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A record of multistage continental break-up on the Briançonnais marginal plateau (Western Alps): Early and Middle-Late Jurassic rifting

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Keywords: Western Alps, Briançonnais, Ligurian Tethys, Continental margins, Rift tectonics, Karst, Diagenetic Log, Neptunian dykes, Inversion
Mots-clés: Alpes occidentales, Briançonnais, Téthys ligure, Marges continentales, Rifting, Karst, Log diagénétique, Filons sédimentaires, Inversion

ABSTRACT

The Briançonnais series in the French Western Alps near Briançon bear evidence of extensional deformation preceding Alpine shortening. Most of these structures have been ascribed to Tethyan rifting processes. However, many of them are younger than the initial opening of the Ligurian Tethys ocean (Late Bajocian-Early Bathonian) and have a different orientation than the syn-rift faults. The combined use of sedimentological, stratigraphic, paleostructural and structural methods allows to distinguish the features related to the Tethyan rifting (Early to early Middle Jurassic) from the younger extensional deformation (Late Jurassic) which in part overprinted them:

– The Tethyan rifting is marked by a subaerial erosional surface (break-up unconformity), bearing karsts which developed along syn-rift faults. The continental to shallow marine diagenetic inprints are analysed (diagenetic log method). The Tethyan syn-rift uplift occurred as pulses from the early Late Triassic (Champcella type units) to the late Early Liassic (Peyre-Haute unit), whereas Tethyan post-rift drowning was synchronous (Late Bathonian thermal subsidence).

– We propose that the post-break-up extensional deformation (Late Jurassic) is linked with intracontinental rifting of the Atlantic realm (Bay of Biscay and/or Valais rifts).

Therefore, the pre-Alpine deformations recorded in the Briançonnais series may result from the interference between different Mesozoic rifting-spreading cycles. Alpine inversion processes are more complex than previously thought since (1) the pre-Alpine structural grain was made of at least two, nearly perpendicular trends, (2) convergence changed in orientation through time, making it possible to reactivate preferentially either one or the other trend, and (3) significant nappe rotations are expected, which may be considered for palinspastic restoration. This has important paleogeographic implications, i.e. the present-day upper units of the Briançonnais pile are not necessarily derived from more distal parts of the Tethyan margin than the lower ones since they may have suffered important lateral, possibly northward, transport before final outward stacking.

RESUME

Les séries briançonnaises des Alpes occidentales dans la région de Briançon portent les traces de déformations antérieures au raccourcissement alpin. La plupart de ces paléostructures distensives ont été attribuées au rifting téthysien, bien que beaucoup d'entre elles soient plus jeunes que l'ouverture initiale de l'océan téthysien ligure (vers la limite Bajocien-Bathonien), et que leur orientation ne corresponde pas aux structures syn-rift. Cette étude pluridisciplinaire (sédimentologie, stratigraphie, analyse des marqueurs paléostructuraux et des structures alpines) permet de caractériser ces structures d'âge jurassique supérieur qui se sont superposées aux déformations syn-rift du Lias-Dogger inférieur. Les phénomènes de paléo-karstification le long de la surface d'érosion continentale correspondant à la discordance post-rift sont analysés, ainsi que la superposition des altérations diagénétiques ayant affecté les roches sous-jacentes (méthode du log diagénétique). La surrection et l'émersion syn-rift se sont probablement échelonnées depuis le Carnien (unités de type Champcella) jusqu'à la fin du Lias inférieur (nappe de Peyre-Haute). La cause de la déformation distensive qui fait suite à l'effondrement «post-rift» du Bathonien est discutée: il pourrait s'agir d'un effet du rifting du domaine Atlantique et de ses dépendances (Golfe de Gascogne et rift Valaisan) superposé à la subsidence thermique de la marge téthysienne. Ainsi, les déformations enregistrées dans les séries briançonnaises résulteraient d'interférences entre plusieurs cycles rifting-ouverture océanique décalés dans l'espace et dans le temps. Les phénomènes d'inversion tectonique sont complexes car (1) le réseau de déformations anté-alpines comporte au moins deux directions principales, presque perpendiculaires, (2) l'orientation de la convergence a changé, ce qui a permis de solliciter alternativement l'une ou l'autre de ces directions, et (3) les nappes peuvent avoir tourné de façon importante. Ces éléments doivent être pris en compte dans les reconstitutions paléogéographiques. En particulier, les unités supérieures dans l'édifice de nappes briançonnais actuel ne proviennent pas nécessairement de secteurs de marge plus distaux que les unités inférieures puisque elles ont pu subir des déplacements latéraux importants, éventuellement vers le Nord, avant d'être empilées vers l'Ouest. Ce pourrait être le cas notamment de la nappe de Peyre-Haute, qui présente des affinités avec certaines séries subbriançonnaises.

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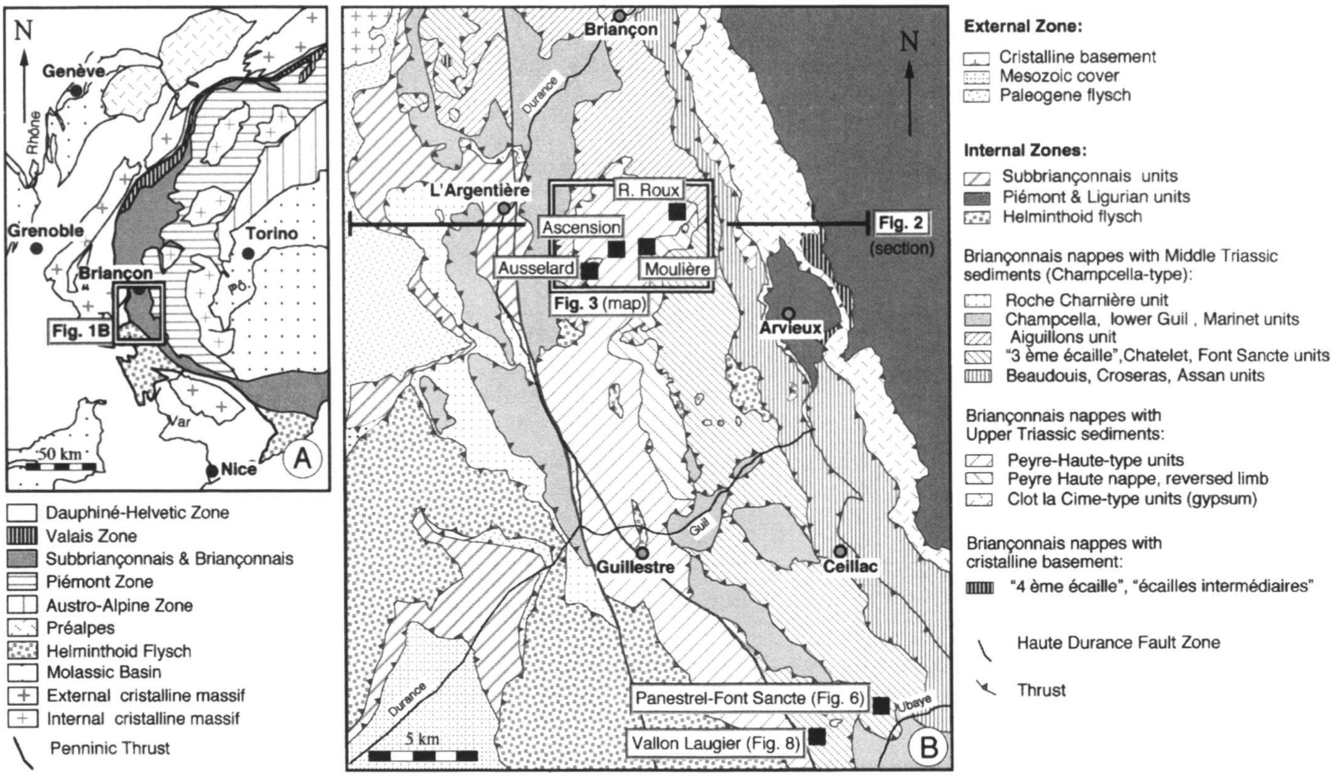

Fig. 1. Structural sketch map of the Briançonnais Zone in the French Western Alps.

1. Introduction

The Briançonnais units of the Western Alps (Fig. 1) derived from a continental fragment on the northern side of the Ligurian Tethys ocean during Mesozoic times. The tectonic evolution of this domain during Tethyan rifting and spreading as well as during Alpine inversion and collision is presently debated. Different geodynamic processes interacted not only during divergence, but also during convergence and collision (Tethyan and Atlantic rifting, Iberian plate motions, Pyrenean, early Alpine and late Alpine-Apenninic collisions), which make palinspastic reconstructions difficult. Following the development of actualistic models in the frame of marine geoscience research, the Mesozoic uplift of the Briançonnais was ascribed to different geodynamic processes such as crustal-scale block tilting (Graciansky et al. 1979, Lemoine 1984, Lemoine & Trümpy 1986), rift shoulder effects (Stampfli & Marthaler 1990, Favre & Stampfli 1992), thermal uplift due to simple-shear crustal stretching (Rudkiewicz 1988), transpression (Faure 1990, Schmid et al. 1990) and inversion (Septfontaine 1995). Stampfli (1993, 1996) considers the Briançonnais domain as an Iberian promontory located between the Ligurian Tethys and the Valais oceanic realms.

This contribution is based on new evidence for block faulting in the Briançon and Guillestre areas. We discuss the classical model of „passive" divergent margins, which ascribes most of this deformation to the Tethyan rifting processes (Laubscher 1975, Bernouilli & Lemoine 1980, Lemoine & Trümpy 1986, Lemoine et al. 1986). Age and geometrical reconstruction of the structures involved are documented by sedimentary, paleontological and structural data. Concerning the erosional and depositional gap due to Jurassic emersion, information was obtained by studying the sequence of diagenetic alterations along the break-up unconformity.

2. Structural and stratigraphic setting

2.1 Alpine structures, inversion and rotation

The Briançonnais pile of nappes results from the shortening of a domain of the European margin of the Tethyan ocean during the Jurassic (Lemoine et al. 1986). Each nappe comes from a different part of this domain and has a specific stratigraphic series (Fig. 2). Within each nappe, many inherited structures were more or less passively transported because they were associated with rigid carbonate (mainly dolomite) wedges that were not easily deformed. Inversion processes were largely dependent on the orientation of the older structures with respect to the shortening direction. The Alpine boundaries are thought to derive from inversion of the Mesozoic extensional

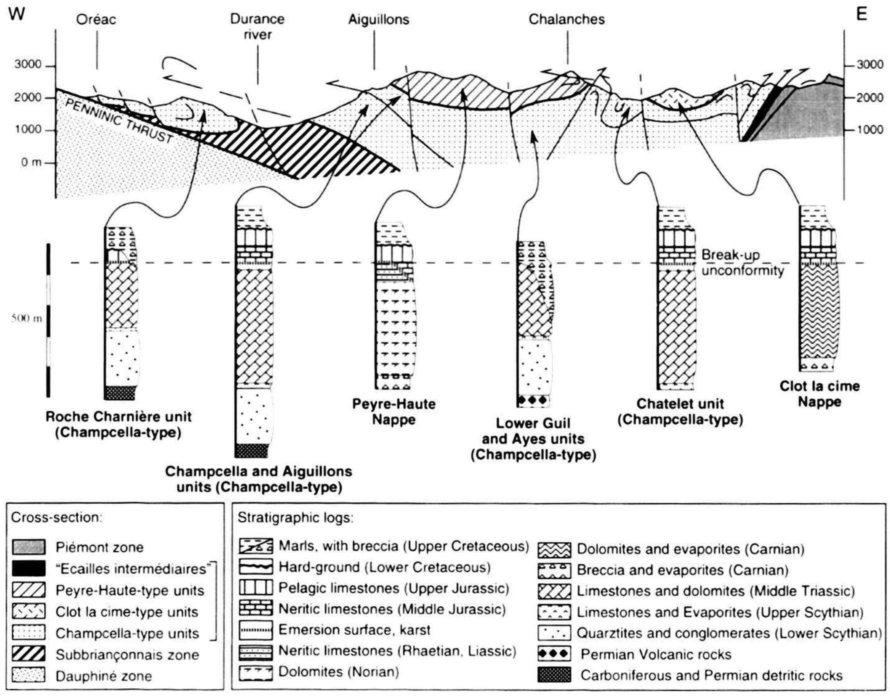

Fig. 2. Main types of stratigraphic successions found in the studied area, with their location within the different nappes (location of the simplified cross section in Fig. 1).

fault pattern. According to Lemoine et al. (1986), the order of the nappes from West to East in the present-day tectonic build-up represents the Jurassic distribution of the domains from which they are issued, from West to East. We think that this hypothesis is rather speculative (Dumont et al. 1997).

According to Tricart (1980), the Briançonnais units were affected by three major phases of deformation: D1, D2 and D3. D1 (latest Eocene) corresponds to westward to northwestward nappe transport and stacking. D2 (Middle Oligocene) is associated with westward to southwestward transport of the early Briançonnais nappe edifice onto the external zone along the Pennine Front. D3 (Miocene) produced folding and backfolding of the pile of nappes. We found evidence of out-of-sequence thrusting associated with D2 and of top-to-the-northwest or top-to-the-north thrusting older than D2 (Dumont et al. 1997). This shows that (1) the reconstruction of the palinspastics of the Briançonnais realm must be based on a detailed kinematic inversion of each Alpine phase according to its specific transport direction (this study is presently in progress), and (2) the present bottom to top arrangement of tectonics units may not represent the original west-east succession of paleotectonic units.

Moreover, preliminary paleomagnetic data indicate that the Briançonnais nappes were rotated counterclockwise by 40°+/–18° relative to the stable Europe since the Oligocene (Thomas et al. 1997). If this is demonstrated by further analysis, this must be considered when restoring the paleotectonic and paleogeographic trends.

2.2 *Pre-Alpine structures*

Mesozoic structures are generally identified using sedimentary criteria. Neptunian dykes, marine breccias derived from fault scarps, tilting and erosion of blocks, thickness changes due to vertical offset along normal faults are used to identify paleofaults, fault scarps and unconformities (Wiedenmayer 1963, Bernoulli 1964, Bernoulli et al. 1990, Castellarin 1966, 1972, Bouillin & Bellomo 1990). In the studied area, the major paleostructures are not preserved because they were reactivated as alpine nappe boundaries. The scale of the observed paleostructures is in the order of centimeters to hundreds of meters. According to their orientation, these paleostructures have been reactivated as strike-slip (if parallel to the compression direction) or as reverse faults (if perpendicular to the compression direction) during nappe transport.

Vertical movements are estimated using facies changes in marine environments (Bourbon 1980, Rudkiewicz 1988) and diagenetic features during syn-rift emersion (this paper). According to Lemoine et al. (1986), most pre-Alpine structures of the Briançonnais are regarded as pre-Bathonian and related to syn-rift extension. However, Bourbon (1980) demonstrated that the Briançonnais realm remained a highly unstable area for a long time also after the Bathonian opening of the Tethys.

2.3 *Stratigraphy*

The Briançonnais series of the Briançon region (Fig. 1 and 2) include thick Triassic platform carbonates (Mégard-Galli &

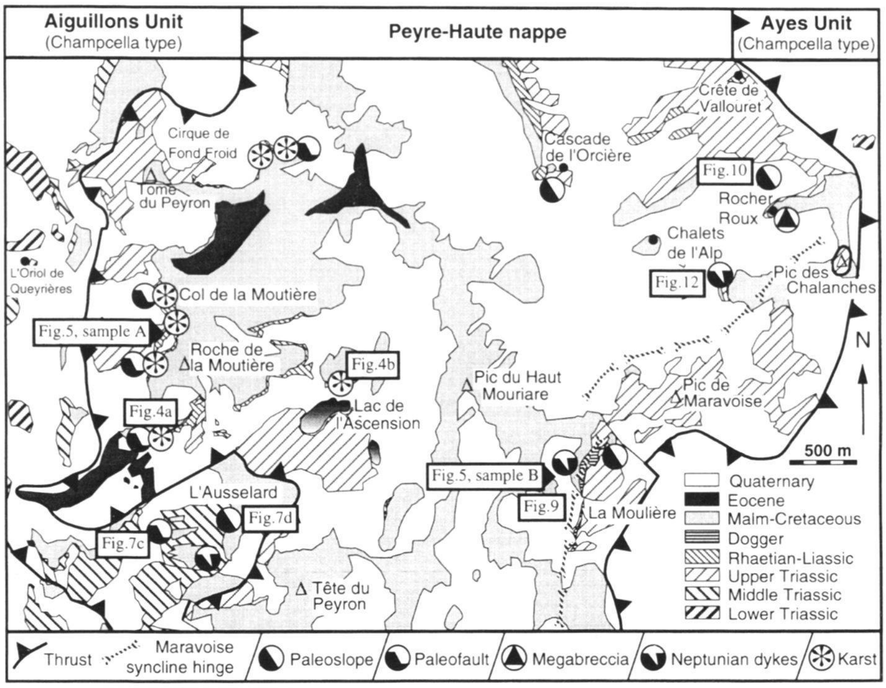

Fig. 3. Detailed map of the Peyre-Haute nappe and the underlying Aiguillons unit, with outcrops described in the text.

Baud 1977) capped by regressive Carnian to Norian wedges (Mégard-Galli 1972). This part of the series is regarded as pre-rift although it reflects a significant rate of subsidence (Lemoine et al. 1986, Rudkiewicz 1988, Faure 1990). Subsidence during the early syn-rift period led to the local deposition of Rhaetian and Early Liassic sequences showing eustatic cyclicity (Dumont 1998). Younger marine syn-rift deposits are not preserved because of uplift and emersion of the entire domain during the late syn-rift period. The lack of a sedimentary record documenting this period can be partly compensated by information provided by a sequence of subaerial and shallow marine diagenetic alterations along the break-up unconformity (3.2). The first post-rift deposits are Upper Bathonian shallow marine platform carbonates (Mercier 1977). The rapid thermal collapse of the margin is shown by a deepening-upward succession of pelagic sediments: Callovian crinoidal limestones, Callovian-Oxfordian red marls and nodular limestones, Upper Jurassic-Lower Cretaceous calpionellid limestones (Bourbon 1980). These post-rift formations unconformably overlie different more or less eroded pre- and syn-rift formations.

This paper deals with two different types of nappes, with different stratigraphic successions (Fig. 2):

- The Champcella-type nappes (Champcella s.s., Aiguillons, Ayes, Chatelet) contain no Late Triassic or Liassic deposits: Middle and Upper Jurassic carbonates were directly deposited upon Lower Carnian karstified and brecciated strata (Mégard-Galli 1972) These nappes were detached along an Upper Scythian gypsum layer, or in the Upper Palaeozoic (Fig. 2).
- The Peyre-Haute nappe was detached along Upper Carnian gypsum layers and contains a thick, dolomitic Norian carbonate wedge which allowed the less competent Jurassic and Cretaceous layers to be transported and preserved from strong Alpine deformation (Fig. 2, Tricart 1980). The most important characteristic of this nappe is the occurrence of Rhaetian-Lower Liassic (Hettangian and Sinemurian) marine strata (Tricart et al. 1988, Dumont 1998) which are quite exceptional for the Briançonnais units. Above them, as a consequence of subaerial exposure plus erosion, Sinemurian to Callovian strata (about 35My) are missing in the western area, whereas the gap ranges from Carnian to Upper Bathonian (about 55My) in the eastern area. This gap is more important in the eastern part of the nappe due to westward or northwestward block tilting coeval with or preceding continental erosion. Karstification is found mainly in the western part of the nappe in Liassic limestones. This emerged area was drowned later than the eastern part, as shown by the sequence of diagenetic events (3.2.2).

3. Mesozoic deformation and vertical movements recorded in the Briançonnais nappes; new data from the Briançon region

3.1 Tethyan chronology

The deposition of the Briançonnais Mesozoic sedimentary series is classically correlated to the development stages of the Ligurian Tethys ocean (Lemoine et al. 1986), based on comparisons with present subaerial margins (Graciansky et al. 1979, Stampfli & Marthaler 1990, Chaulieu 1992, Manatschal et al. 1997). The Liassic rifting phase is regarded as particularly important, which is consistent with the Early Bathonian age of the oldest Ligurian oceanic crust (166 Ma-old gabbro intrusions, Bill et al. 1997) and of the overlying sediments (De Wever & Baumgartner 1995), and with the age of kilometric-scale tilted blocks in the External Zone of Dauphiné (Lemoine et al. 1981).

Following this point of view, the thick Middle and Late Triassic carbonate wedges are regarded as „pre-rift" although they reflect significant subsidence. „Syn-rift" sediments would then be represented only by the thin, Lower Liassic platform limestones of the Peyre-Haute nappe but are typically missing in the Briançonnais realm. The „late syn-rift" period corresponds to the erosional gap due to Late Liassic to Bathonian emersion, which is interpreted by Stampfli & Marthaler (1990) as a rift-shoulder uplift (thermal anomaly + isostatic rebound). The „post-rift" sediments are Upper Bathonian neritic limestones and Callovian to Cretaceous pelagic limestones and marls, which are coeval with thermal subsidence of the Tethyan margin. However, the sedimentary record shows some features, we would not expect in this classical rift sucession: (1) a stronger subsidence during pre-rift than during „syn-rift" time, (2) an important syndepositional deformation recorded in the „post-rift" strata, as will be illustrated by the following examples (3.3).

To sum up, the rifting-spreading dynamics of the Ligurian Tethys ocean can only partly explain the evolution of the Briançonnais domain during the Mesozoic. The field examples given below make it possible to discriminate deformation related to Tethyan syn-rift extension from those related to others causes.

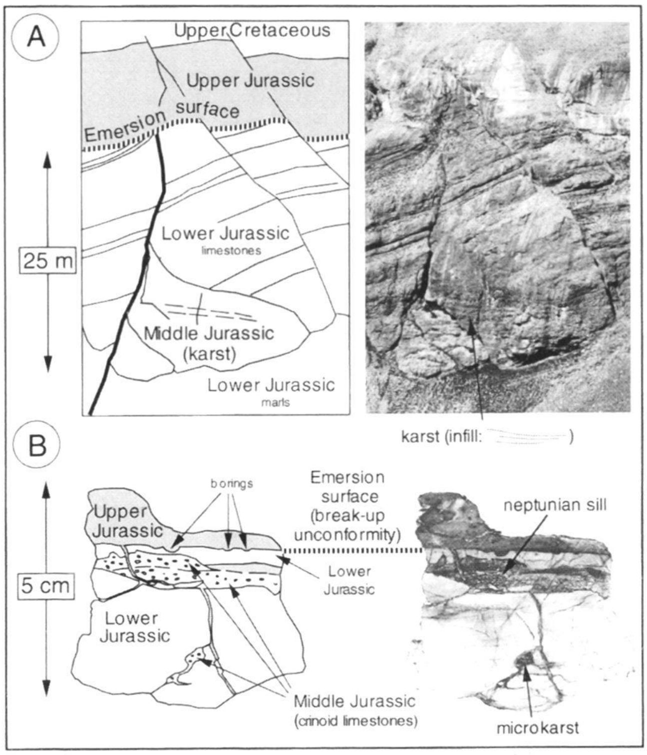

Fig. 4. Jurassic karstic features at different scales near Ascension lake: decametric caves cutting across the Liassic limestones developed upon Liassic normal faults (example in A). The same features are observed at a hand-specimen scale (B). Location of the karstic features (A) and (B) in Fig. 3.

3.2 Tethyan rift structures and diagenetic alterations

3.2.1 Karstic features associated with Liassic faults (Peyre-Haute nappe)

Jurassic suaerial exposure of the Briançonnais domain near Briançon was first demonstrated by Debelmas (1955, 1987), and karstification was subsequently studied in the mostly dolomitic series of the Champcella nappe by Faure & Mégard-Galli (1988). It is also known in other parts of the Briançonnais realm: Vanoise (Ellenberger 1955, Jaillard 1985), Ligurian Alps (Bloch 1963, Vanossi 1965) and Préalpes Médianes (Baud & Masson 1975, Baud et al. 1979).

In the western part of the Peyre-Haute nappe, the subaerial erosion surface is marked by a siliceous crust overlain by a thin conglomerate containing Upper Triassic and Lower Liassic clasts. Six karstic cavities are found in this area (Fig. 3). They are ten to twenty meters wide and cut downward across about 20 to 30 m of Sinemurian and Upper Hettangian massive limestones. Their bottom coincides with a Lower Hettangian impermeable marly layer (Fig. 4A). Four cavities developed along pre-existing small-scale normal faults, later sealed by Callovian and Upper Jurassic deposits. All of them contain collapse breccias and coarse conglomerates with exclusively Lower Liassic limestone clasts (predominantly Sinemurian cherty limestones). The infillings show a high-angle hour-glass stratification, which suggests that the cavities were rapidly filled by littoral material at the beginning of Middle Jurassic drowning.

Similar features are observed at a hand-specimen scale along the erosional surface (Fig. 4B): microkarstic cavities cut the uppermost Liassic beds (Hettangian or Sinemurian limestones). Carbonate dissolution was often following fractures. The fractures and cavities (either perpendicular or parallel to stratification, so-called „neptunian dykes" or „neptunian sills", respectively) are filled by marine transgressive sediments of late Middle Jurassic age.

In this part of the Peyre-Haute nappe, the following sequence of events can be reconstructed from these observations: (1) deposition of marine Lower Liassic limestones, which do not show significant lateral changes in thickness or facies, (2) post-Sinemurian small-scale normal faulting, (3) emersion and subaerial dissolution along pre-existing faults, (4) infill of cavities in a shallow marine environment, with particles fragmented during the time of exposure, (5) deposition of open marine Callovian limestones.

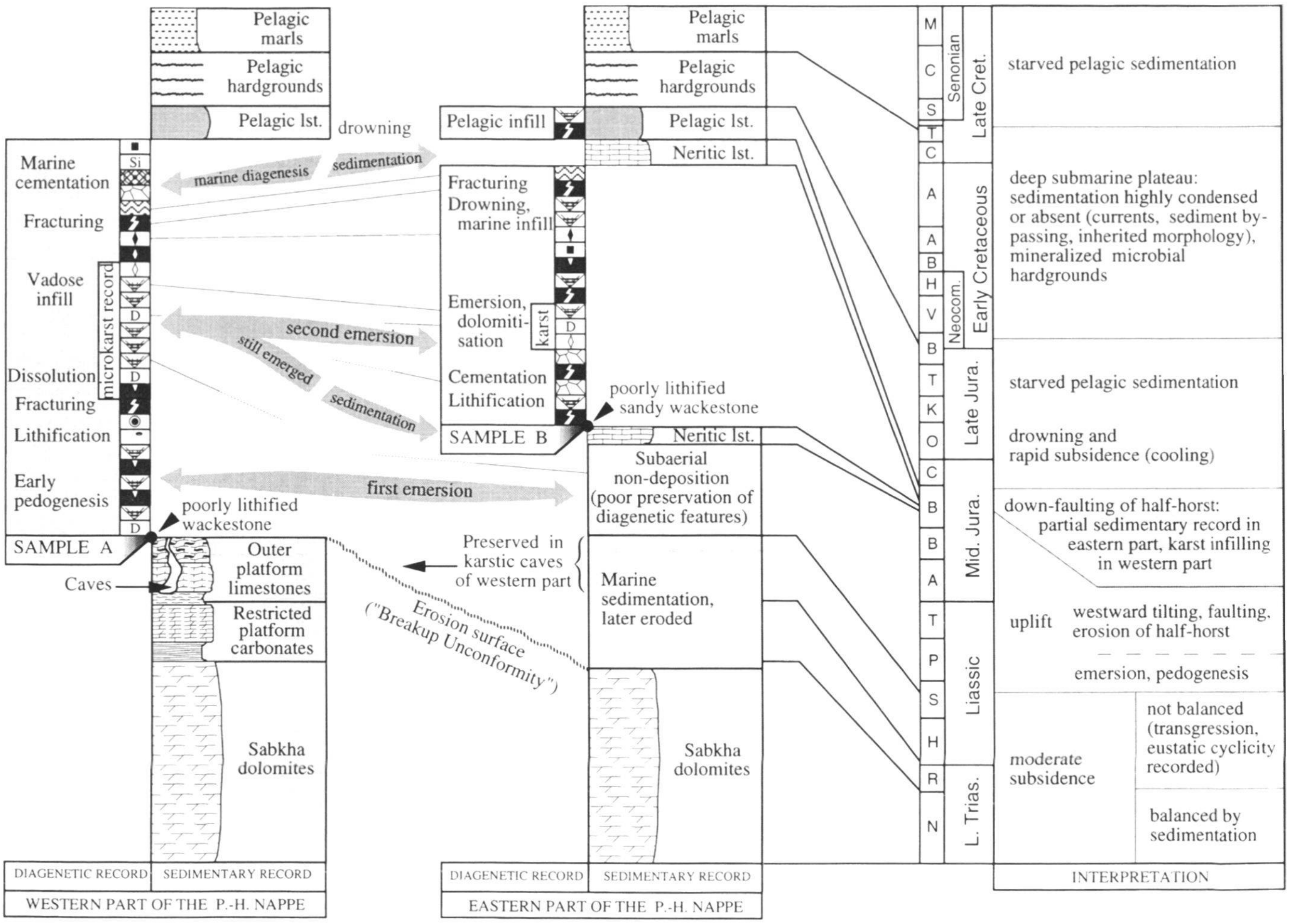

Fig. 5. Compared sedimentary and diagenetic record in the Western (Moulière section/sample A) and Eastern (Moutière section/sample B) parts of the Peyre-Haute Nappe. The „Diagenetic Log" (left side of the columns) illustrates the successive phases of alteration, fracturing and cementation which affected samples A and B (taken along the emersion surface) before they were covered by post-rift sediments. This comparison shows that, despite the eastern area was more strongly eroded during Jurassic uplift, it was drowned earlier during the post-rift transgression (down-faulting of half-horst).

Legend of diagenetic log:

Sediment infill, Fracturing, Pedogenesis, Compaction, D Dissolution, Pyritization,

Si Silicification, Dolomitization, Dedolomitization, Ankeritization, Syntaxial overgrowth,

Blocky calcite, Speleothems, Palisade calcite.

This sequence does not document all of Middle Jurassic events because of the incomplete sedimentary record, however, more information can be obtained from the study of the subaerial to shallow-marine diagenetic alterations in samples collected just below the erosion surface.

3.2.2 Sequence of diagenetic alterations and differential vertical movements (Peyre-Haute nappe)

The used diagenetic log method (Durlet et al. 1992) is based on the sample-scale identification of superimposed diagenetic features (dissolution features, infill, fracture, cement, etc.) which occur in a vertical sequence (Fig. 5). Such sequences document the relative chronology of environmental changes which affected the rock, and give relative time constraints for the phases of micro-fracturing. Samples, documented by diagenetic logs, can be correlated like stratigraphic logs. We used this method in addition to stratigraphic correlation in order to compare samples from the western and the eastern parts of the nappe (Fig. 5). Sample A comes from Sinemurian strata immediately underlying the Upper Jurassic in the western part of the Peyre-Haute nappe. Sample B is of Late Bathonian age

(*Kilianina blanketi*, det. M. Septfontaine) and was taken in the eastern part of the nappe (Fig. 3, 5), not far from the Middle Jurassic-Triassic unconformity. Thus sediments A and B are not coeval, but their diagenetic imprint is thought to be partly coeval as will be argued in the following. The main diagenetic features observed are:

(i) Roots and paleosoil (sample A only):

The oldest observed diagenetic feature is pedogenesis, with roots developed before complete lithification. This suggests an emersion immediately after deposition of the uppermost Sinemurian beds.

(ii) Fractures (samples A and B):

Polyphase micro-fracturing is found in both samples. The oldest generation of fractures postdates pedogenesis and lithification but predates dissolution and microkarst infill (sample A), allowing subaerial dissolution along fissures (Fig. 4, 5). Other micro-fracturing events affected both samples during drowning, producing many neptunian dykes filled with upper Middle to Upper Jurassic sediments (3.3).

(iii) Dissolution feature D, sediment infill, marine cementation (samples A and B):

A microkarst record is more developed in the host rock of sample A, which is older and suffered a longer emersion than sample B. Several types of infilling and at least two cycles of dissolution/sediment infill are found (only one in sample B). The correlation between the two diagenetic logs (Fig. 5) suggests that the karstic episode documented in sample B corresponds to the upper cycle of dissolution/sediment infill in sample A. If so, marine sedimentation (the Middle Jurassic host rock B) and marine cements (lower part of diagenetic log B) in the eastern part of the nappe correspond to subaerial alteration in the western part (lower part of microkarst record, sample A). This means that the eastern area sunk below sea level during Late Bathonian while the western area was still emerged. The uppermost microkarstic infill (sample A) is a reddish clay with detrital quartz, typical for tropical subaerial alteration (Laterite). The last diagenetic phases found in both samples are marine cements and marine sediment infills. In sample B only, they are coeval or alternating with marine sedimentary layers. These sediments onlapped from the eastern, down-faulted area toward the western, still high-standing area.

This specific study confirms our field observations given in 3.2.1, and documents that karstic dissolution occurred after an early event of fracturing. Moreover, emersion must have occurred soon after the deposition of the uppermost Sinemurian strata and still during Early Liassic times (roots in nonlithified sediments). Despite the length of subaerial exposure (about 35 My), little of the series has been eroded: a few tens of meters in the western part of the nappe, no more than 200m in the eastern part. Limestones were selectively removed, which suggests that the altitude of land was low and/or that the major erosion factor was chemical dissolution. There was also a change in differential vertical movements during Middle Jurassic: the eastern area was first affected by the strongest uplift (half-horst tilted westward), and then submerged below sea-level during Late Bathonian times (collapse of the half-horst), while the western area was still subaerially exposed. Accommodation space created by this tectonic event allowed deposition of shallow-marine sequences. The flooded domains were episodically emerged again before final drowning, probably as a consequence of eustatic sea level changes (Haq et al. 1987).

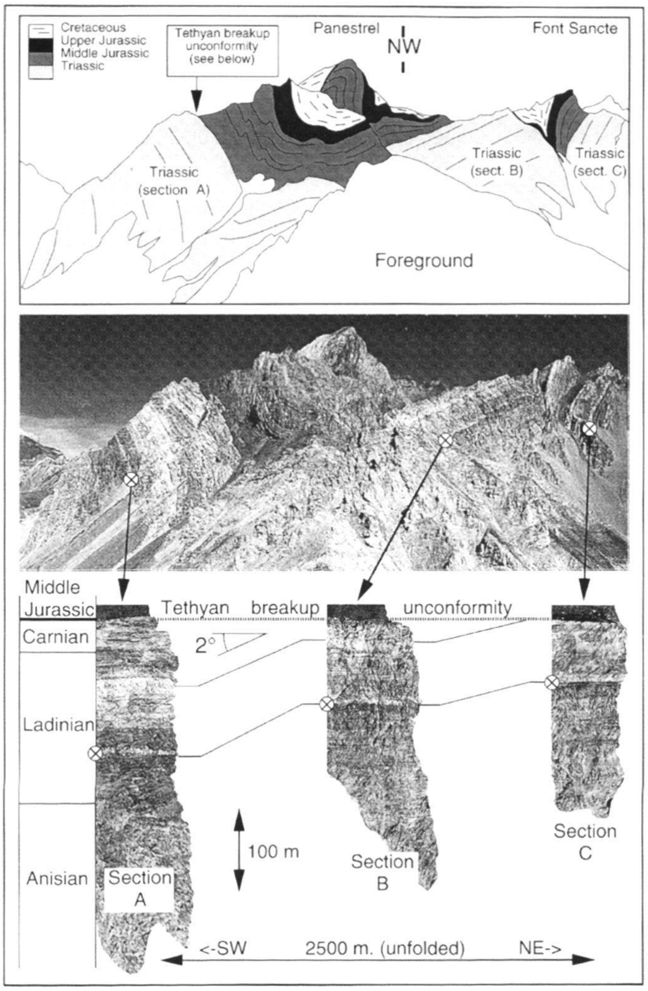

Fig. 6. Synrift (pre-Bathonian) westward tilt in the Chatelet unit (Champcella type), Font Sancte massif, Haute Ubaye valley.

3.2.3 Other field evidence

An important pre-Bathonian fault scarp (Cascade de l'Orcière, Peyre-Haute nappe, Fig. 3) consists of a steep, east-dipping surface cutting across 200m of Lower Jurassic and Rhaetian formations in the foot-wall block. Its Mesozoic age is shown by

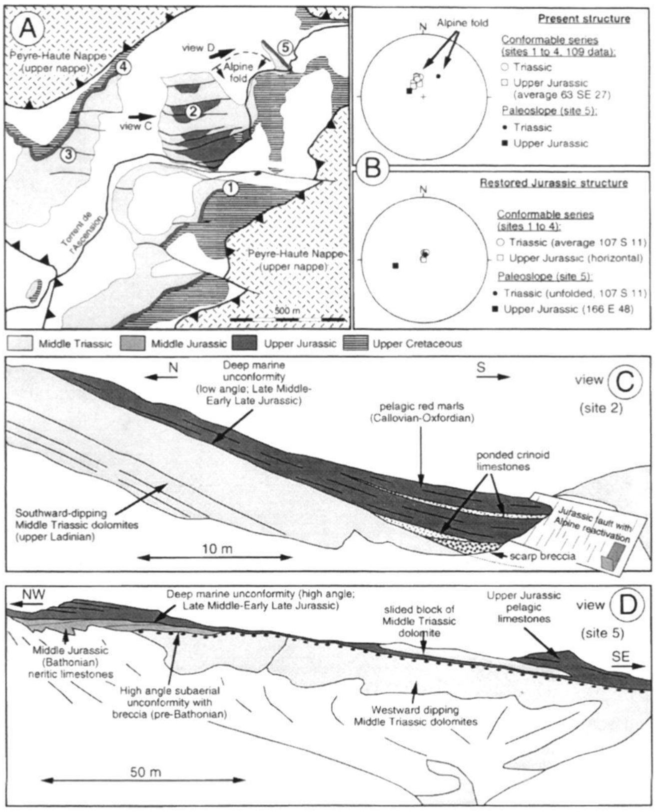

Fig. 7. Evidence of „post-rift" (Callovian-Oxfordian) small-scale block faulting associated with low-angle southward tilt in the Aiguillons unit (Champcella type). The associated submarine erosion modified the earlier, subaerial syn-rift structures whose trend was different.
Fig. 7A: Location of sites 1 to 5 (L'Ausselard valley).
Fig. 7B: Bedding and angular unconformities between Middle Triassic dolomites and Late Middle Jurassic pelagic limestones (today and restored from Alpine deformation): high-angle unconformity at site 5 (ENE-facing scarp) and low-angle unconformity at other sites (11° southward tilt). Submarine scarp at site 5 is superimposed on a pre-Bathonian, subaerial relief (Wulf stereograms, lower hemisphere).
Fig. 7C: Callovian-Oxfordian (post-rift) half-graben at site 2. Its age is demonstrated by (1) a tilt between Triassic and Jurassic, (2) breccia deposits at the toe of the fault scarp, (3) crinoidal limestones probably reworked from the hard substrate of the footwall block (right) and ponded in the marls of the lowest part of the half-graben.
Fig. 7D: Superimposed unconformities at site 5: the Tethyan break-up unconformity is marked by subaerial breccia on top of the Triassic (dots), while a younger, drowning unconformity (post-rift) is found on the northern side (left of the picture). Both are merging on the southern side, indicating that the drowning unconformity settled on a subaerial topography inherited from syn-rift structuration.

very thin Bathonian limestones (*Trocholina* sp., det. M. Septfontaine) unconformably overlying the Rhaetian strata. Rhaetian and Liassic rocks remained partly exposed along the fault scarp during Late Jurassic and Cretaceous times.

Another pre-Bathonian, east-dipping submarine scarp is described in 3.3.1 (l'Ausselard, Aiguillons unit, Fig. 3) because it has been reactivated during the Late Jurassic extensional phase.

A pre-Bathonian angular unconformity is found in the Font Sancte Massif (northern side of the Ubaye Valley, Chatelet unit, Fig. 6). About hundred meters of Middle and Upper Triassic dolomites (Upper Ladinian and Carnian *p.p.*) are cut away north-eastward by this erosional unconformity, within a lateral distance of about 2500m (after palinspastic restoration). This unconformity indicates a pre-Bathonian southwestward or westward tilting of about two degrees.

3.2.4 Characteristics of the Tethyan syn-rift extension

To sum up, the specific features of the Liassic extensional deformation, contemporaneous with Ligurian Tethyan rifting and with emersion of the Briançonnais, are:

- Predominantly N-S to N30° striking (present-day orientation), east-dipping normal faults along which karstic cavities (post-Sinemurian emergence) developped.
- Small-scale faults with offsets of a few tens of meters only (except for the higher Cascade de l'Orcière fault scarp).
- Predominantly westward, low angle block tilting.

The small width of the fault blocks and their low tilt preserved the Triassic series from deeper subaerial erosion during and following this deformation phase. There is actually no paleontological evidence at any place in the study area that the Tethyan break-up unconformity represented by the pre-Bathonian subaerial erosional surface cut down to the lower part of the Triassic carbonates (Anisian) or to the Lower Triassic sandstones (Scythian). This is consistent with the lack of any Lower Triassic or older reworked material in the numerous breccias found along the break-up unconformity. Such deep-reaching erosional unconformities exist, but they are younger (latest Middle to Late Jurassic) and reflect submarine erosion, as will be shown below.

The present-day orientation of Tethyan syn-rift extension inferred from these observations is approximately West-East. This estimation is slightly different from the proposition of previous authors (NW-SE orientation of extension, Faure & Mégard-Galli 1988, Tricart et al. 1988).

3.3 Structures younger than the opening of the Tethyan ocean

One would expect the syn-rift structures to be sealed by post-rift pelagic limestones of Late Jurassic age. Thermal subsidence following the opening of the Ligurian Tethys is not supposed to have induced extensive deformation of the passive margin. In fact, thickness changes in the post-rift sediments can be partly explained by a submarine relief inherited from Liassic rifting. However, these changes in formation thickness also bear evidence of submarine erosion related to at least three tectonic „crises" (Bourbon 1980, Faure 1990, Chaulieu 1992). We give here new examples and a reappraisal of some other sites which document such paleotectonic features.

3.3.1 Middle and Late Jurassic superimposed unconformities and small-scale block tilting (Champcella type nappes).

Late Jurassic small-scale southward block tilting is documented by thickness changes along the eastern side of the Font Froid valley (Aiguillons unit). The thickness of Middle to Upper Jurassic reddish pelagic marls and limestones overlying Middle Triassic dolomites is gradually increasing southward from 5 m to 30 m towards the toe of a scarp bearing sedimentary breccias (foot-wall block). The hanging-wall block bears a reduced series (6m). Alpine faults with domino-type geometry (Virlouvet et al. 1996) cut the Jurassic beds close to the scarp, which suggests that neotectonic activity partly reactivated the Jurassic faults.

Similar features are found further south in L'Ausselard valley (Aiguillons unit, sites 1 to 5, Fig. 3, Fig. 7A). Callovian-Oxfordian pelagic nodular limestones and marls rest with slight angular unconformity upon Middle Triassic dolomites (Fig. 7B, top). This area is cut by N90 to N110, northward dipping late Alpine faults which postdate the most recent Alpine cleavage (Virlouvet et al. 1996). At least some of these faults reactivate Late Jurassic small-scale normal faults (Fig. 7C):

- At sites 1 to 4, Alpine tilting can be compensated by restoring the Upper Jurassic layers in a horizontal position (Fig. 7B, bottom). Then the Triassic beds show a southward dip of about 10°, which is consistent with E-W-trending normal faults (Fig. 7C).
- At site 5, the Upper Jurassic limestones rest with a high angular unconformity on a slope truncating Middle Triassic beds; they contain a 50m wide redeposited block of Middle Triassic dolomites (Fig. 7D). The Jurassic unconformity was affected by Alpine top-to-the-west shearing which may have enhanced its angle. The restored slope was dipping 45° towards ENE (Fig. 7B, bottom), but this is an overestimated value because of the Alpine reactivation along the angular unconformity. The Late Jurassic unconformity at site 5 is superimposed on a pre-Middle Jurassic erosional surface, marked by whitish and yellowish dolomitic breccia of subaerial origin (Faure & Mégard-Galli 1988, Fig. 7D). The two surfaces are separated in the northern part of site 5 by a pinching-out wedge of Middle Jurassic transgressive neritic limestones (coquina and crinoid limestones). This demonstrates that the Late Jurassic submarine slope (site 5) was inherited from an earlier subaerial morphology created by syn-rift deformation.

These outcrops document two successive tectonic events: 1) creation of an ENE-dipping slope during Middle Jurassic emersion (or earlier), which can be tentatively interpreted as a result of block-faulting along a N-NW trend, and 2) small-scale block faulting along an E-W trend and low-angle southward tilting during latest Middle to early Late Jurassic, with renewed erosion/deposition along the previous slope. Event (1) can be ascribed to Tethyan syn-rift deformation because it occurred during the emersion of the Briançonnais domain. Its

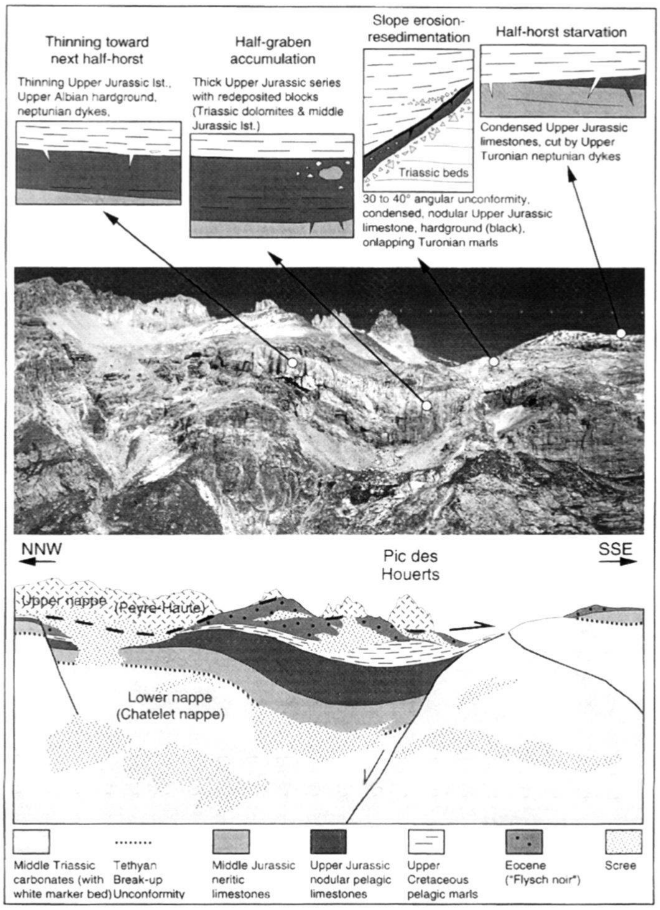

Fig. 8. Late Jurassic („post-rift") southward tilt and half-graben in the Escreins massif (Crête du Vallon Laugier). The Late Jurassic fault is cutting across and displacing the Tethyan break-up unconformity (Triassic-Middle Jurassic contact).

orientation fits with E-W extension inferred from the data of § 2. Event (2) is younger (post-rift) and it is marked by a change in orientation of the extensional structures; this suggests a shift in orientation of the extension to North-South.

3.3.2 Kilometric-scale Late Jurassic block faulting in the Chatelet unit

Within the Chatelet unit (south of the Guil Valley), well preserved pre-Alpine extensional structures are found (Gidon et al. 1994). The best example is the Vallon Laugier fault block (Claudel et al. 1997 and Fig. 8). It consists of a two kilometers-wide half-graben filled with Upper Jurassic pelagic limestones. Many criteria demonstrate a Late Jurassic age for its first and main stage of deformation: sediment accumulated in the hanging-wall block, the foot-wall block was sediment-starved, scarp erosion and resedimentation of breccias, together with neptunian dykes document active faulting. The fault scarp is nearly

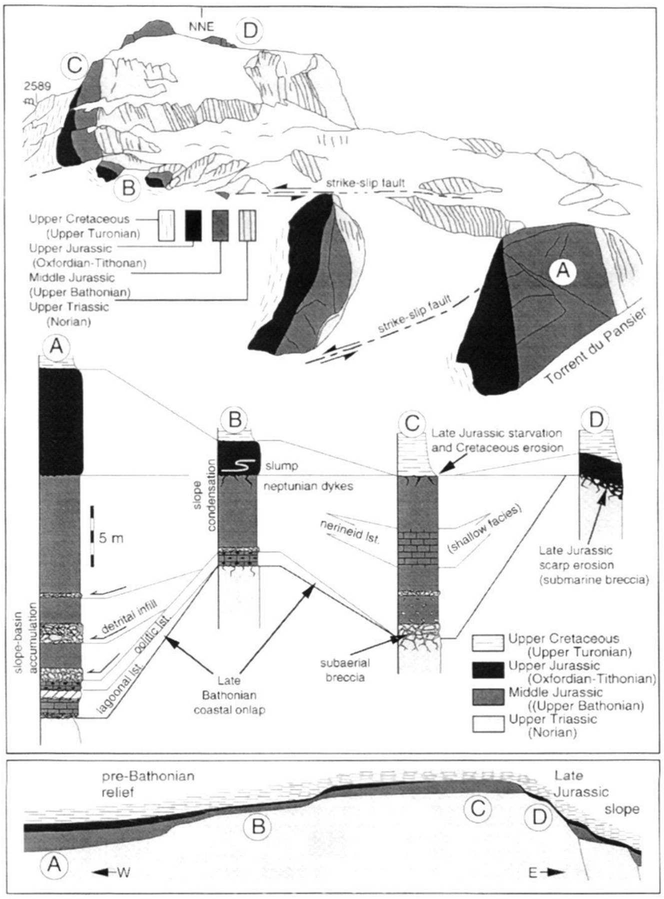

Fig. 9. Late Jurassic („post-rift") erosional unconformity affecting a Bathonian relief at La Moulière. This Mesozoic structure is involved in a Alpine kilometric-scale recumbent syncline hinge at the internal border of the Peyre-Haute nappe (Maravoise fold), which probably coincides with a major Jurassic tectonic boundary (tectonic inversion feature).

undeformed and displays the features of a steep submarine slope covered by an Albian-Cenomanian mineralized hardground. The present-day orientation of the fault is N80°, that is subparallel to the Alpine shortening trend, which explains the good preservation of this pre-Alpine structure. The orientation of the fault plane and the direction of tilt are similar to those of the faults described in 3.1, whereas the scale is larger.

This Late Jurassic extensional structure was reactivated later (Claudel et al. 1997):1) during the Late Albian, the hanging-wall block was cut by a new northward-dipping normal fault, and 2) during the Turonian, the Jurassic fault plane moved again as shown by sea-floor erosion, sliding of sediment and by the injection of pelagic sediment into the fault plane itself.

3.3.3 Late Jurassic tilting and submarine erosion in the eastern Peyre-Haute nappe

Many evidences of Mesozoic extensional tectonic activity were described in this nappe (Debelmas & Lemoine 1957, Bourbon & Graciansky 1975, Mercier 1977, Tricart et al. 1988). Most of this activity has been ascribed to Tethyan rift tectonics, presumably during Liassic to early Middle Jurassic times. We propose a reinterpretation of two paleostructures, which are significantly younger than previously thought and which are thus „post-rift":

(1) Polyphase deformation with Late Jurassic scarp erosion at La Moulière

The investigated Mesozoic structure is located at La Moulière in the eastern part of the Peyre-Haute nappe (Fig. 3). It is now involved in the hinge of a major N-S-trending, westward recumbent fold, so that the stratification is nearly vertical (Fig. 9). This Alpine structure is easy to unfold. The restored Mesozoic structure has been described by Mercier (1977) as a small horst bounded on both its eastern and western sides by Early to Middle Jurassic normal faults.

The sedimentary record on the western side is consistent with this interpretation (Fig. 9, sites A, B, C): depositional geometry of the Upper Bathonian strata documents an eastward onlap on the subaerial surface. These beds contain breccias derived from the gradually onlapped paleoslope. Moreover, the Upper Bathonian strata on top of the paleohigh (C) contain abundant nerineids (*Nerinella scalaris*, *Cossmannea* sp., det. J. Wieczorek) suggesting that it remained in a high-energy shallow environment longer than its toe (A).

In contrast, the features observed on the eastern side (Fig. 9, site D) do not fit with the model of Mercier (1977). They consist of a rugged erosional surface along which thin Upper Jurassic limestones with Oxfordian to late Kimmeridgian ammonites (*Sowerbyceras tortisulcatum*, *Sowerbyceras loryi (-silenum)*, det. R. Enay) unconformably overlie Norian dolomites. These sediments with abundant dwarfed ammonites, bivalves and echinoids show a specific facies of starvation on a pelagic high. They also contain pebbles of Norian dolomites. The Middle Jurassic limestones were eroded at that place, and they are found only a few tens of meters to the west. The eastern paleoslope of the Moulière horst is thus due to Late Jurassic erosion, which cut across the pre-Bathonian relief.

(2) Late Jurassic megabreccia on an erosional slope surface at Le Rocher Roux (Fig. 3)

Following Debelmas & Lemoine (1957), Mercier (1977) attributed two superimposed angular unconformities to Rhaetian and Middle Jurassic tectonic pulses, respectively. This place was thus regarded as evidence of polyphase Tethyan syn-rift block tilting.

We propose an alternative hypothesis supported by the following arguments (Fig. 10):

– The Rhaetian beds of the Rocher Roux outcrop, resting with a 35° angular unconformity on tilted Norian dolomites, are perfectly concordant with the latter 500 m

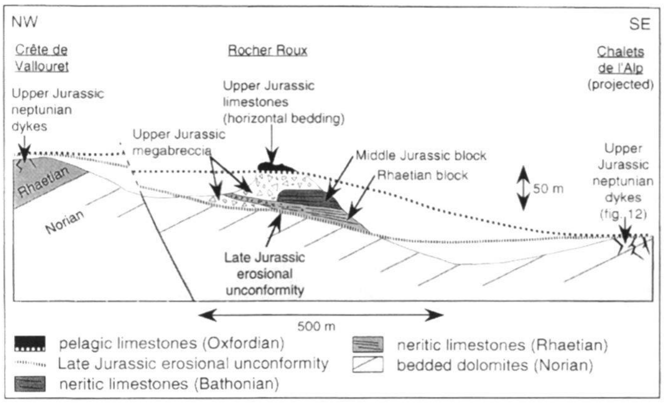

Fig. 10. The Late Jurassic („post-rift") erosional slope of the Rocher Roux (Peyre-Haute nappe) with associated megabreccia and neptunian dykes. These features were probably linked to the nearby erosional unconformity of La Moulière (Fig. 9), since both are of the same age and display similar geometrical relationships (Fig. 11).

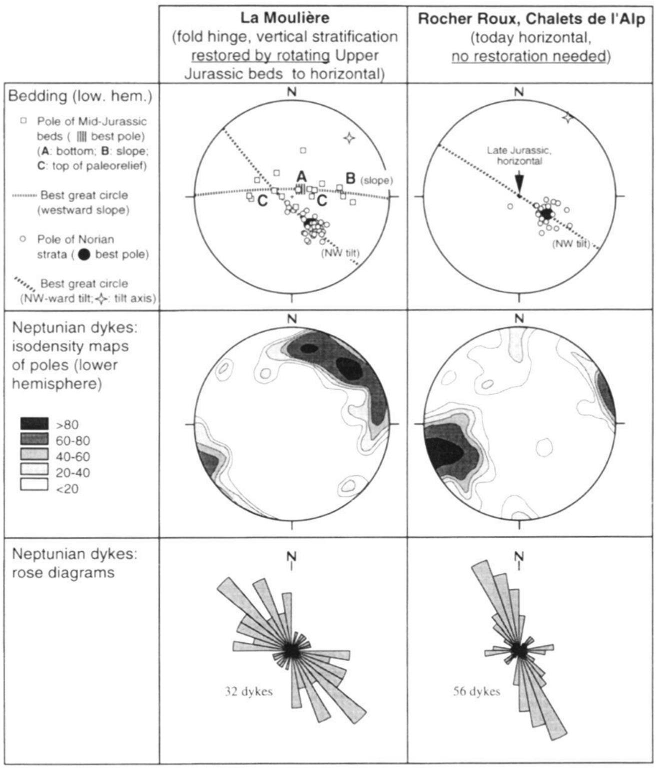

Fig. 11. Paleotectonic signatures in the Rocher Roux-Chalets de l'Alp (Fig. 10) and in the Moulière (Fig. 9) areas (Wulf stereograms, lower hemisphere). Alpine folding has been restored in La Moulière. The Late Jurassic northwestward dip of the Triassic beds could related to a major southeastward dipping normal fault bounding the Peyre-Haute paleogeographic domain, inversion of which resulted in the Maravoise recumbent fold (Fig. 3, Fig. 9).

further north. At both localities, they show a regular parallel stratification and no evidence of redeposition, which is incompatible with a deposition on a steep slope.

– The tilted Norian dolomites and the overlying Rhaetian limestones of the Rocher Roux are separated from each other by a thin dolomitic breccia layer (0.5m) with a pinkish or dark red, barren, micritic limestone matrix. This kind of sediment is never found in such a stratigraphic position, but closely resembles the Upper Jurassic pelagic limestones.

– The Rhaetian stratified „series" of the Rocher Roux, supposedly deposited unconformably on Norian dolomites, grades northward into a sedimentary breccia made of Rhaetian material (dark coquina limestones and shales) and intercalated between two Upper Jurassic breccia layers. Therefore, the Rhaetian strata of the Rocher Roux represent an olistolite mantled by breccia, which was emplaced by sliding on a Late Jurassic slope.

– The Middle Jurassic, nearly horizontal limestone wedge overlying the Rhaetian beds of the Rocher Roux is separated to the North by a vertical contact from the Jurassic breccia adjoining it. Mercier (1977) interpreted it as a Jurassic fault scarp, although the downward trace of this presumed fault is unclear. By contrast, we think this northern boundary represents the abrupt termination of a decametric block of Middle Jurassic limestones surrounded by Upper Jurassic breccia.

– The Upper Jurassic (Oxfordian-Kimmeridgian) breccia bears numerous evidences of redeposition along a slope (Bourbon 1980, vol. 2 p. 476): slumps, upside-down geopetal structures, soft pebbles. At Chalets de l'Alp (Fig. 3), 500 m further south, the coeval strata are extremely condensed and devoid of blocks. They rest unconformably upon Norian dolomites and fill neptunian dykes indicating a fracturing during the Callovian to early Oxfordian (Bourbon & Graciansky 1975).

In our opinion, both the Rhaetian and Middle Jurassic (Bathonian) limestones of the Rocher Roux are slide-blocks within a megabreccia of Late Jurassic age, overlain by Late Jurassic pelagic limestones (Oxfordian-Middle Kimmeridgian, Bourbon 1980). The tectonic event responsible for tilting, erosion and fracturation is of Callovian to Oxfordian age, and not earlier as proposed by previous authors.

Geometrical analysis and palinspastic restoration of small-scale paleostructures in the Moulière and Rocher Roux areas give consistent results, despite their very different structural setting (Fig. 11):

- The Norian dolomites were tilted 30° to 40° towards the NW before the deposition of the Upper Jurassic strata.
- Erosion of the northwestward tilted Norian series increased towards the Southeast. There is evidence for a sou-

theastward dipping submarine erosional slopes overlain by Upper Jurassic pelagic limestones.

- Dominantly low-angle, westward dipping slopes onlapped by Middle Jurassic neritic limestones (La Moulière), are older subaerial topographic features.
- Neptunian dykes were mainly NW-SE to N-S oriented with a minor E-W trend, which seems to be independent from Late Jurassic features (northwestward tilt). However, as shown by Fig. 11, they result from re-opening of an old (pre-Bathonian) joint pattern within the Norian dolomites. Several generations of neptunian dykes are found, which suggests a change in orientation of tensional stress, but many examples show that the orientation of neptunian dykes was strongly influenced by gravity due to sea-bottom topography.

Our data strongly suggest that the eastern boundary of the Peyre-Haute nappe with its recumbent fold originated from inversion of a Late Jurassic major fault: the Eastern, folded part of the nappe (syncline hinge, Fig. 3) was a half-horst as shown by Late Jurassic tilting and erosion. This half-horst was apparently oriented SW-NE, as indicated by (1) structural data of the Rocher Roux and Moulière outcrops and by (2) the present cartographic distribution of Jurassic erosion below the break-up unconformity: deep in eastern and southern parts of the nappe, shallow in its northwestern part. However, both (1) and (2) may have underwent a significant counterclockwise rotation (2.2) so that the initial trend of this Jurassic structure was possibly closer to E-W.

3.3.4 Characteristics of „post-rift" deformation

Once palinspastically restored, the studied structural markers of the late Middle to Late Jurassic deformation consistently indicate that:

- The dominant deformational process was extension with block tilting. It produced extensional structures at different scales with some reactivation of pre-existing, syn-rift structures.
- This deformation was oriented differently from that of the syn-rift stage. Newly formed structures show E-W or SW-NE trends, nearly perpendicular to the pre-Bathonian structures (3.2.4).
- During this stage of deformation, starting during Callovian-Oxfordian times, erosion cut down to deeper levels into the underlying series than during the older, syn-rift stage: contrary to the upper Bathonian neritic limestones which always rest on younger Triassic horizons (upper Norian in the Peyre-Haute nappe or upper Ladinian in the Champcella or Chatelet nappes), the Callovian and younger pelagic limestones rest on Anisian or Scythian formations in several of the Briançonnais nappes (Bourbon 1980). This suggests that either the size of the tilted blocks or the tilt angle were more important during this „post-rift" phase of deformation than during the syn-rift one.

4. Discussion

4.1 Orientation of Mesozoic structures

The first step to interpret our paleostructural data is to use them as indicators of Mesozoic deformation and paleostress orientations. As suggested by our study, the orientation of small-scale sea-floor structures such as neptunian dykes depends both on inherited fracture patterns and on gravity (sea-floor topography). A dense pattern of fractures was created during the Tethyan rift phase within the Triassic dolomites. This pattern guided the „post-rift" (Late Jurassic) opening and filling of neptunian dykes, particularly if the inherited fractures were perpendicular to the dip of the slope. Therefore, these features can not be always interpreted as stress indicators. However, they help to identify medium-scale (hectometric to kilometric) structures such as tilted blocks, fault scarps and angular unconformities, which are more reliable indicators of deformation at a regional scale. Our examples indicate that most of the late Middle to Late Jurassic structures (faults and tilt axes) are NE-SW to E-W oriented. The occurence of such structures in different places from Briançon to the Ubaye Valley and in different nappes, demonstrates that the Briançonnais realm was affected at that time by regional extension, which was apparently NW-SE to N-S oriented.

These present directions have to be rotated back clockwise if the investigated Briançonnais nappes underwent significant counterclockwise rotation of $40° \pm 18°$ during late Alpine evolution, which is indicated by preliminary data (Thomas et al. 1997). Accordingly, Liassic to early Middle Jurassic syn-rift extension was NW-SE oriented, similarly to the External Alps (Grand 1988), and late Middle to Late Jurassic „post-rift" extension was N-S to NE-SW oriented.

4.2 Implications for inversion tectonics

Tectonic inversion in the Briançonnais zone is usually regarded as a simple process since Tethyan extension and Alpine shortening are assumed to have been roughly parallel (E-W, Lemoine et al. 1986). Our data indicate that this assumption has to be reconsidered, both concerning Mesozoic extension (NW-SE extension during rifting, then N-S which created E-W-trending structures during Tethyan spreading) and early Alpine shortening (N-S, Dumont et al. 1997). The early structures of tectonic inversion and nappe stacking were strongiy oblique, if not perpendicular to the younger, E-W to NE-SW-trending structures, which implies that: (1) the present structure of the tectonic edifice, shortened during at least two obliquely oriented inversion phases, has probably not preserved any pre-collisional paleogeographic arrangement (the present order of the nappes does not reflect their original paleogeographic position), and (2) the early collisional phases (N-S) were strongly oblique with respect to the orientation of the Tethyan margin (NE-SW) and may have preferentially inverted some of the oblique structures of the margin such as transfer faults. This occurred along the W-E-trending Provence platform edge (regarded as a transform zone by Lemoine et al. 1989) which shows N-S inversion structures in the Alpine foreland, and whose eastward extension must have been included into the internal Alpine buildup before the late collisional phases.

4.3 Emersion of the Briançonnais domain since the Late Triassic?

Uplift and emersion of the Briançonnais domain during Mesozoic times produced gaps in the sedimentary record. The time interval of emersion is difficult to constrain because the gap resulted from both subaerial erosion and/or non-deposition. The lower bracket of this interval is regarded as Liassic based on the specific sedimentary record of the Peyre-Haute nappe (2.4), and this local datum is extrapolated to all the other Briançonnais nappes, which have neither a Late Triassic nor Early Liassic record. This extrapolation is questionable for the following reasons:

- This would imply that the Upper Triassic and Lower Liassic strata were deposited and then removed during Jurassic emersion on most of the Briançonnais area (except the Peyre-Haute area): continental dissolution would have easily removed the Liassic limestones everywhere but not the 400 m thick Upper Triassic shales (Rhaetian) and massive dolomites (Norian).
- Erosional products typical from Upper Triassic or Liassic lithologies should be found in the continental conglomerates or in the karsts, which is never the case (except in the Peyre-Haute nappe).
- A regional-scale angular unconformity would be expected, with the subaerial erosional surface cutting down to various levels in the Triassic series. By contrast, this surface rests in most places (Champcella and Chatelet nappes) at the same stratigraphic level (base of Carnian).

In our opinion, the typical Briançonnais nappes (except Peyre-Haute) have undergone subaerial non-deposition since Carnian times, due to a tectonic event which affected the Tethyan realm at that time and which produced paleogeographic differentiation and vertical movements (Mégard-Galli & Baud 1977, Mégard-Galli & Faure 1988). Our interpretation differs from the interpretation of Baud (1972) in the Préalpes Médianes, who assumes that no significant paleogeographic differentiation occurred before Middle Liassic times, but it is compatible with an alternative interpretation of Ligurian Briançonnais units (Lualdi 1990). From a geodynamic point of view, our interpretation suggests that the initiation of Tethyan rifting in the Briançonnais domain occurred much earlier than the Triassic-Jurassic boundary. This hypothesis is consistent with recent interpretations concerning the Central Atlantic margins (Favre & Stampfli 1992, Le Roy et al. 1997) along which two stages of rifting are identified (Carnian-Hettangian and Sinemurian-Pliensbachian).

4.4 Mesozoic paleogeography

The Briançonnais pre-Bathonian carbonate series of the Briançon region cannot be regarded as derived from a unique paleogeographic domain. We must distinguish on one hand the Peyre-Haute nappe, with its Upper Triassic dolomites and Lower Liassic limestones, and on the other hand a number of Champcella-type units including Middle Triassic carbonates overlain by an emersion surface. As discussed above, it is likely that Mesozoic emersion occurred earlier in the Champcella-type units (Late Triassic) than in the Peyre-Haute nappe (Early Liassic). Structural analysis in progress indicates that the Peyre-Haute nappe and related units from North of the Durance river to South of the Guil valley may have been thrusted on top of all the Champcella-type units during the early shortening phases, before being overthrusted by some of them during out-of-sequence stacking. According to this, the stratigraphic signature of this higher nappe should be compared with those of innermost Briançonnais or Piémont nappes. There are indeed some similarities between the Upper Triassic-lowermost Liassic series of the Peyre-Haute nappe and the coeval beds in the Roche des Clots-Grande Hoche Piemont units (Lemoine et al. 1978, Dumont et al. 1984) or in the Grande Motte unit in Vanoise (Ellenberger 1963, Jaillard et al. 1986, Deville 1990), despite their thickness being much higher there. However, there are also striking similarities between the series of the Peyre-Haute nappe and the series of some Subbriançonnais nappes in Ubaye (Morgon) or near the Argentera massif (Stura di Demonte, Dumont 1998). The Peyre-Haute series also has many features in common with the „Médianes Plastiques" (regarded as Subbriançonnais) in the French and Swiss Prealpine nappes (Septfontaine & Lombard 1976, Baud & Septfontaine 1980, Maury & Ricou 1983, Borel 1997).

There is thus a contradiction between arguments derived from Alpine structural analysis, which indicate that the Peyre-Haute domain should have been originally located closer to the Tethyan ocean than the other (Champcella-type) Briançonnais domains and then thrusted above them, and arguments derived from some stratigraphic signatures, which suggest in contrast that this domain could have been located more continentwards. This contradiction is due in our opinion to (1) the inadequacy of a two-dimensional mode of palinspastic restoration which assumes that intracontinental extension and inversion/nappe stacking followed more or less the same orientation with opposite sense, an assumption which is strongly questionable, (2) the obliquity of collision with respect to margin structures and the changes in orientation of shortening, and (3) the probable non-cylindricity of the Mesozoic paleogeographic pattern.

If the Briançonnais nappes underwent important oblique (northward) displacement, they were initially located further south, that is to the east or to the south of the Provence realm (Laubscher 1975, 1991, Maury & Ricou 1983, Stampfli 1993, 1996). This is supported by similarities in stratigraphic signa-

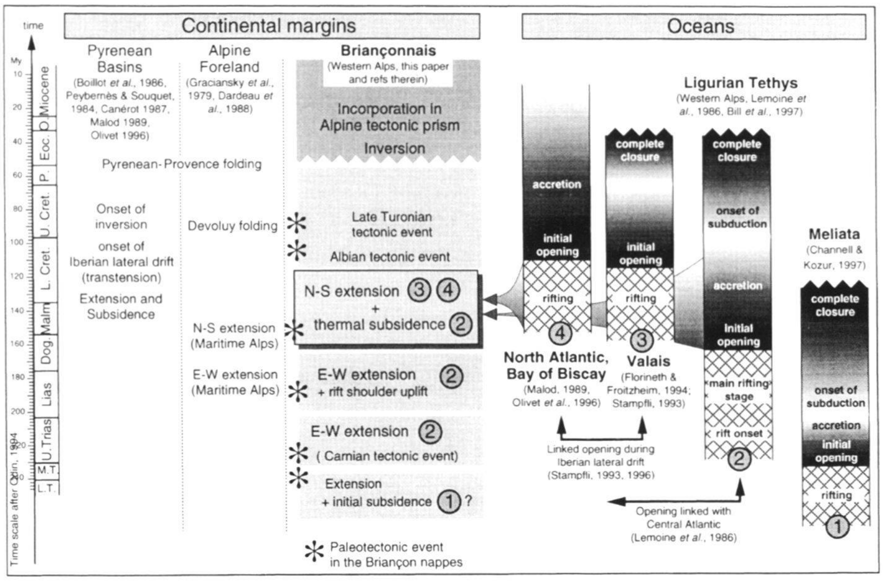

Fig. 12. The paleotectonic events recorded in the Briançonnais passive margin of the Briançon region are due to the combined effects from several oceanic domains whose rifting-spreading cycles occurred at different places and times.

tures of the Provence, Maritime Alps, Subbriançonnais and Briançonnais series (Middle Triassic, uppermost Triassic-Lower Liassic, Middle Jurassic), whereas there are striking differences between the Briançonnais and the Dauphinois sedimentary record (Lemoine et al. 1986) and subsidence pattern (Rudkiewicz 1988).

4.5 Multistage Mezozoic extension: riftings related to different oceans?

Extensional deformation related to the rifting of the Ligurian Tethys ocean, which is sealed by Bathonian sediments, is clearly distinguishable from the Callovian-Oxfordian extensional event (this paper and Claudel et al. 1997). This latter event occured after the initial opening of the Tethyan ocean (Fig. 12) and is thus regarded as post-rift. However, it includes typical rift features such as tilted blocks. The event is widespread in the French Briançonnais realm (Bourbon 1980). It is also present in the External Alps and their foreland in Southeastern France, where it produced both extension and strong subsidence (Vocontian Terres Noires basin, Graciansky et al. 1979, Dardeau et al. 1988). Further evidence is known in the Callovian-Oxfordian Subbriançonnais series (Chénet 1979, Lereus 1986, Maury & Ricou 1983, Samec et al. 1988) and in the Prealpes médianes nappes (Septfontaine 1983, Septfontaine & Lombard 1976, Borel 1997). This event is also marked by a cusp in the subsidence curves of various Briançonnais units (Borel 1995), which corresponds to vertical movements of tectonic origin superimposed on the thermal subsidence trend of the Tethyan cooling margin.

The Callovian-Oxfordian event corresponds to a kinematic change in the Atlantic realm (acceleration of relative motion between Gondwana (including Adria) and Laurasia (including Iberia at that time, Olivet 1996). Late Jurassic to Early Cretaceous extensional rift tectonics is known along the Iberian and Armorican margins (Portugal, Guery 1985, Parentis basin, Boillot 1984, Matthieu 1986) and in Pyrenean basins (Kimmeridgian pull-apart basins, Peybernès & Souquet 1984, Canérot 1987). This intracontinental extension led to the rifting of Bay of Biscay and to its opening in Early Cretaceous times (Early Aptian based on magnetic anomalies, Malod 1989, Olivet 1996). The Valaisan rift whose remnants are found in the French (Jeanbourquin 1994, Cannic et al. 1995 and references herein) and Swiss Alps (Schmid et al. 1990, Florineth & Froitzheim 1994) evolved more or less synchronously with the Bay of Biscay rift; indeed these two rifts may have been connected (Stampfli 1993). The Briançonnais domain, which was located between the Tethys ocean and the Valais rift during late Middle and Late Jurassic times, underwent both thermal subsidence from the former and extensional deformation from the latter. This interpretation is consistent with the observed change in orientation of the paleostructures from the Tethyan rift event (Liassic) to the Valais rift event (Late Jurassic).

The Mesozoic sedimentary, diagenetic and paleotectonic record from the French Briançonnais units allows to identify the imprint of at least two interfering rifting-spreading cycles linked with the Western Tethyan and the North Atlantic systems, respectively (Fig. 12). An analogous situation is found along the continental margin off northwestern Australia (Dumont 1992), where Mesozoic uplift and subsidence of the northern Exmouth marginal plateau were driven by the successive rifting-spreading cycles of the Tethys (Argo Abyssal Plain, Late Jurassic) and of the Indian Ocean (Gascoyne Abyssal Plain, Early Cretaceous). As regards the Briançonnais, a third, earlier (Triassic) cycle may have occurred in relation with an Eastern Tethyan break-up (Meliatic ocean, Channell & Kozur 1997, Plasienka et al., 1997). The difference in timing between these rifting-spreading cycles is linked to microplate motions between Western Gondwana and Europe (Ricou 1994). It is likely that not only the Adriatic, but also the Iberian microplate had a major influence on the evolution of the Briançonnais domain.

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