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The sedimentary record of Mid-Cretaceous events in the Western Tethys and Central Atlantic Oceans and their continental margins[1])

By Pierre Charles de Graciansky[2]), Maurice Bourbon[2]), Marcel Lemoine[3]) and Jacques Sigal[4])

ABSTRACT

Cretaceous sedimentary records both from the Central Atlantic (D.S.D.P. sites on both margins) and from the Western Tethys (especially from the Alps) are compared, especially for the "Mid-Cretaceous" transition or crisis. Before this crisis, during Jurassic-Early Cretaceous times, both oceans followed an analogous tectonic-sedimentary evolution of initial rifting followed by seafloor spreading coupled with tensional and/or strike-slip movements within the continental margins. The 100-m.y. crisis coincided with the beginning opening of the North Atlantic Ocean and with an inversion of the relative motions between Africa and Europe: one might expect, therefore, to find strong divergences in the sedimentary records of the Atlantic and of the Western Tethys.

In fact, the sedimentary record results from the superposition of two different components, namely a pelagic background sedimentation and a detrital overprint due to more or less local tectonic disturbances. The pelagic background sedimentation shows striking similarities in nearly all studied sections, both from the Central Atlantic and from the Western Tethys. It consists of 1. limestone-marl alternations (Hauterivian to Lower Aptian), 2. a first gap in sedimentation (beginning in the late Early Aptian and extending up to the Late Aptian and even to the Albian), 3. black shale deposition (Late Aptian to Cenomanian), 4. a second gap in sedimentation (Early Cenomanian), and 5. a late limestone episode (Turonian-Senonian). These extensive sedimentary events must reflect global "oceanwide" changes as in the rate of seafloor spreading, oceanic environment and circulation and eustatic changes of sea level.

Detrital pollution of this background sedimentation often resulted in flysch deposition, starting as early as in Aptian-Albian-Cenomanian times and often lasting over the whole Late Cretaceous, even extending into the Tertiary. However, clastic sedimentation was not restricted to the Alpine areas, then the site of compressional tectonics: for instance, detrital turbiditic interbeds, linked with the opening of the North Atlantic, are known from Upper Barremian-Aptian deposits along the Iberian continental margin. In spite of their divergent tectonic evolution, the Central Atlantic and Western Tethys Cretaceous sedimentary basins show more similarities than differences.

RÉSUMÉ

On compare des séries sédimentaires crétacées de l'Atlantique Central (forages D.S.D.P.) et de la Téthys Occidentale (principalement dans les Alpes). Avant le milieu du Crétacé, ces deux océans ont

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suivi la même évolution tectonique: d'abord «rifting» (au Lias), puis expansion océanique (Jurassique moyen à Crétacé inférieur) accompagnée d'une évolution des marges continentales en extension et/ou en décrochement. Mais la «crise médio-crétacée», vers 100 m.a., est caractérisée par le début de l'ouverture de l'Atlantique Nord et par une modification profonde des mouvements relatifs Europe-Afrique, et l'on doit s'attendre à partir de cette époque à une divergence d'évolution entre les domaines Atlantique (toujours en expansion) et Téthysien (dès lors en compression) - ce qui devrait se retrouver dans les enregistrements sédimentaires.

En fait, les séries sédimentaires étudiées résultent de la superposition de deux composantes, d'une part un «fond pélagique», d'autre part une «pollution détritique» liée à des événements tectoniques plus ou moins locaux. Le fond pélagique montre de très grandes analogies dans toutes les coupes étudiées, avec la succession suivante de grands événements sédimentaires: 1. alternances marno-calcaires (Hauterivien à Aptien inférieur), 2. première lacune, débutant au Bédoulien supérieur, et montant plus ou moins haut dans l'Aptien et même l'Albien, 3. épisode des «Black Shales» (Aptien à Cénomanien), 4. deuxième lacune, débutant au Vraconien-Cénomanien inférieur, enfin 5. épisode calcaire supérieur (Turonien-Sénonien). Ces événements, qui se retrouvent sur de très grandes étendues, doivent trouver leur explication dans des conditions océaniques générales (environnement marin, régime des courants, variations eustatiques du niveau marin, vitesse de l'expansion océanique, etc.).

Les «pollutions» détritiques qui se superposent au fond pélagique donnent souvent une sédimentation de type flysch, se manifestent à partir de l'Aptien-Albien-Cénomanien, et durent souvent pendant tout le Crétacé supérieur, voire même pendant une partie du Tertiaire. Ce détritisme est bien sûr avant tout largement répandu dans les domaines Alpins (Téthysiens) soumis alors à une tectonique de compression, mais il peut aussi apparaître parfois dans le domaine Atlantique: c'est le cas par exemple des intercalations turbiditiques du Barrémien supérieur-Aptien de la marge Ibérique de l'Atlantique, manifestement liées à une tectonique en extension. En outre, ces «pollutions», même de type flysch, ne masquent pas totalement le fond pélagique général. Ainsi, en dépit d'évolutions tectoniques fondamentalement différentes à partir de 100 m.a., la comparaison Atlantique-Téthys Occidentale montre plus d'analogies que de différences.

Introduction: Setting of the problem

The segment of the Mesozoic Tethyan Ocean now represented in the Alps-Corsica-Northern Apennines area is called the Piemont-Ligurian domain. It belongs to the Western Tethys (Fig. 1). Its continental margins are 1. the North-Tethyan or European and 2. the South-Tethyan or Apulian margin, the sediments of which now outcrop respectively 1. in the Helvetic and part of the Penninic domains of the Alps, and 2. in the Austro-Alpine and South-Alpine domains of the Alps as well as in the Tuscan, Umbrian and Marchean zones of the Northern Apennines (Fig. 1 and 2). The Mesozoic evolution of these zones has been compared with that of present-day passive margins of the Atlantic Ocean (Bernoulli 1972; Bernoulli & Jenkyns 1974; Lemoine 1975; de Graciansky et al. 1979).

It is now generally accepted that in the Alps-Apennines area, the Liassic deposits more or less reflect a "rifting" stage which immediately preceded or was partially even coeval with the birth of the Tethyan oceanic crust. In fact, oceanic crust is believed to have appeared in the Piemont-Ligurian domain during latest Liassic or Middle Jurassic times, i.e. more or less at the same time as in the Central Atlantic (Pitman & Talwani 1972; Dewey et al. 1973). Consequently, the Late Jurassic and Early Cretaceous were periods both of spreading in the oceanic areas and of subsidence in the continental margins, both in the Central Atlantic and in the Western Tethys (Bernoulli & Lemoine 1980).

In the context of plate tectonics, all the Alpine tectonic and sedimentary events can be correlated with the major movements of the African, European and Iberian plates as deduced from the magnetic anomalies of the Atlantic Ocean - assuming that the motions of the smaller Apulian plate were similar to, if not identical with, those of the African plate. The first breakup of the Variscan continental mass started in Middle Liassic times (180 m.y.) with the opening both of the Central Atlantic and of the Western Tethys. Between 180 m.y. and 100 m.y., the relative motion of the African-Apulian margin of the Western Tethys with respect to its Iberian-European counterpart was a left-lateral strike-slip displacement (Fig. 1). This movement induced first rifting and then both spreading and strike-slip faulting in the embryonic Piemont-Ligurian Ocean as well as in its continental margins (BOURBON et al. 1977; LEMOINE 1980).

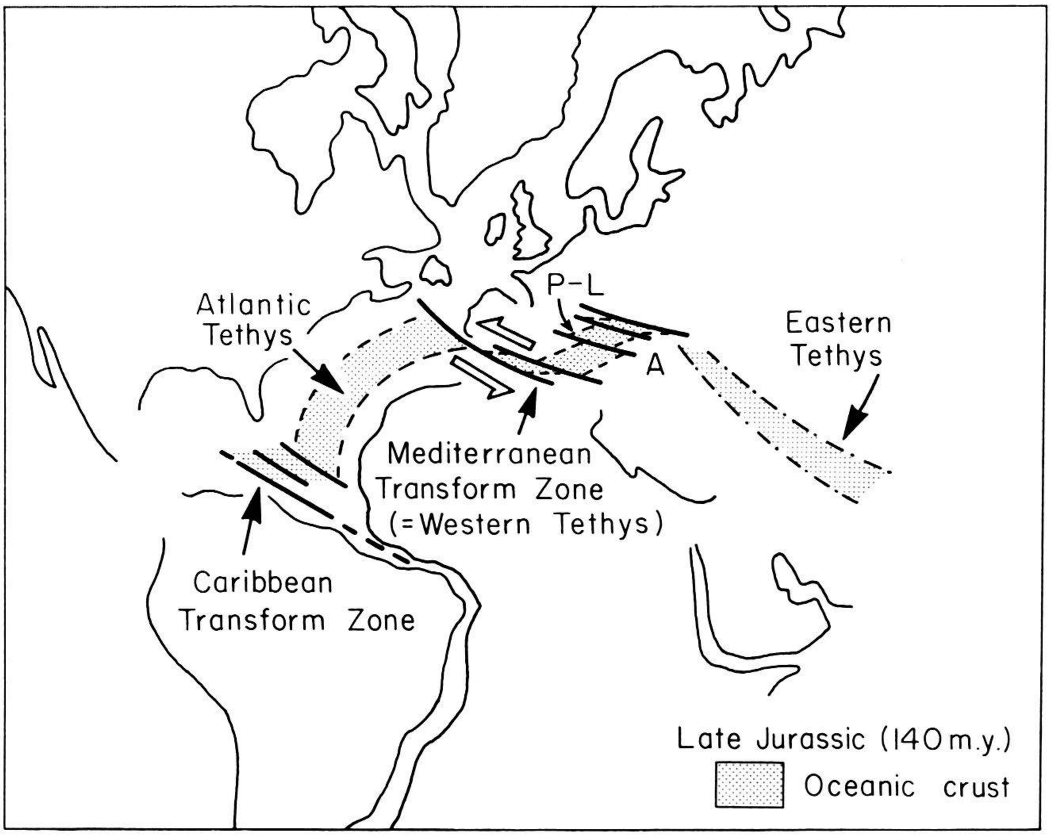
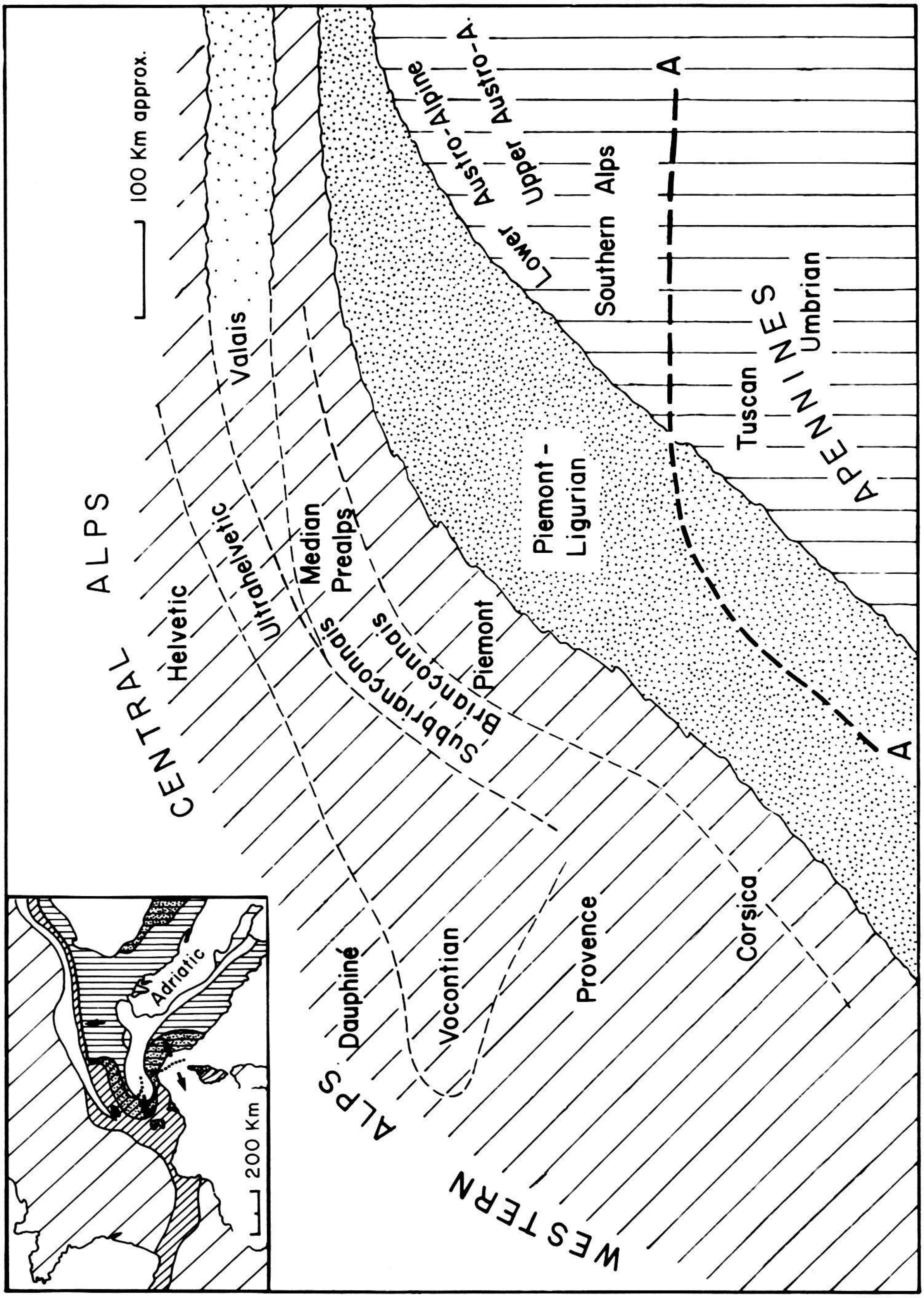


Fig. 1. Tentative palinspastic sketch of the Late Jurassic Tethys (after LEMOINE 1980 and BERNOULLI & LEMOINE 1980, modified).
The Eastern Tethys was a complex domain, probably with areas of both oceanic and continental crust, whose kinematic evolution remains difficult to decipher. The Atlantic Tethys was the early Central Atlantic Ocean, with a spreading axis active since Early Jurassic times and more or less perpendicular to the continental margins. Between the two areas, and to the west of the Atlantic Tethys, were two complex domains where both spreading and left-lateral strike slip faulting occurred: 1. The Western Tethys, comprising the Piemont-Ligurian "Ocean", may be considered as a megatransform zone between the Atlantic Tethys and the Eastern Tethys. 2. The Caribbean Tethys, which probably played an analogous role.
A = Apulia. P-L = Piemont-Ligurian oceanic domain.


100 Km approx.
CENTRAL ALPS
Helvetic
Ultrahelvetic
Valais
Median
Prealps
Subbriançonnais
Briançonnais
Piemont
Piemont -
Ligurian
Lower Austro-Alpine
Upper Austro-A.
Southern Alps
A
A
Tuscan
Umbrian
APENNINES
Corsica
Provence
Vocontian
Dauphiné
WESTERN ALPS
Adriatic
200 Km

In Late Cretaceous times, however, from 100 m.y. onwards, the relative motions of Africa, Apulia, Iberia and Europe were drastically changed as a result of the opening of the North Atlantic Ocean between Iberia and North America and of the Bay of Biscay. These new motions must then have been both of right-lateral strike-slip and of convergence resulting in the first compressional movements in the Alps. In fact, Late Cretaceous folding and thrusting occurred along the Apulian margin (Austro-Alpine domain of the Alps), and also in the European one (Devoluy, Provence, Pyrenees); moreover, high pressure/low temperature metamorphism is documented in the Sesia and Piemont zones of the Alps (distal Apulian margin and ocean), yielding radiometric ages between 100 and 80 m.y. Nevertheless, large parts of both margins (e.g. Lombardia-Trento domains in the Southern Alps; the major part of the Helvetic-Dauphiné zones in the Western and Central Alps, etc.) remained sites of pelagic (and in some places turbiditic) sedimentation throughout Late Cretaceous times; one may therefore wonder whether or not these areas were involved in compressional tectonics at that time.

In short, while after 100 m.y., spreading in the Atlantic Ocean continued, the Western Tethys, notably the Piemont-Ligurian oceanic domain and its margins, became the site of plate convergence and, possibly, of subduction. One may, therefore, expect differences in the relative sedimentary records. The aim of this paper is an attempt to evaluate both the nature and the importance of these differences.

For this purpose, two sets of sedimentary columns will be taken into consideration (Fig. 4): 1. Deep Sea Drilling Project holes from the Central Atlantic (Fig. 3), and 2. sedimentary sequences from the Alps-Apennines sector (especially from the Alps), i.e. from the Piemont-Ligurian Ocean and its continental margins.

The Cretaceous sedimentary record: a palimpsest

As will be seen later on, we shall emphasize the fact that sediments, and especially pelagic sediments, bear the imprint of two kinds of deposition: 1. of "pelagic sedimentation" which for a given epoch may remain unchanged over wide areas (which may be as wide, for instance, as both the Central Atlantic and the Western Tethys together; Lancelot 1980a, 1980b) and 2. of detrital "pollution" caused by more or less local tectonic movements such as tensional blockfaulting, thrusting, etc.

Fig. 2. Simplified palinspastic sketch map of the Western Tethyan Ocean and of its continental margins in the Alps-Apennines segment (approximately Early Cretaceous). *Oblique hatching:* European margin (including Corsica); *vertical hatching:* Apulian margin; *dots:* Piemont-Ligurian area of oceanic crust; *spaced dots:* Valais domain (possibly oceanic in the east); the scale is highly approximative, and is not valid for the width of the Piemont-Ligurian Ocean, which remains conjectural but was certainly less than 1000 km. A-A: site of future separation between structural units of Alpine or Apennine destination. *Upper left:* Simplified sketch map of the Alps and Apennines in their present situation. *Oblique hatching:* Europe, Iberia, Corso-Sardinia. *Vertical hatching:* Apulia. *Closely spaced hatching:* parts of the continental margins that were affected by Late Cretaceous and Tertiary folding and thrusting. *Dots:* areas with scattered tectonic outliers of rocks, derived from the ocean (ophiolites and their sedimentary cover).

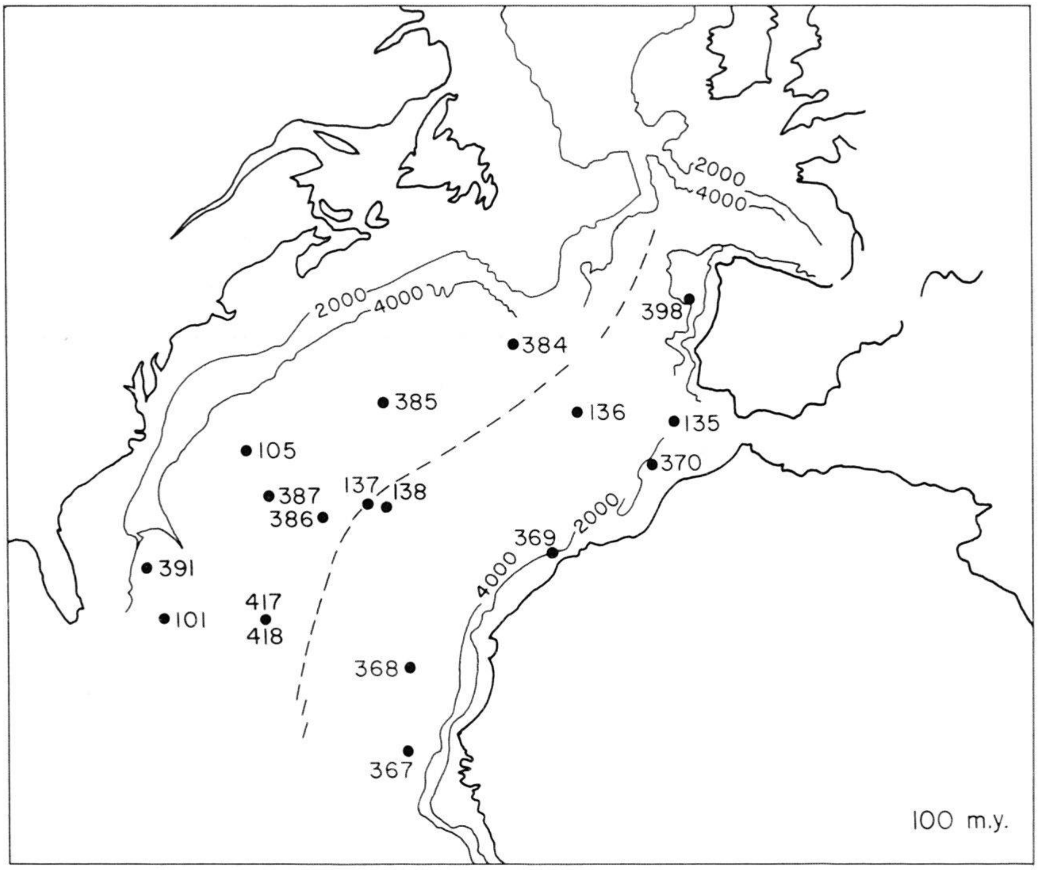
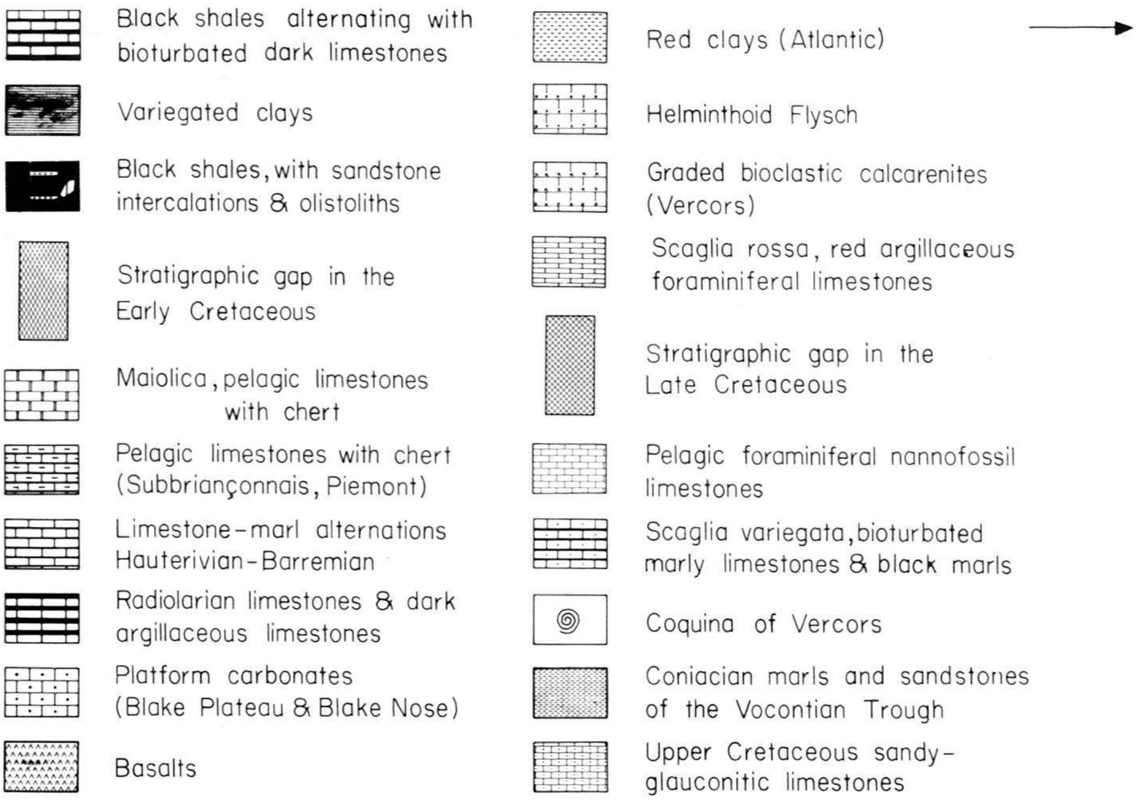


Fig. 3. Palinspastic map of the Mid-Cretaceous (100 m.y.) Central Atlantic with locations of Deep Sea Drilling Project Sites mentioned in the text. Contours after J. Olivet (personal communication 1980).



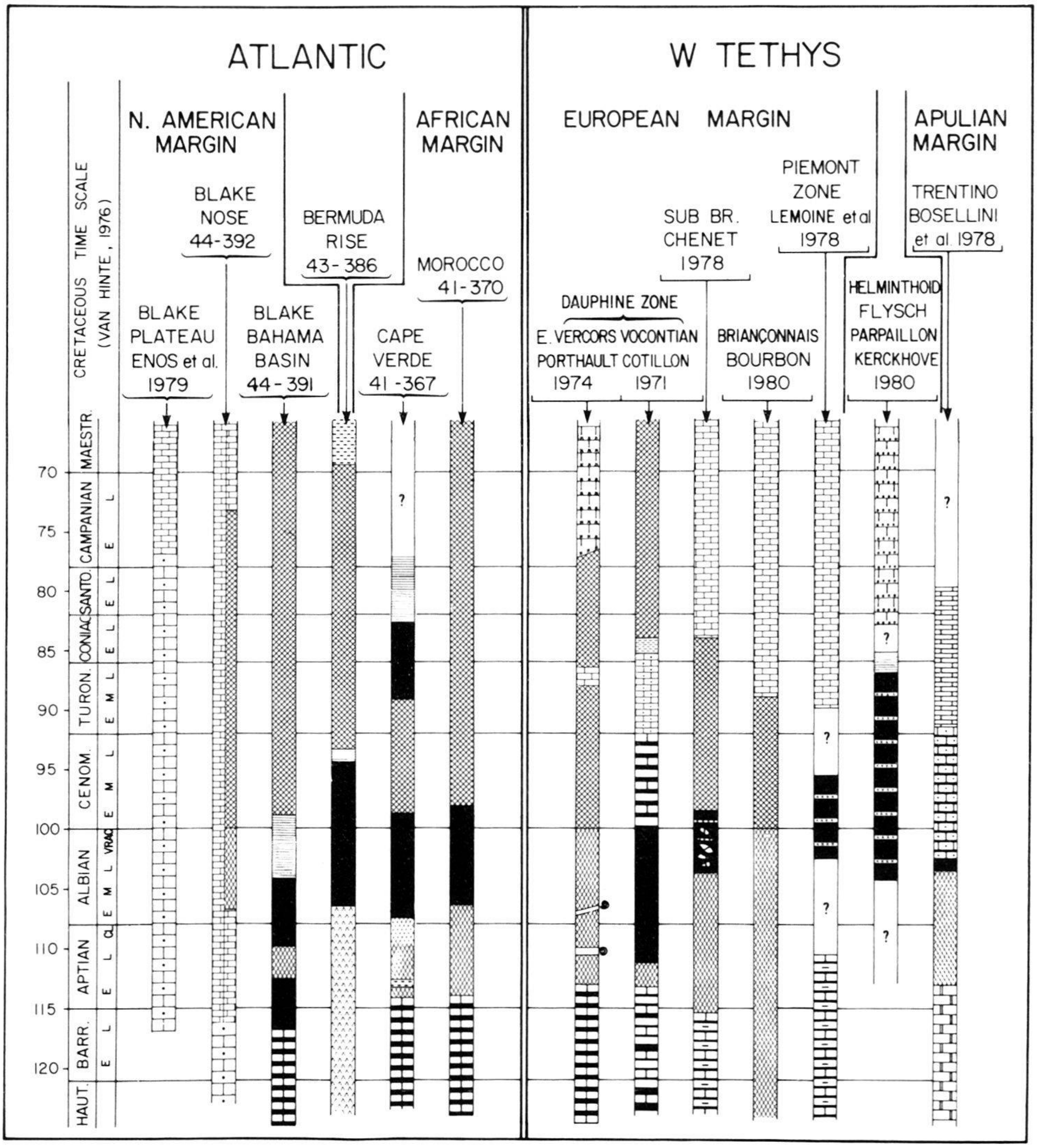


Fig. 4. Comparative stratigraphic columns of Cretaceous sequences, Central Atlantic and Western Tethys.

For location of Deep Sea Drilling Project sites see Figure 3, for location of Western Tethys sections (Alps, Apennines) Figure 2. In addition: the Vercors is situated immediately to the north of the Vocontian Trough; the Helminthoid Flysch, now overthrusted, is probably derived from the area between the closing Tethyan Ocean and the Apulian margin; the Trentino domain is located in the South-Alpine facies belt. Sources of Deep Sea Drilling data are Sheridan & Enos (1979) for the Blake Plateau; Lancelot, Seibold et al. (1977) for the northwest African margin (Leg 41); Tucholke, Vogt et al. (1979) for the Bermuda Rise (Leg 43) and Benson, Sheridan et al. (1978) for the Blake-Bahama Basin (Leg 44). The stratigraphy of Sites 367, 370, 386 and 391 has been reinterpreted by J. Sigal on the basis of new, partly unpublished, determinations of foraminifera, nannofossils and palynomorphs carried out by J. Sigal, C. Müller and D. Habib.

Pelagic background: major events in the Cretaceous

Considering first the pelagic record only, the following major subdivisions can be recognized in nearly all the sedimentary columns (Fig. 4): 1. an early marl-limestone episode (Hauterivian to Early Aptian), 2. a first stratigraphic gap, 3. a black shale episode, 4. a second stratigraphic gap, and 5. a late limestone episode (Turonian-Senonian).

1. Hauterivian to Early Aptian: limestones and limestone-marl alternations

On the continental margins, e.g. on the European margin of the Tethys in the Western Alps, deposits of this age exhibit a classical lateral facies change from platform carbonates (e.g. Urgonian facies) to pelagic ammonite- and nannofossil-bearing marl-limestone alternations (e.g. Vocontian facies).

Such limestone-marl alternations occur along both margins of the Tethys (e.g. in the Vocontian and Helvetic facies belts in the Western and Central Alps; in the Maiolica Formation in the Southern Alps and elsewhere) as well as in the Central Atlantic D.S.D.P. holes, and even in the Pacific (Mid-Pacific mountains, D.S.D.P. Site 463; FERRY & SCHAAF, in press). The origin of this widespread facies may be explained in various ways. In some cases, it may result from the emplacement of distal calcareous turbidites (MEISCHNER 1964; FERRY 1978, 1979; LE DEUFF 1977). On the other hand, at least for certain occurrences, new research provides a different explanation (COTILLON et al. 1980; WEISSERT et al. 1979). In fact, cyclic variations in nannofossil content and in the isotopic ratios of oxygen and carbon are recorded between limestone beds and marl interbeds which could suggest a climatic influence on the oceanic environment. Of course, generalization of this latter explanation needs further research, but it would provide a global explanation for the widespread occurrence of such facies during Early Cretaceous times.

In other cases it may be noted that the Lower Cretaceous pelagic deposits are not true limestone-marl alternations, but only bedded pelagic limestones with no significant marly interbeds (e.g. in the Briançonnais and Subbriançonnais Zones).

2. First stratigraphic gap

This gap occurs almost everywhere in the area studied but there may be exceptions, especially where detrital sediments record tectonic movements (see below).

The stratigraphic position of the gap is remarkably constant in all sections, from the Eastern Central Atlantic to the Alps and the Jura, and even as far as the Mid-Pacific mountains (FERRY & SCHAAF, in press). The period of nondeposition begins in the latest Early Aptian (approximatively 110-115 m.y.) and includes various parts of the Late Aptian to Albian interval. In the western Central Atlantic, the gap, observed at D.S.D.P. Sites 387 (Bermuda Rise) and 105 (North American lower continental rise), begins locally in the Barremian, i.e. somewhat earlier than in the more eastern areas considered here; at the neighbouring Site 392 (Blake Nose), there is no gap but an abrupt facies change up-section from platform carbonates to foram-nanno-ooze (Fig. 4). This major event shows several characteristics:

a) It occurs over large areas and in various types of environments:
- In platform-carbonate environments where it is linked with the sudden interruption (Pyrenees, Aquitaine) or the definite disappearance (Provence, Western Alps; ARNAUD et al. 1979) of Urgonian platform deposition along the European Tethyan margin.
- In epicontinental pelagic environments, as for example in the Vocontian Trough (COTILLON 1971) or in the Subbriançonnais Zone (CHENET 1979), both located on the European margin in the Western Alps.
- In deep pelagic environments, where the gap probably corresponds to a time of raised calcite compensation depth in the deep oceans (Atlantic: THIERSTEIN 1979; JANSA et al. 1979; Tethys: BOURBON 1980).

b) It marks the transition from predominantly calcareous to predominantly argillaceous sedimentation. This transition cannot be regarded as the first appearance of black shales which already occur in the limestone-marl alternations, it underlines, however, the disappearance of the purely calcareous beds, leading to true black shales without limestone intercalations. Exceptionally, the true black shales appear earlier as at D.S.D.P. Site 391 C, Blake Bahama basin (Fig. 4).

c) The event is probably coeval with the rifting phase which preceded the opening of the North Atlantic, as can be evidenced at D.S.D.P. Site 398 D on the Iberian margin (SIBUET, RYAN et al. 1980).

d) The event is strictly coeval with an (eustatic?) sea-level rise (HANCOCK 1975; VAIL et al. 1980) and is also more or less contemporaneous with a positive peak on the $\delta^{13}C$ curve (ARTHUR 1979).

3. Black shale episode

The so-called black shales are argillaceous or marly, organic carbon-rich sediments of "Mid-Cretaceous" (mainly Aptian to Cenomanian) age. They occur both in Atlantic D.S.D.P. cores and in Tethyan oceanic and continental margin sediments (JENKYNS 1980). Their organic matter is of various origin (TISSOT et al. 1979).

The carbonate content of the "black shales" may vary as a result of depositional depth relative to the calcite compensation depth; they may be marls in epicontinental domains (e.g.: Vocontian Trough in the Western Alps; D.S.D.P. Site 370 in the Atlantic) or noncalcareous shales in deeper pelagic environments (e.g.: Simme nappe s. l. in the Western Alps; most of the Central Atlantic D.S.D.P. sites).

The main features common to the pelagic/hemipelagic component of the black shales are the following:

a) Color rhythmicity: Beside redeposited beds (DEAN et al. 1977; DE GRACIANSKY & CHENET 1979), the Atlantic black shales show an alternation of carbon-rich black clays and of greenish clays, the latter being practically void of organic matter. Both, however, contain much pyrite. In the Vocontian Trough, the Aptian-Albian "marnes bleues" also exhibit a subtle greyish hue-rhythmicity observable only in much weathered outcrops. This rhythmicity may be the result of (?climatic) variations in the oceanic environment, but satisfactory explanations await further research.

b) Presence of variegated clays: Green to red clays (and even brick-red clays carrying up to 10% and in cases even 40% of hematite) are known both from the Central Atlantic (with the exception of the Cape Verde–Gibraltar confined basin: D.S.D.P. Sites 367, 368, 369, 370) and from the Western Tethys (e.g. "basal complexes" of Upper Cretaceous flysch sequences of the Simme nappe s.l., of the Helminthoid Flysch nappe, etc., see KERCKHOVE 1980). If not redeposited, their occurrence might suggest strong, rapid and rhythmical changes in the redox-conditions on the sea bottom. These red shales contain terrigenous quartz, and are thus more detrital than the associated darker shales.

c) Specific geochemical and mineralogical features: Minerals such as pyrite, marcasite, sphalerite, barite, celestite, and also authigenic carbonates (calcite, dolomite, siderite and rhodochrosite) are commonly described both in Atlantic and in Western Tethys black shales. The variegated clays also exhibit abnormally high iron- and manganese-oxide ratios.

4. Second stratigraphic gap

The end of the black shale episode, which is often marked by the deposition of variegated clays, is followed by a second period of nondeposition, beginning roughly at the same time both in the Central Atlantic and in the various Alpine domains.

In the Central Atlantic, the period of nondeposition starts in Vraconian or Early Cenomanian times (98–101 m.y.) (D.S.D.P. Sites 105, 137, 368, 370, 387, 398 D, 400, 417 D, 418 B) but it can end at various times as in the Turonian (e.g. Site 307) or even in the Pleistocene (e.g. Site 417 D). In fact, the gap may at some places be of long duration, encompassing the whole Late Cretaceous and even parts of the Tertiary; this may be due either to local tectonic events preventing sediment deposition (creation of submarine slopes or seamounts) or to Tertiary erosion. In the Tethyan domain, the period of nondeposition falls into the same general time interval as e.g. in the Briançonnais Zone (BOURBON 1980). However, its stratigraphical position is usually more variable and sometimes more difficult to ascertain for two main reasons: 1. detrital overprint due to tectonic movements, and 2. the lack of index fossils in certain formations.

This event is followed by a progressive return to dominantly calcareous sedimentation, also in purely pelagic domains (e.g. Vocontian Trough; D.S.D.P. Sites 369, 398 D). It is coeval with a rapid (?eustatic) variation in sea level and with another positive peak in the $\delta^{13}C$ curve (VAIL et al. 1980; ARTHUR 1979).

5. Turonian–Senonian: later limestone deposition

In places where the Upper Cretaceous is not missing altogether, sediments of latest Cretaceous age exhibit a lithological variety which reflects a paleogeographic diversification due both to the increasing width of the Atlantic Ocean and to the areal reduction of the Western Tethys.

In the Central Atlantic, two kinds of facies may occur: 1. carbonate-free clays, either brick- or maroon-colored (well oxygenated bottoms: D.S.D.P. Sites 105, 317, 386, 417 D) or black-colored and carbon-rich (persistence of a confined environment in the deepest parts of Cape Verde basin: Site 367); 2. calcareous foram-nanno-oozes on shallower margins, both on the African-European (Sites 369, 398 D, 400, 401) and North-American (98) sides of the Atlantic.

On those parts of Tethyan margins which were not affected by thrusting and folding, similar calcareous oozes were deposited (e.g. "couches rouges" of the Préalpes médianes in the Western Alps; Scaglia rossa, etc.). Nevertheless, flysch deposition in the internal Alpine zone hampers a comparison with the coeval Atlantic sediments.

Detrital overprint on pelagic sedimentation

As a result of the above-mentioned global-tectonic events, Cretaceous (particularly Late Cretaceous) detrital sedimentation occurred in various paleogeographic domains of the Alpine chains derived from the Western Tethys. These clastic sediments are of different facies. In the Vocontian domain glauconitic green quartz sandstones are intercalated in the Aptian–Albian black shale sequence and quartz grains are dispersed throughout the whole Upper Cretaceous deposits. Olistoliths may also occur (e.g. Subbriançonnais and Briançonnais). In the deeper, formerly pelagic domains detrital deposits are mostly of flysch type: these are the well-known Upper Cretaceous flysch sequences of the Alps and of the Apennines. In these flysch sequences, the turbiditic detrital material does not always completely mask the pelagic background sedimentation: For instance, the Helminthoid Flysch of the Western Alps begins with probably Cenomanian manganiferous black shales with interbedded sandstones (Kerckhove 1980). These black shales pass into variegated shales and are followed by a calcareous flysch which is of Senonian age at its top. In places, flysch sedimentation starts earlier than in the Cenomanian (Eastern Alps), a feature which is commonly interpreted as a result of earlier plate convergence.

Between the Alps–Apennines sector of the Western Tethys and the Atlantic, Cretaceous flysch sedimentation also occurs in the Betic and North African chains (Raoult 1974). Here, flysch sedimentation may start as early as during the Tithonian or the Early Cretaceous and may be the result of first left-lateral and then right-lateral strike-slip motions between the Iberian and African plates rather than of convergence.

Detrital overprint is not restricted to the Alpine sediments but appears also at Atlantic D.S.D.P. sites. For instance, slumped beds, breccias and turbidites are intercalated in the Upper Barremian and Aptian beds of D.S.D.P. hole 398 D, located on the Iberian margin of the Atlantic (de Graciansky et al. 1978): obviously they are derived from fault scarps connected with the rifting period preceding the opening of this sector of the Atlantic Ocean. Here, the detrital interbeds, although numerous, do not mask the pelagic-hemipelagic background sedimentation of the Barremian–Early Aptian marl–limestone alternations and the Late Aptian black shales. Only the Early Aptian period of nondeposition is not recorded here due to uninterrupted detrital sedimentation.

Conclusions

The motions of the major plates suggest that the 100 m.y. date may have marked a crucial change in the evolution of the Western Tethys. It is at that time approximately that the Piemont-Ligurian segment must have changed from a tensional tectonic regime of spreading to a convergent one, whereas spreading in the Atlantic went on. In other words, while both oceans followed a common tectonic path before the "Mid-Cretaceous crisis", their evolutions diverged after this. One may therefore expect that this divergence is recorded in the sediments. As a matter of fact, such a divergence exists, but our inquiry shows that nonetheless striking analogies persist during the whole Cretaceous when sedimentological features of both oceans and their continental margins are compared.

Pelagic background sedimentation: global explanations needed

The pelagic background sedimentation reveals the same succession of sedimentary events and facies throughout the Cretaceous, both in the Central Atlantic and in the Western Tethys. This cannot be explained by processes affecting the Alps-Apennines area alone; a global explanation is required, at least for two sets of problems:

a) The gross lithological successions, i.e. above all the occurrence of the black shale episode intercalated between two episodes of prevailing carbonate sedimentation. The occurrence of the black shale facies (which in places appears again in Coniacian-Santonian times) implies 1. an important supply of clay minerals; 2. a probable uplift of the calcite compensation depth; 3. an increased supply of organic matter of various origins and 4. conditions favoring preservation of this material. All these conditions were controlled by processes acting on a global scale such as rate of seafloor spreading, eustatic changes of sea level, circulations in the oceans, etc. (see e.g. LANCELOT 1980a, 1980b; JENKYNS 1980).

b) The gaps in sedimentation cannot originate from local events such as the creation of submarine slopes where sediments cannot accumulate or of current-swept seamounts. Again, a global explanation is required which in turn may be related to oceanic circulation, eustatic sea-level changes and the like.

Detrital overprint: local tectonic movements of various types

Intercalations of clastic material occur at several places in the "Mid-Cretaceous" and Upper Cretaceous pelagic series and are not restricted to the Alpine paleogeographic domains. Of course, they are more abundant and widespread in the latter since these were subjected, from 100 m.y. onwards, to plate convergence, possibly to subduction and obduction, and finally to continental collision in the Tertiary. However, clastic gravity flow and turbiditic sedimentation in pelagic basins may be triggered by very different tectonic events: 1. rifting preceding seafloor spreading (e.g. Iberian margin of the North Atlantic), 2. compressional movements linked with a minor strike-slip component (e.g. Upper Cretaceous flysch sequences of the Alps and Apennines), and even 3. predominant strike-slip movements (e.g. Tithonian and Cretaceous flysch of the Betides and the Maghrebides).

We conclude that comparison of the different sequences (Fig. 4) shows that those sections which do not lie too close to a source of clastic terrigenous or carbonate material, or which do not lie within an orogenic zone, exhibit facies successions which are surprisingly similar. In fact, the facies of coeval pelagic deposits are identical both in the Atlantic and in the Western Tethys and only their thickness may vary. As for the periods of nondeposition, their duration may vary as a result of submarine erosion, but they start more or less at the same time all over the area studied. Local tectonic influences may induce changes in the sedimentary record, but in most cases they do not conceal the bulk of the pelagic background sedimentation, which reflects global oceanic events.

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