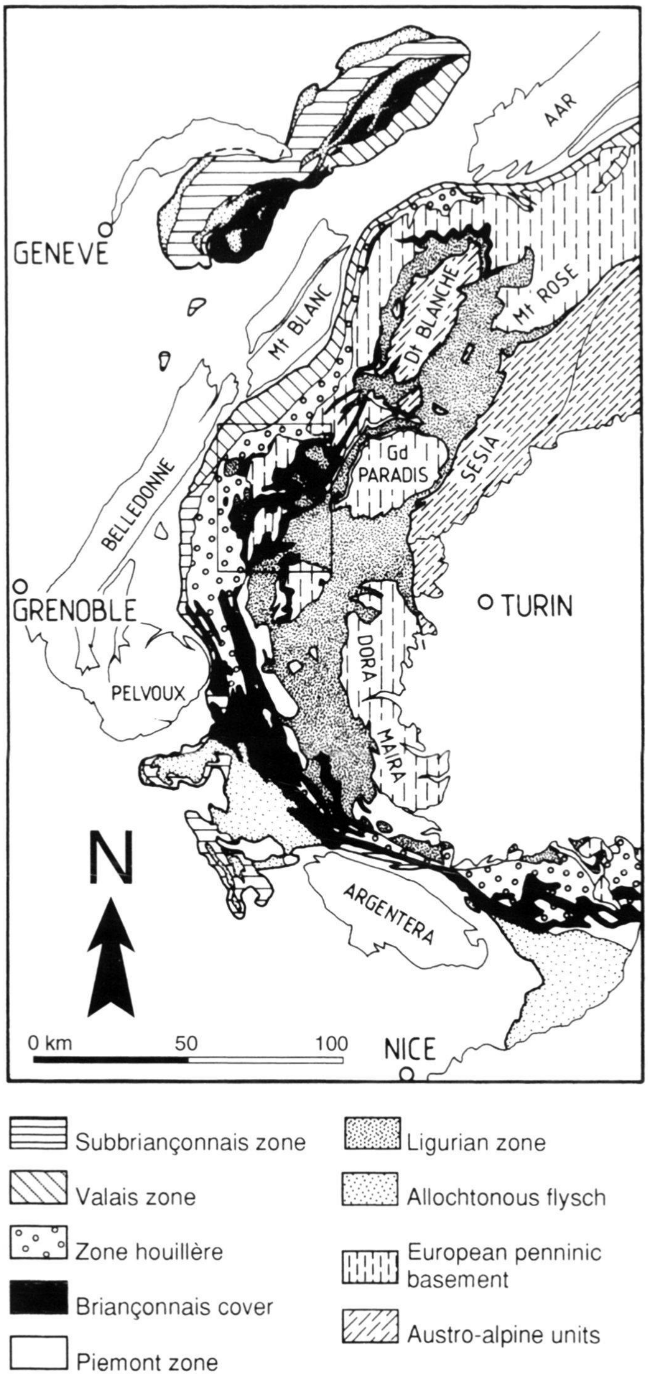

Fig. 1. Structural sketch of the internal zones of the Western Alps with location of the Vanoise massif.

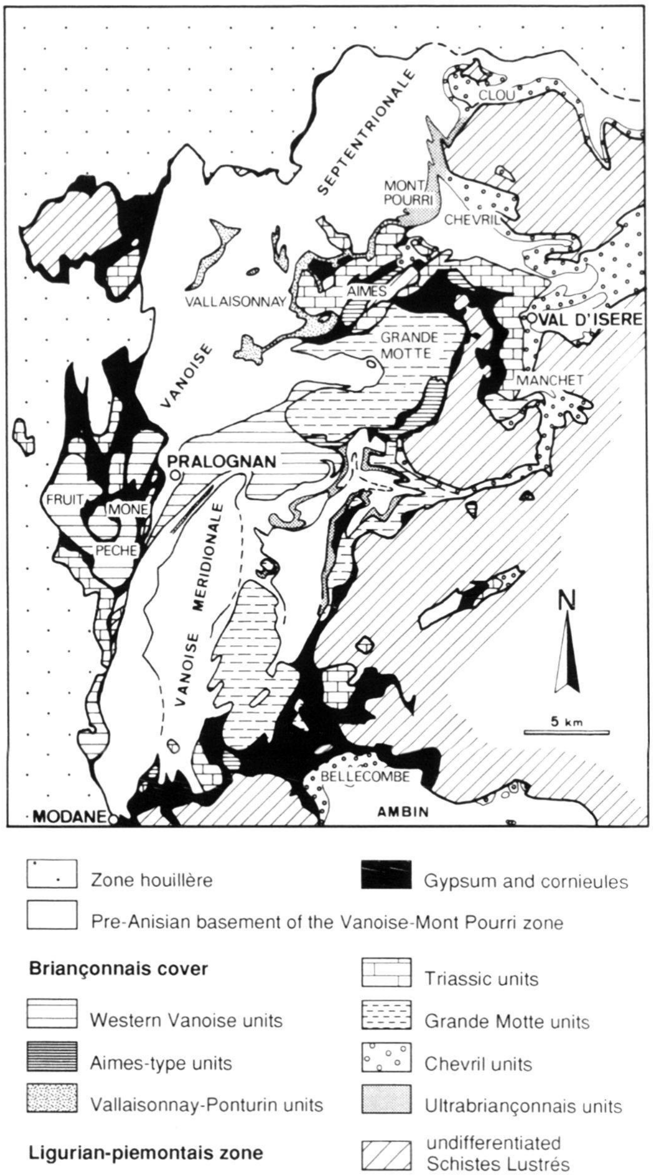

Fig. 2. Structural sketch of the Vanoise and location of the names cited in the text.

ration of the Briançonnais zone from the European margin. Then, the ongoing rotation of the Iberia Plate provoked the oblique consumption of both the Valais and Piemontais oceans beneath the Briançonnais Zone during the Late Cretaceous (Stampfli et al. 1998).

Ellenberger (1958) established the stratigraphy and paleogeography of the Briançonnais series of Vanoise. However, more recent studies brought up numerous new data on the Mesozoic-Tertiary series of Vanoise (Ellenberger & Raoult 1979; Marion 1984; Jaillard 1985, 1987, 1989, 1990; Broudoux 1985; Broudoux et al. 1985; Deville 1987; Broudoux & Raoult 1989). In spite of numerous uncertainties due to a very complex structure (Fig. 2), the paleogeographic evolution of the briançonnais zone of Vanoise may be simply regarded as follows (Jaillard 1988). During the rifting phase (Early-Middle Jurassic), the Briançonnais Zone of Vanoise may be considered as a major high tilted block, including localised half-grabens (Grande Motte zone, Fig. 3). At this time, the Briançonnais Zone was marked by erosions, the importance of which increased toward internal zones, and by a diachronous post-rifting transgression, which began earlier toward the external zones (Vanoise occidentale). Near the Middle-Late Jurassic boundary, the Briançonnais tilted-block was broken up into two main domains. Between Late Jurassic and Paleogene times, the external, probably uplifted, Briançonnais zones received a condensed pelagic sedimentation without breccias, whereas the internal Briançonnais zones received abundant detrital deposits, breccias and re-sedimentations (Chevril zone, Fig. 2 and 3). During the Late Jurassic, the fracture zone acted probably as a slope and was marked by strong unconformities, breccias and condensed sections (Aimes zone, Jaillard 1988). This paleogeographic pattern seems to have persisted until the Late Cretaceous (Fig. 3). Alternative paleogeographic models have been proposed (e.g. Deville 1987), which do not change significantly the tectonic context assumed for these deposits.

The aim of this paper is to analyze the stratigraphy, repartition, depositional processes and tectonic significance of the Late Cretaceous and Paleogene re-sedimentations, which are well-exposed in the internal Briançonnais Zone of Vanoise.

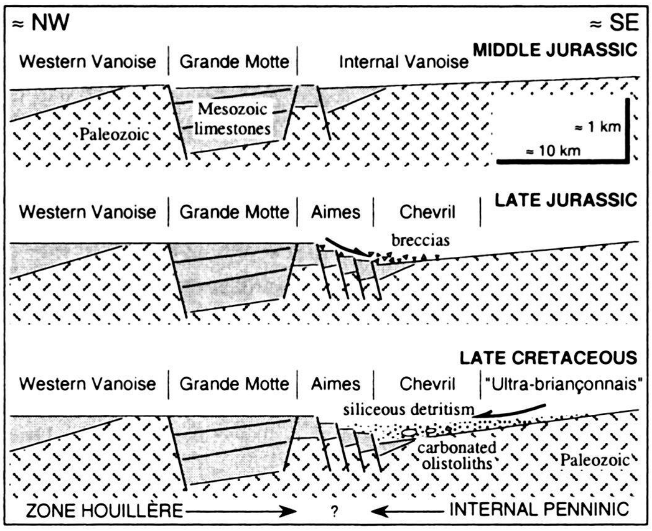

Fig. 3. Pre-Tertiary evolution of the Briançonnais zone of Vanoise.

2. The Late Cretaceous – Tertiary sedimentation in the Brianconnais zone of Vanoise

2.1. Presentation

In the Vanoise, Late Cretaceous-Eocene pelagic deposits are presently represented by massive chloritic marbles, overlain by dark schists and calcschists (Pralognan Schists). The weathered Chloritic Marbles ("Marbres chloriteux", Ellenberger 1958) exhibit a green, brown to beige colour, while fresh rock is green, beige, red or pink. However, the stratigraphic succession differs according to the regions.

In the external Briançonnais Zone of Western Vanoise, two chronostratigraphic units have been distinguished in the Chloritic Marbles (Ellenberger & Raoult 1979; Jaillard 1985; Broudoux 1985). The first one overlies white marbles ascribed to the Late Jurassic, by means of a discontinuous mineralized hard-ground dated by Cenomanian-Turonian microfaunas. This Lower Chloritic Marbles unit yielded planktic foraminifera of early Late Cretaceous age (Ellenberger 1958; Ellenberger & Raoult 1979), and would correlate with the Rote Platte Formation of the Préalpes Médianes (Switzerland), dated as Late Turonian to Late Santonian (Guillaume 1986).

The upper unit often overlies a hard-ground dated by Late Paleocene and/or Early Eocene foraminifera (Ellenberger 1958; Ellenberger & Raoult 1979; Fig. 6). It would correlate with the Chenaux Rouges Formation of the Préalpes Médianes, of most probably Early Eocene age (Guillaume 1986). The Upper Chloritic Marbles unit rests either on the Lower Chloritic Marbles, or on the Jurassic white marbles, the upper surface of which may be eroded and exhibits locally a karstic aspect (Broudoux 1985). The disconformity between the two units of Chloritic Marbles (Jaillard 1985), as well as the frequent occurrence of reworked faunas at the base of the upper unit indicate that erosions took place at least locally before the deposition of the Paleogene Upper Chloritic Marbles. Finally, detrital quartz is noticeably more abundant in the upper unit (23 % SiO_2) than in the lower one (8 % SiO_2) (Broudoux 1985).

The Upper Chloritic Marbles rapidly grade upwards into dark-coloured sandy schists and calcschists ("Schistes de Pralognan", Fig. 6). These are ascribed to the Middle to Late Eocene, by comparison with the "flysch" dated as Lutetian in the Briançonnais Zone of Switzerland (Préalpes Médianes, Caron et al. 1989) and locally as Early Priabonian in the Briançon area (Barféty et al. 1992, 1995).

In the internal areas of the External Briançonnais zone, the Lower Chloritic Marbles are often lacking. In the Grande Motte area, however, a Late Maastrichtian hard-ground is overlain by a meter-thick layer of reworked volcanic products of alcaline affinity, which indicate an intraplate extensional regime during the Late Maastrichtian (Deville 1987), or more probably during the Paleocene.

In the internal Briançonnais Zone of Vanoise, Chloritic Marbles are generally associated with abundant resedimentations (Tsanteleina Breccias, Ellenberger 1958; Niemeyer 1979; Deville 1987; Jaillard 1987). From the matrix of the "Tsanteleina Breccias", Ellenberger (1958: 319 and 448) reported Late Cretaceous microfaunas (Pointe du Front, Pelaou Blanc), and Deville (1987: 94) mentions Late Turonian to Senonian foraminifera (Lacs de Bézin).

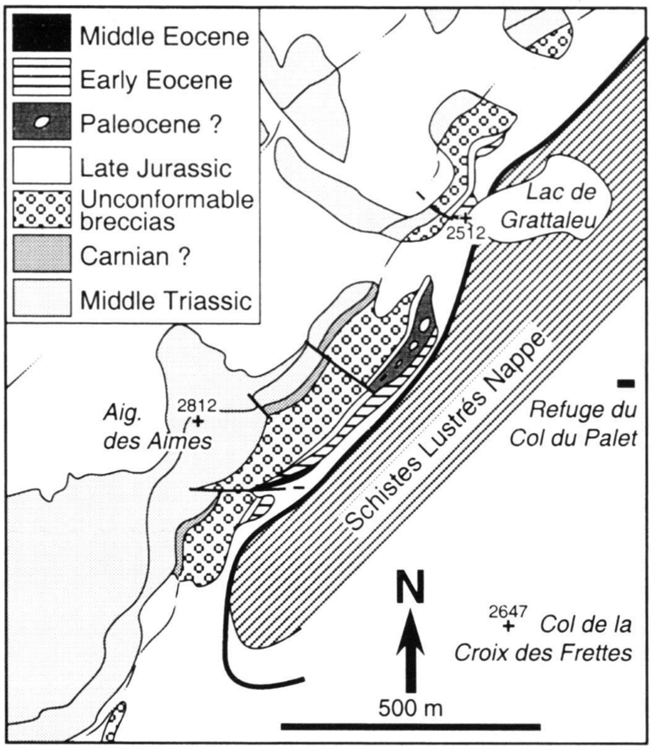

Fig. 4. Geological map of the Aiguille des Aimes unit (after Jaillard 1989).

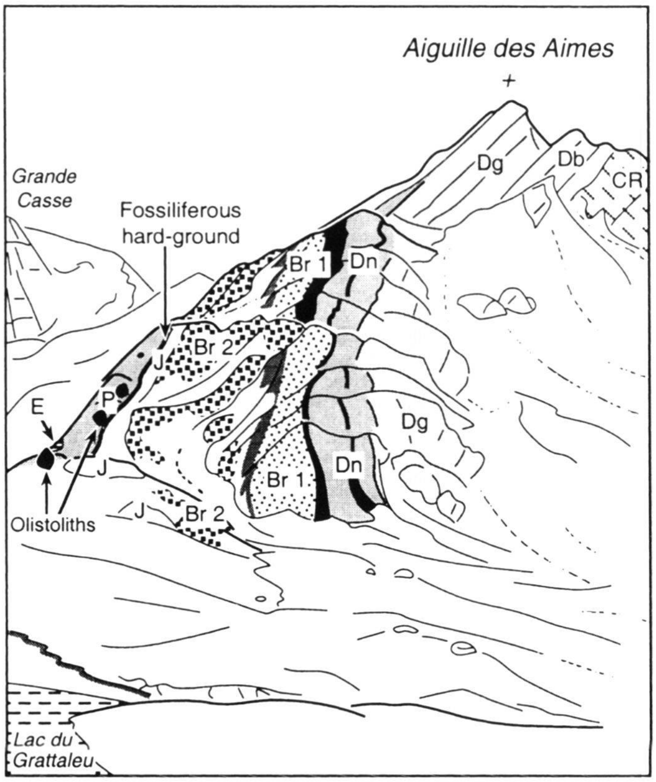

Fig. 5. The Aiguille des Aimes section, viewed from the NE.
CR, Db, Dg : Calcaires rubanés, Dolomies blanches, Dolomies grises (Middle Triassic); Dn: "Post-Ladinian" dolomites and breccias (Carnian?); Br 1, Br 2: Undated disconformable breccias (probably Jurassic); J: White marbles (Late Jurassic); P: Olistolith-bearing calcschists (Paleocene and/or earliest Eocene); E: Upper Chloritic Marbles (Early Eocene).
The hard-ground bearing well-dated Late Cretaceous clasts is located between J and P.

2.2. New stratigraphic data from the Aiguille des Aimes section

The Aiguille des Aimes unit tectonically overlies Triassic units and is overlain by the Grande Motte and Schistes Lustrés nappes (Fig. 2). It is regarded as belonging to the hinge zone located between the external and internal Vanoise domains (Fig. 3, Jaillard 1989). In the Aiguille des Aimes section, the Jurassic white marbles are overlain by a 20 cm-thick, mineralized and microbrecciated hard-ground, in turn overlain by Paleogene deposits (Fig. 4 and 5). The study of a dozen of thin sections collected in the hard-ground and the analysis of the overlying field section allows to recognize four distinct episodes of sedimentation during the Late Cretaceous-Early Eocene interval.

(1) In the hard-ground, calcareous clasts contain planktic foraminifera among which large carinated forms indicate a Late Turonian-Santonian age: *Heterohelix reussi*, *Marginotruncana coronata*, *M. pseudolinneiana*, *M. schneegansi* and *Rosita fornicata*. They indicate that a depositional episode occurred during the Late Turonian – Santonian p.p. interval, which correlates with the Rote Platte Formation of the Swiss Préalpes Médianes (Guillaume 1986).

(2) These clasts are encrusted by an albite-rich stromatolite containing a Late Senonian foraminiferal association, which represents a sedimentary gap of ?Campanian-Early Maastrichtian? age.

(3) The same hard-ground also contains other carbonated and mineralized clasts bearing a Late Maastrichtian microfauna: *Globotruncana linneiana*, *Globotruncanita angulata*, *G. stuarti*, *Globotruncanita* spp., *Planoglobulina acervulinoides*, *Pseudotextularia elegans*, *Racemiguembelina fructicosa* and *Rosita contusa*. They evidence a second episode of sedimentation of Late Maastrichtian age, coeval with the Forclettes Formation of the Briançonnais zone of the Préalpes Médianes (Guillaume 1986).

(4) The Late Maastrichtian clasts exhibit cracks and are in turn encrusted by an other mineralized stromatolite containing a pyritized microfauna with *Globigerina* sp. of Tertiary age, which express a second sedimentary gap. The brecciated hard-ground containing the two generations of Late Cretaceous clasts probably formed during this Early Tertiary sedimentary gap.

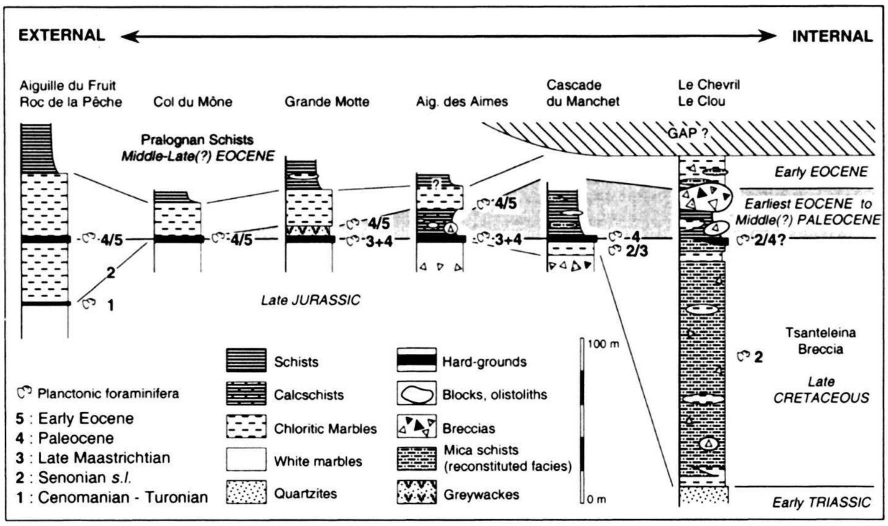

Fig. 6. The Cretaceous and Tertiary sedimentation in the Briançonnais zone of the Vanoise, as displayed by selected, well-dated sections. Numbers refer to paleontologic dates.
Sources: Aiguille du Fruit and Roc de la Pêche: Ellenberger (1958), Jaillard (1985); Col du Mône: Ellenberger (1958); Grande Motte: Deville (1987); Aiguille des Aimes: Ellenberger (1958), Broudoux and Raoult (1989), this work; Cascade du Manchet: Ellenberger (1958), Deville (1987), Broudoux and Raoult (1989); Le Chevril and Le Clou: Jaillard (1990).

(5) The hard-ground is overlain by a 20 m-thick series of dark sandy calcschists, part of which may represent turbidite beds. This series wedges out southwestwards (Fig. 4). It contains blocks made of carbonated breccias exhibiting a matrix of light-coloured marble, presumably of Late Jurassic age (Jaillard 1989; Fig. 5). These olistolith-bearing calcschists express a sedimentary episode, in an unstable, active tectonic context. Because of their stratigraphic position, the olistolith-bearing calcschists are of Paleocene p.p. to earliest Eocene age (Fig. 6), and would be equivalent to the lens-shaped "Hochmatt Calcarenite" of the Préalpes Médianes of western Switzerland, dated as Middle Paleocene to earliest Eocene (Guillaume 1986).

(6) The olistolith-bearing calcschists are stratigraphically overlain by the upper unit of Chloritic Marbles. Toward the southwest, the latter directly rest upon the Jurassic marbles and are dated as Late Paleocene(?)-Early Eocene (Ellenberger 1958; Broudoux & Raoult 1989; Fig. 4 and 6). These Upper Chloritic Marbles are coeval with the Chenaux Rouges Formation of the Préalpes Médianes of Early Eocene age (Guillaume 1986). They evidence the resumption of pelagic, mostly carbonated sedimentation.

(7) The overlying black schists may be ascribed to the Middle-Late Eocene Pralognan Schists (Broudoux & Raoult 1989; Deville et al. 1991). They are in tectonic contact with the Schistes Lustrés Nappe (Fig. 4), from which they are locally difficult to distinguish.

2.3. *New data from the Chevril zone*

The Chevril zone rests in tectonic contact on the Vanoise septentrionale basement, and is covered by the Schistes Lustrés Nappe (Fig. 2). It crops out in the whole Val d'Isère area, and good, well correlatable sections can be studied all around the Grande Sassière massif (Jaillard 1990). The Chevril zone is interpreted as representing the external part of the Internal Vanoise (Fig. 3). It was paleogeographically bordered to the East by the "Ultra-Briançonnais Zone", where the Paleozoic basement is directly overlain by the Late Jurassic marbles or, more frequently, by the Late Cretaceous-Paleogene Chloritic Marbles. A detailed analysis of the Cretaceous to Paleogene series of the Chevril zone and of the Tsanteleina Breccia displays a three-fold succession (Jaillard 1990; Fig. 6):

- The *lower unit* begins often with sandy chloritic marbles, overlain by accumulations of siliceous detrital lenses (micaschists, chloritic schists, micaceous white quartzites) mimicking various Paleozoic to Early Triassic lithofacies. They are classically known as "reconstituted facies" (Lemoine 1967). The Late Turonian to Senonian microfaunas quoted by Ellenberger (1958) and Deville (1987) proceed from this unit. These facies are locally very thick and were called the Tsanteleina Breccia (Ellenberger 1958; Niemeyer 1979). According to the available data, and since the Cenomanian-Turonian interval is usually represented by a sedimentary gap, the age of this unit would be of post-Turonian and pre-Maastrichtian age. However, the fact that, locally, these sediments are slided and mixed with the overlying olistolith-bearing black schists of probable Paleocene-earliest Eocene age suggests that, unless they remained unlithified until the deposition of the olistolith-bearing black schists, their deposition may have gone on during Late Senonian and Paleocene times.
- The *middle unit* consists of carbonated olistoliths, up to several hundred meter large, wrapped in a black schist matrix, which is locally abundant and may contain siliceous detrital lenses. At the col de la Bailletta (≈ 4 km ENE of Val d'Isère), this middle unit directly overlies Jurassic breccias by means of a hard-ground bearing microfaunas of Senonian age (*R. fornicata*?), and its base yielded crushed

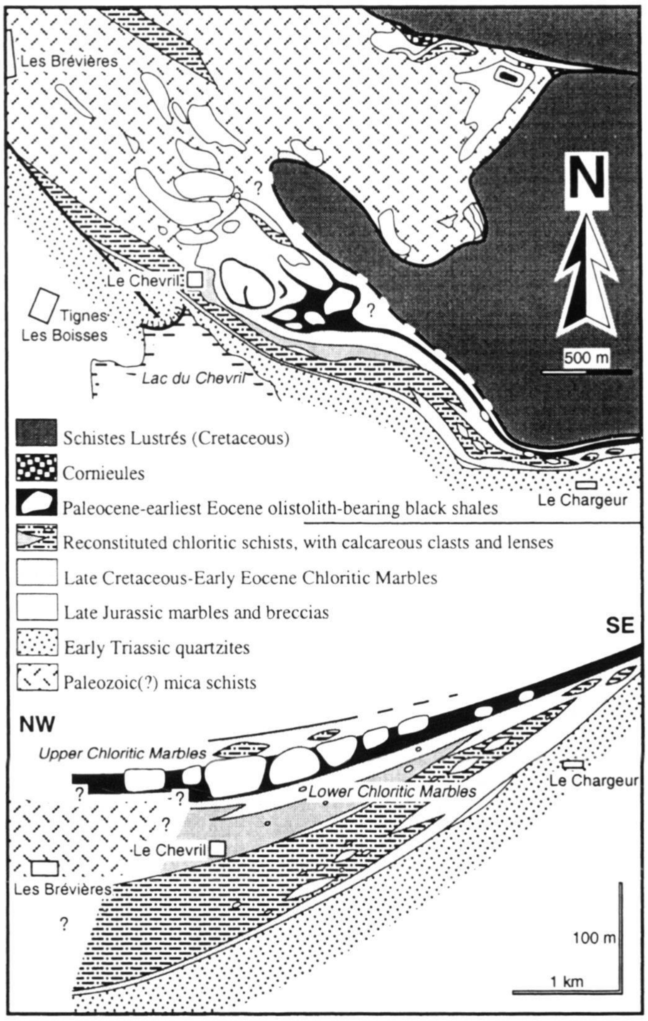

Fig. 7. The resedimentations in the Le Chevril series.
A: Geological sketch map of the Le Chevril area.
B: Interpretative section between le Chargeur and les Brévières.

foraminifera of probably Tertiary age (Jaillard 1990). At the Manchet waterfall (≈ 3 km South of Val d'Isère), the olistolith-bearing black schists overly layers bearing microfaunas of Senonian (including Maastrichtian) (Ellenberger 1958, p. 317–9; Deville 1987, p. 49) to Late(?) Paleocene age (Broudoux 1985; Deville 1987; Broudoux & Raoult 1989). Therefore, the olistolith-bearing black schists of the Chevril zone are of Early Tertiary age. Because of their stratigraphic position, they would correlate with the olistolith-bearing calcschists of the Aiguille des Aimes, and with the "Hochmatt Calcarenite" of the Swiss Préalpes, of Middle Paleocene to earliest Eocene age (Guillaume 1986).

– *The upper unit* is constituted by undated Chloritic Marbles which contain scattered calcareous blocks and thin and small-scale detrital siliceous lenses comparable to those of the "Tsanteleina Breccia". This unit can be observed and mapped in the same stratigraphic position in most sections of the Le Chevril area and along the western and northern sides of the Grande Sassière nappe (Jaillard 1990). It is, therefore, interpreted as the youngest stratigraphic unit of the Chevril succession. By comparison with the Aiguille des Aimes section, it can be correlated with the Upper Chloritic Marbles of the external zones, of Early Eocene age.

The Pralognan Schists of external Vanoise (Middle to Late Eocene) have not been reliably identified in the internal zone of Vanoise. Many oucrops presently ascribed to this formation (Deville et al. 1991) may be alternatively interpreted as representing the olistolith-bearing black shales of Paleocene-earliest Eocene age. However, it is also possible that the Middle Eocene Pralognan Schists have been tectonically removed during the overthrusting of the Piémontais units.

In other sections of the internal Briançonnais zones of Vanoise, the lithologic succession is less clear, because of intense deformations and/or synsedimentary sliding and slumpings, which obscured the stratigraphic relations. However, "reconstituted facies" associated with chloritic marbles and olistolith-bearing schists or calcschists containing detrital lenses are generally present (Fig. 6). Nevertheless, one cannot exclude that resedimentations occurred at different periods according to the regions. The presented correlations must be considered, therefore, as a tentative and preliminary stratigraphic framework.

3. Origin, depositional processes and significance of the detrital sediments

Alpine deformations and metamorphism preclude detailed sedimentological analysis of the internal Briançonnais series. Nevertheless, observations carried out mainly in the Chevril zone allow to specify the depositional processes of the Late Cretaceous-Eocene sediments (Jaillard 1987). We shall examine successively the three units presented above.

3.1. Siliceous detrital lenses in the Lower Chloritic Marbles (Late Cretaceous)

Some detrital lenses mimicking Paleozoic schists, micaschists or quartzites have been interpreted as olistoliths (Ellenberger 1958). However, most of them contain carbonated clasts and/or discontinuous intercalations of Chloritic Marbles. In most cases, it is impossible to determine wether these lenses of Chloritic Marbles are clasts or sedimentary interbeds. Moreover, in the Chevril area, I did not observe sedimentary features classically associated with olistoliths, such as small clasts exhibiting the same lithology as the olistolith and surrounding the latter, or cracks opened in the olistoliths and filled by the enclosing marbles. Therefore, most of the lenses exhibiting Paleozoic or Early Triassic lithofacies, if not all, must be considered as resulting from the metamorphism of detrital sedimentary bodies (Niemeyer 1979).

The few brown carbonated clasts are scattered in the siliceous detrital lenses or in the Chloritic Marbles and do not constitute massive breccias (except in some thin mineralized hard-grounds). They do not derive, therefore, from collapses at the foot of fault escarpments, as frequently observed in extensional tectonic context.

Within a single outcrop, one can observe Chloritic Marbles containing scarce small-sized detrital lenses grading laterally into thick accumulations of "reconstituted" micaschists containing scarce intercalations of Chloritic Marbles (Fig. 7). This suggests that the paleotopography was uneven, with positive zones receiving an autochtonous condensed pelagic sedimentation, and depressions where thick resedimentations were accumulated (Fig. 7).

Each siliceous detrital lens usually presents a single well-defined lithology, which reflects a single, well defined and localised source zone. This suggests that the source zones were close and transport was short (Lemoine 1967). In contrast, detrital lenses of different lithologies may occur vertically in a same site, thus suggesting that the source zones and/or the feeding channels were changing in time and space.

Since clasts and detrital particles of quartz, micas or clay are mixed within the detrital lenses, little or no granulometric sorting occurred during transport (Lemoine 1967). This suggest a transport by debris flows processes, rather than by turbidity current.

In the Chevril zone, the most frequent siliceous detrital facies is that of greenish chloritic micaschist mimicking facies formerly ascribed to the Permian in the internal penninic massifs (Ambin, Southern Vanoise, Ellenberger 1966). Other facies are dark coloured micaschists similar to Paleozoic facies of the Mont Pourri Massif, and white quartzites resembling the Early Triassic quartzites of the Briançonnais zone. The carbonated clasts and boulders are often brown and brecciated, but are difficult to ascribe to any typical Briançonnais facies.

With the exception of the micaceous white quartzites, none of these facies can be ascribed to external briançonnais deposits. On the contrary, the chloritic micaschists, grey micaschists or the brownish dolomitic clasts proceed most probably from penninic domains more internal than the Chevril zone (Ultra-Briançonnais zone).

3.2. Olistolith-bearing black schists (Middle? Paleocene-earliest Eocene)

The black schists of the matrix suggest that the environment was not favorable for carbonate sedimentation, and that deposition took place possibly below the CCD. This indicates that the sedimentary context noticeably changed with respect to the Late Cretaceous.

The olistoliths were emplaced most probably by sliding. They are often laterally sorted according to their size, the largest being accumulated along what were probably slope breaks (Fig. 7). Some outcrops are constituted by carbonated micaschists bearing abundant scattered carbonated clasts and olistoliths (Fond des Fours). They are interpreted as resulting from the mixing of chloritic marbles, siliceous detrital lenses and olistoliths during synsedimentary sliding. The abundance of boulders and olistoliths in these mixed deposits suggests that slumpings occurred during the deposition of the olistolith-bearing black shales. This observation is consistent with the interpretation of an active tectonic context marked by the creation of slopes.

The olistoliths of the middle unit are most frequently polygenic breccias with white marble matrix, yellow dolomitic breccias and yellow to brownish argillaceous dolomites, associated with subordinate massive white quartzites (Early Triassic facies) and chloritic marbles. Most of these elements seem to proceed from the substratum of the Chevril series. Therefore, as noted by Lemoine (1967) in the Briançon area, the olistoliths may proceed from the proper zone upon which they are re-deposited. As a consequence, we have to admit that the internal zones of Vanoise were involved in deformational processes during the deposition of the olistolith-bearing black schists.

3.3. Upper Chloritic Marbles (Early Eocene)

The Upper Chloritic Marbles express the restoration of a mainly carbonated pelagic sedimentation, with only subordinate detrital lenses and blocks. However, in the external zones detrital quartz is more abundant than in the Lower Chloritic Marbles (Broudoux 1985). Therefore, the tectonic activity seems to have significantly decreased by the Early Eocene.

4. Tectonic interpretations

The resedimentations in the internal Briançonnais and "Ultrabriançonnais" zones witness of significant tectonic events which affected the internal penninic zones during Late Cretaceous and Paleocene-earliest Eocene times (Fig. 8).

4.1. Late Cretaceous (≈ 88–75 Ma)

During the Coniacian-Campanian (?) period, debris flows of siliceous detrital material of internal origin dominated, and were intercalated in the autochtonous pelagic carbonated sedimentation (Fig. 6 and 7). The changing source areas and the migrating feeding channels suggest that the source areas were unstable and mobile. The siliceous lenses may be interpreted as lower slope accumulations ("immature fans" of Homewood & Caron 1982; slope-apron of Stow 1986) (Fig. 8). The reduced thickness of these detritic lenses and the scarcity of olistoliths suggest a distal position with respect to the deformed zone located in more internal Penninic zones.

The lack of massive breccias with angular clasts of chloritic marbles may be due to the pelagic environment, which is not favorable for the early diagenesis of carbonate oozes. Never-

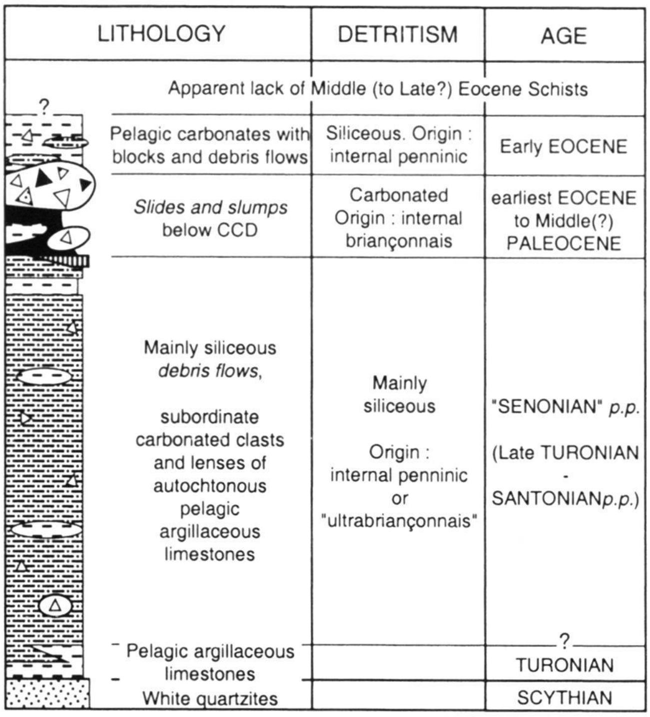

Fig. 8. Interpretation of the resedimentations in the Le Chevril series.

theless, the apparent lack of breccias containing angular pre-Cretaceous clasts suggests that steep-dipping faults, such as normal faults, were not active. This observation, together with the apparently continuous deformation of the source-areas rather suggest a compressional or transpressional context, marked by thrust faults, accretionary wedges or flower structures. Although breccias may be generated also by such structures, the evolution of the latter is consistent with the observed mobility of the basement and the changing, ephimeral and localised character of the source zones.

This deformation seems to be coeval with the flysch-like deposits reworking oceanic and continental rocks in the Piémontais (Deville 1993; Fudral 1996) and Valais zones (Fudral 1996). Coeval deformations account for the unconformity observed below the Maastrichtian flysch in the Piémontais zone of Vanoise (Deville 1987, 1993) and between the Early Cretaceous-Early Santonian folded succession and the Late Campanian-Maastrichtian limestones in some external zones of France (Dévoluy, Arnaud et al. 1974, 1984 in Philip: 355–58) and Switzerland (Trümpy et al. 1980). These deformations are probably related to the rotation of the Iberic plate, which together with the northward shift of the African plate, triggered the oblique closure of the Ligurian-Piemont and Valais oceans (Lemoine & De Graciansky 1988; Stampfli et al. 1998).

The Late Maastrichtian time-span (≈ 70–65 Ma) is often marked by a sedimentary gap (hard-ground). However, the local occurrence of clasts in the Tertiary hard-grounds (Aig. des Aimes) indicates that Upper Maastrichtian pelagic oozes have been deposited locally.

4.2. Middle(?) Paleocene-earliest Eocene (≈ 60–52 Ma).

During the Middle(?) Paleocene – earliest Eocene time-span, chiefly carbonate olistoliths were deposited by mass sliding, presumably below the CCD (Fig. 8). The significant deepening of the internal Vanoise may be related to a flexural subsidence related to compressional deformations. The age of this possibly short-lived event is still poorly constrained. The origin of the olistoliths and the occurrence of slumpings involving underlying deposits indicate that the substratum of the Chevril zone proper was deformed.

This interpretation is consistent with the occurrence in the Prealps of olistostromes dated as Paleocene-Early Eocene in the Ultrahelvetic zone (Lempicka-Münch et al. 1993), of megabreccias in some Briançonnais units (Hürlimann et al. 1996), and of a "wildflysch" in the Brèche Nappe (Steffen et al. 1993), formerly ascribed to the Eocene (Caron & Weidmann 1967). In other areas of the Penninic domain, this period is frequently marked by a stratigraphic gap (Gübler 1953; Bourbon 1980; Barféty et al. 1995).

The plate kinematic reorganization around 58–53 Ma (Olivet et al. 1984; Gordon & Jurdy 1986; Atwater 1989; Mayes et al. 1990), which included the opening of the Norwegian and Arctic Seas, may have led to a discontinuity in the convergent motion between Europe and Africa (Savostin et al. 1986; Dewey et al. 1989; Olivet 1996), the latter evolving from an extensional regime to a transcurrent or compressional regime (Klitgord & Schouten 1986). This change may have resulted in a westward jump of the deformations, which could have affected, therefore, the internal parts of the Penninic domain (cf. Froitzheim et al. 1996).

4.3. Eocene (≈ 52–35 Ma)

The Early (to Middle?) Eocene is marked in the internal Vanoise by a pelagic calcareous sedimentation intercalated with some debris flows reworking mainly siliceous material. It expresses a decrease of the tectonic activity (Fig. 8). The resumption of carbonate sedimentation may be due either to the deepening of the CCD recorded in many oceanic basins by the Eocene (van Andel 1975), or to the tectonic uplift of the internal Briançonnais zone. If the accretionary prism model of Stampfli et al. (1998) is admitted, the observed uplift of internal Vanoise may be due to the westward shift of the flexural bulge.

During the Middle Eocene (?) (≈ 45 Ma), the external zones of Vanoise recorded the deposition of detrital shales, marls and sandstones ("Pralognan Schists"), the equivalent of which have been dated as early Late Eocene in the Briançon area (Barféty et al. 1992, 1995). These deposits preceded the deformation and metamorphism of the Briançonnais zone (Froitzheim et al. 1996, Mosar et al. 1996, Stampfli et al. 1998, and references therein) and are coeval with important resedimentations known in the external zones (e.g. Kerckhove & Pairis 1986; Kindler et al. 1995). If not due to the subsequent thrust of the Piémontais units, the apparent lack of typical "Pralognan Schists" facies in the Chevril zone would suggest that the sedimentation ceased earlier in the internal Briançonnais zone of Vanoise than in the Western Vanoise, and that the former was already involved in compressional deformation and burial, while the latter still received a marine sedimentation.

5. Conclusions

In spite of the scarcity of reliable stratigraphic data, the study of the re-sedimentations in the internal Briançonnais zones of Vanoise led to the following conclusions :

During the Late Cretaceous (?Coniacian-Campanian, ≈ 90–75 Ma), the erosion of internal Penninic basement units, deformed by a compressional or transpressional tectonic regime resulted in the deposition of siliceous debris flows in the internal Briançonnais zone.

During the Middle(?) Paleocene-earliest Eocene (≈ 60–52 Ma), the westward migration of compressional deformations resulted in the deformation and possibly the subsidence of some internal Briançonnais zones. Although still poorly documented, this event may have been significant.

The Early Eocene (≈ 52–50 Ma) is marked by a decrease of the tectonic activity and the restauration of a pelagic carbonate sedimentation. During the Middle Eocene (≈ 50–40 Ma), sedimentation may have ceased in the internal Briançonnais zone, while it certainly went on in the external Briançonnais zone.

By the Late Eocene (≈ 40–35 Ma), the external Briançonnais zone is in turn reached by tectonic-metamorphic deformation and burial.

These data and their interpretation bear important consequences.

It is classically admitted that the Briançonnais zone has not been deformed before the Middle Eocene, since sedimentation still occurred at that time in this zone. According to our interpretation, some ultra-Briançonnais zones may have undergone compressional or transpressional deformation as early as in the Late Cretaceous, and some internal Briançonnais zones (Chevril zone) have probably been deformed by a compressional regime during the Paleocene and/or earliest Eocene.

In some other Penninic zones, black shale units bearing boulder and/or "reconstituted" detrital lenses have been ascribed to the Middle Eocene. According to our data, part of these deposits might be of Middle(?) Paleocene to earliest Eocene age. Therefore, the sedimentary evolution of the internal Briançonnais and Ultra-Briançonnais zones where sedimentation may have ceased by the end of the Early Eocene, and that of the external Briançonnais zone where sedimentation went on at least until the Middle Eocene (Ellenberger 1958; Barféty et al. 1992, 1995), should be considered separately.

Acknowledgements

I am greatly indebted to Michèle Caron (Fribourg, Switzerland), who determined all the planktic foraminifera, although many of them were quite poorly preserved. I appreciated the help of J. Debelmas, M. Gidon, F. Guillot, C. Kerckhove, B. Landès and G. Mascle during field study. J.-C. Barféty, M. Caron, M. Lemoine and M. Marthaler stimulated the redaction and criticized the content of first drafts of this text. Reviews and suggestions of M. Sartori and G. Stampfli significantly improved the final version of this work.

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Manuscript received July 2, 1998
Revision accepted April 6, 1999