University of Lyon
23-24 November 1989

MESOZOIC EUSTACY RECORD on WESTERN TETHYAN MARGINS

Abstract book

DES ASSOCIATION SEDIMENTOLOGISTES FRANÇAIS

Meeting on

MESOZOIC EUSTACY RECORD

ON

WESTERN TETHYAN MARGINS

UNIVERSITY of LYON, France

23-24 November 1989

Held with the support of

Institut National des Sciences de l'Univers (CNRS - Paris)
Association des Sédimentologistes Français
Association des Géologues du Sud-Est

AVANT-PROPOS

Les bassins des marges ouest-téthysiennes et parmi eux le bassin du Sud-Est de la France figurent parmi les mieux connus dans le monde car utilisés depuis longtemps pour étalonner les échelles stratigraphiques, plus récemment pour y rechercher les moteurs externes et internes de la dynamique sédimentaire. Ces bassins se prêtent donc tout particulièrement aux études sur l'eustatisme nécessitant tout à la fois une bonne connaissance de l'enchaînement des corps sédimentaires des plates-formes au domaine pélagique et un cadre chronologique précis.

Dans le prolongement du 2ème congrès de l'ASF, le Colloque de Lyon fait le point sur ces recherches pour le Mésozoïque, période-clé de l'histoire du globe. Sur les 27 communications de cette réunion, certaines font le bilan de travaux réalisés au sein des programmes DBT et GSGP ; beaucoup témoignent d'un approfondissement de la réflexion autour du modèle de P. Vail, notamment en contexte carbonaté où des aménagements sont proposés, tout en soulignant la difficulté à appréhender les relations entre eustatisme, tectonique et climat. Des tentatives sont menées en direction de l'océan avec l'espoir d'y recueillir des messages plus directs des variations du niveau marin tandis que se dessine une voie pleine de promesses : la mise en correspondance de la stratigraphie séquentielle et des phénomènes de l'évolution biologique.

La stratigraphie séquentielle apparaît aujourd'hui comme une clé essentielle pour la compréhension de la dynamique externe de la Terre et par conséquent comme un carrefour d'idées nouvelles. Notre voeu est que le Colloque de Lyon contribue efficacement à ce grand débat.

P. COTILLON et S. FERRY

PROGRAMME

All communications are allowed 25 minutes including 5 minutes for discussions

23th November

morning 09^{30}-10^{00} Opening session
10^{00} Communications

Sequence stratigraphy in carbonate systems

10^{00}-10^{25} - FLOQUET M., MENOT J.-C. & PASCAL A. - Enregistrement de l'eustatisme par les systèmes sédimentaires bathono-callovo-oxfordiens de Bourgogne.

10^{25}-10^{50} - ARNAUD-VANNEAU A. & ARNAUD H. - Faciès, paraséquences et séquences de dépôt dans le Crétacé inférieur des Massifs Subalpins septentrionaux et du Jura (S-E de la France).

10^{50}-11^{15} - CALVET F., TUCKER M.E. & HENTON J. M. - Middle Triassic carbonate ramp systems in the Catalan Basin, N.E. Spain: facies, cycles, depositional sequences and controls.

11^{15}-11^{40} - SALAS R. & QUEROL X. - Stratigraphie séquentielle du Malm et du Crétacé sur la marge orientale de la plaque ibérique. Causes tectoniques et eustatiques.

Coffee break

12^{00}-12^{25} - STRASSER A. - Cyclic sedimentation in peritidal carbonates (upper Tithonian - lower Berriasian, French Jura Mountains).

12^{25}-12^{50} - COMBES P.J. & PEYBERNES B. - Tectonique et eustatisme dans les gisements de bauxite de l'Ariège.

12^{50}-13^{15} - JUIGNET P. & BRETON G. - Séquences eustatiques et cyclicité dans le Crétacé moyen du Bassin Parisien.

Lunch at the nearby campus restaurant

afternoon **Sequence stratigraphy in carbonate systems (continued)**

14^{30}-14^{55} - FERRY S. & RUBINO J.-L. - Climatic-eustatic mixed control on carbonate deposition, Mesozoic, S-E France.

14^{55}-15^{20} - RUBINO J.-L. - Problem of eustatic 3rd order depositional sequence recording during transgressive supercycle. Example of the Albian carbonate/clastic mixed deposits of S-E France.

15^{20}-15^{45} - FERRY S., RUBINO J.-L., ATROPS F., CHEVALLIER T., DROMART G., CRUMIERE J.-P. & MOUTERDE R. - A revision of the Mesozoic sea level chart of Haq et al (1987), from the carbonate wedge of the French Alpine margin.

Coffee break

16^{15}-16^{40} - PEYBERNES B. - Séquences de dépôt et cycles eustatiques de troisième ordre dans les alternances calcarénites-radiolarites du Jurassique de la Nappe de Balagne (Corse).

16^{40}-17^{05} - DUMONT T. - Eustacy and rift tectonics: the western Alps and south-east basin of France across the Triassic-Liassic boundary.

17^{05}-17^{30} - DECONINCK J.-F., CHAMLEY H., ACCARIE H., BEAUDOIN B. & RENARD M. - Clay minerals as a tool in recording eustatic fluctuations: example of Cretaceous to Eocene pelagic sediments from the Umbria-Marche basin (Italy).

evening

18^{00} - Guided tour of the old inner town

20^{00} - Dinner on the river passenger boat "Hermes"

24th November

morning **Pelagic and/or condensed sections, organic matter deposition and sequence stratigraphy**

08^{30}-08^{55} - COTILLON P. - Eustacy record off Tethyan margins: a new approach through the study of carbonate flux variations in the Tithonian-Aptian section at DSDP Site 534 (Central Atlantic).

08^{55}-09^{20} - MARTIRE L. - The eustatic control over carbonate pelagic sedimentation on submarine plateaus.

09^{20}-09^{45} - DUPASQUIER C. & METTRAUX M. - Hard-ground and condensed horizons (Liassic and Cretaceous, Swiss Mediane Nappe): a story of differentiated subsidence and sea level change.

09^{45}-10^{15} - DROMART G. - Deep-water microbial biostromes, depositional sequences, ans sea-level fluctuations: the Upper Jurassic of the western Subalpine margin (S-E France).

10^{15}-10^{40} - METTRAUX M., DOMERGUES J.-L. & MEISTER C. - Liassic mineralized ammonite-bearing beds: a record of episodic deposition in the western Swiss Prealps.

Coffee break

11^{15}-11^{40} - GORIN G. & STEFFEN D. - Influence of eustacy on the organic facies of the Berriasian stratotype at Berrias (Ardèche, France).

11^{40}-12^{05} - CRUMIERE-AIRAUD C. & CRUMIERE J.-P. - The Cenomanian-Turonian oceanic anoxic event (CTOAE) on the northwestern Tethyan margin.

12^{05}-12^{30} - BREHERET J.-G. - Hydrodynamism and sediment distribution by Albian time in the Vocontian domain (S-E France).

Tectonic overprint on eustacy

12^{30}-12^{55} - BUROLLET P.F. - Eustacy versus tectonics as processes of the Cretaceous sedimentation in Tunisia.

Lunch at the nearby campus restaurant

afternoon Tectonic overprint on eustacy (continued)

14^{45}-15^{10} - SOUQUET P. & DERAMOND J. - Essai d'application de la stratigraphie séquentielle à l'étude des relations tectonique-sédimentation.

15^{10}-15^{35} - VAIL P.R. & EISNER P.N. - Stratigraphic signatures separating tectonic, eustatic and sedimentologic effects on sedimentary sections.

Faunal turnovers versus sequence stratigraphy

15^{35}-16^{00} - ATROPS F. & FERRY S. - Sequence stratigraphy and changes in the ammonite fauna, Upper Jurassic, S-E France.

16^{00}-16^{25} - MAGNIEZ-JANNIN F. - Réponse des foraminifères bathyaux aux oscillations eustatiques et corrélation avec les séquences de dépôt: analyse dans le Valanginien-Hauterivien du bassin vocontien (S-E de la France).

Coffee break

17^{00}-17^{25} - MOUTERDE R., SADKI D., CHEVALLIER T. & FERRY S. - Sea level changes and ammonite turnovers in the Bajocian of the Vocontian Trough (S-E France).

17^{25}-17^{50} - GARCIA J.-P. & LAURIN B. - Communautés à brachiopodes et discontinuités dans le Bathonien-Callovien de la plate-forme bourguignonne.

ABSTRACTS

Faciès, paraséquences et séquences de dépôt dans le Crétacé inférieur des massifs subalpins septentrionaux et du Jura (S-E de la France)

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RESUME. - Les faciès des plates-formes carbonatées du Crétacé inférieur ont été reconnus depuis longtemps dans le Berriasien-Valanginien et le Barrémien-Aptien inférieur des massifs subalpins septentrionaux ou du Jura. Il en est de même pour leur agencement vertical en grandes séquences de comblement (séquences "klupféliennes". Par contre, l'interprétation des séquences de dépôt (séquences de Vail) est beaucoup plus récente et pose encore quelques problèmes dans certains secteurs, car, comme l'ont fait remarquer Ferry & Rubino (1989), les limites des séquences de dépôt ne correspondent généralement pas à celles des séquences "klupféliennes" qui avaient été précédemment définies.

Dans ce cadre, chaque cortège sédimentaire défini à l'intérieur des séquences de dépôt peut être caractérisé par des ensembles de paraséquences typiques par leur épaisseur et par les faciès qui les constituent. Cinq catégories de paraséquences peuvent ainsi être distinguées grâce à l'examen de diverses plates-formes, tant en France que dans d'autres régions de la Téthys.

1. PARASEQUENCES ET FACIES DES CORTEGES DE BAS NIVEAU MARIN

D'après Vail et al. (1987) deux types de cortèges de bas niveau peuvent se distinguer selon que le niveau de la mer est bas ou très bas : *les prismes de bordure de plate-forme* se déposent dans le premier cas (séquences de dépôt de type 2, plate-forme interne partiellement exondée), les *prismes de bas niveau* dans le second cas (séquences de dépôt de type 1, plate-forme interne totalement exondée).

1.1. Paraséquences des prismes de bas niveau

Deux cas se prrésentent selon la position des paraséquences à l'intérieur des prismes de bas niveau.

Les paraséquences de type slope fan, d'épaisseur plurimétrique à décamétrique, sont déposées à l'amont du talus externe pendant la période de chute rapide du niveau relatif de la mer. Elles passent latéralement, côté bassin, aux paraséquences à faciès hémipélagiques. Elles sont représentées par des faciès bioclastiques extrêmement grossiers (éléments plurimillimétriques à centrimétriques), très mal classés, à ciment micritique ou sparitique disposés en gros bancs souvent ravinants à la base et fréquemment granoclassés. Le dépôt du sédiment semble s'effectuer sous l'effet de courants de tempête responsables du ravinement du substrat et de l'entraînement des éléments vers des milieux relativement plus profonds que ceux dont sont originaires les bioclastes.

Les paraséquences de prisme de bas niveau progradant (lowstand prograding wedge), d'épaisseur métrique à décamétrique, de type shallowing upward, sont constituées par des sables bioclastiques grossiers, généralement bien classés, et par des sables oolitiques déposés dans des milieux soumis à un hydrodynamisme constant. Ce dernier est essentiellement dû à l'action des vagues (petits lits centimétriques granoclassés, litages entrecroisés), mais l'influence des tempêtes (stratifications de type hummocky), voire celle de courants bidirectionnels (présence de rares herringbones) est aussi sensible, notamment en sommet de séquence.

1.2. Les séquences des prismes de bordure de plate-forme

Dans le secteur considéré, les prismes de bordure de plate-forme montrent une zonation des faciès très nette, aussi bien latéralement que verticalement. Cette disposition correspond au modèle standard des plates-formes carbonatées. Contrairement à une opinion antérieure (Arnaud & Arnaud-Vanneau, 1989), c'est dans cette catégorie que nous plaçons actuellement les parties les plus massives, à faciès interne, des séries de plate-forme, opinion qui rejoint celle de Ferry & Rubino (op. cit.).

Les paraséquences ont également une épaisseur métrique. Celles situées sur le domaine externe de la plate-forme présentent les mêmes caractères généraux que les paraséquences des prismes de bas niveau. Elles en diffèrent par leur localisation dans des secteurs qui semblent souvent plus étroits et par un plus faible développement de la sédimentation oolitique. Les paraséquences du domaine interne de la plate-forme sont plus variées, mais représentées principalement par des faciès à Milioles (et à Rudistes), des faciès à oncolites, ou à stromatolites ou à Pseudotriloculines et, parfois, des faciès d'émersion (plages), voire des tempestites.

Lorsque les prismes de bordure de plate-forme correspondent à des bas niveaux relatifs de la mer situés à l'intérieur d'une période de très haut niveau (cas, par exemple, des *plates-formes noyées* du Valanginien supérieur, de l'Hauterivien inférieur ou du Clansayésien), les paraséquences sont constituées principalement par des sédiments bioclastiques ou bio-ooclastiques à Crinoïdes et Bryozoaires, déposés sous l'influence de courants, souvent bidirectionnels (courants de marée ?).

2. PARASEQUENCES ET FACIES DES CORTEGES TRANSGRESSIFS

Deux périodes peuvent se distinguer dans le cortège transgressif : à la base, la période d'ouverture et, au sommet, la période d'approfondissement des milieux.

La période d'ouverture est caractérisée par des successions de paraséquences, d'épaisseur décroissante vers le haut, constituées par des sédiments déposés dans des milieux de moins en moins confinés d'une séquence à une autre (par exemple, faciès à oncolites ou petits Rudistes à la base, faciès à gros Rudistes et rares Cnidaires au sommet). Les tempestites sont souvent si nombreuses dans ces paraséquences qu'elles pourraient servir, dans certains cas, de critère de reconnaissance. Sur la plate-forme, ces paraséquences sont parfois absentes. Lorsqu'elles existent, elles peuvent traduire le début d'une rétrogradation des faciès (back stepping), d'où notre proposition de les placer dans le cortège transgressif bien qu'elles s'intègrent très bien au sommet des prismes de bordure de plate-forme par l'ensemble de leurs caractères, tant lithologiques que faciologiques.

La période d'approfondissement est par contre très reconnaissable sur les plates-formes. Les paraséquences sont nombreuses, généralement peu épaisses (souvent décimétriques), caractérisées par des surfaces basales ravinantes et des faciès particuliers (dont les faciès de transgression sensu Arnaud-Vanneau, 1980). Les faciès de transgression, rencontrés essentiellement à la base de cet intervalle, sont typiques par leur coloration, la présence d'éléments ferruginisés, l'abondance relative des apports détritiques terrigènes et, surtout, par l'importance des remaniements qui témoignent de l'ampleur des ravinements à la base des paraséquences : remaniement des éléments, mélanges de faciès, mélanges de faunes d'origines variées. En plus des faunes typiques des divers milieux de la plate-forme, des formes pélagiques et, surtout, des Characées remaniées s'observent fréquemment. Dans la région considérée, la présence de Characées souligne presque toujours les périodes d'approfondissement des cortèges transgressifs (par exemple à la base de la transgression D1 du Berriasien supérieur ou à la base des couches inférieures à Orbitolines de l'Aptien basal). Au-dessus des faciès de transgression, les paraséquences sont constituées par des faciès (à Dasycladales, ou à nodules à Bacinelles,...) souvent différents de ceux des plates-formes standard. Le maximum d'approfondissement (maximum flooding) est souvent net, parfois souligné par la présence de formes pélagiques (Ammonites, Calpionelles) ; dans certains cas cependant, des difficultés subsistent pour le localiser avec précision.

3. PARASEQUENCES ET FACIES DES CORTEGES DE HAUT NIVEAU MARIN

Compte tenu de la réinterprétation des prismes de bordure de plate-forme, les cortèges de haut niveau semblent peu épais, voire même localement absents entre le maximum d'approfondissement et la limite de séquence de dépôt située au-dessus. Les faciès sont semblables à ceux des plates-formes standard, avec une disposition latérale zonée. Les paraséquences diffèrent de celles des prismes de bordure de plate-forme par une rétrogradation très nette des faciès à l'échelle de la plate-forme (par exemple, faciès hémipélagiques sur la même verticale que les faciès de plate-forme interne des prismes de bordure de plate-forme) et par la prépondérance des faciès de type externe (faciès bioclastiques fins à plaques d'Echinodermes, faciès oolitiques, petites bioconstructions à Cnidaires). Les faciès oolitiques sont souvent très développés mais, contrairement à ceux des paraséquences des prismes de bas niveau, ils peuvent s'observer sur de très grandes surfaces.

4. CONCLUSION

Dans les séries carbonatées de plate-forme, plusieurs types de paraséquences peuvent être reconnus non seulement par leurs caractères lithologiques (épaisseurs, litages), mais aussi par des ensembles de faciès différents selon les cortèges sédimentaires considérés. Cette constatation illustre les changements de modèles sédimentaires (plates-formes standard, plates-formes noyées), les modifications des milieux de dépôt et les variations de la productivité sédimentaire qui sont liés aux fluctuations du niveau relatif de la mer.

REFERENCES

ARNAUD H. & ARNAUD-VANNEAU A. (1989) - Séquences de dépôt et variations du niveau relatif de la mer au Barrémien et à l'Aptien inférieur dans les massifs subalpins septentrionaux et le Jura (SE de la France). *Bull. Soc. géol. France*, (8), V, 3, p. 651-660.

ARNAUD-VANNEAU A. (1980) - Micropaléontologie, paléoécologie et sédimentologie d'une plate-forme carbonatée de la marge passive de la Téthys : l'Urgonien du Vercors septentrional et de la Chartrfeuse (Alpes occidentales). *Géologie Alpine*, Grenoble, mém. n° 10, 3 vol., 874 p.

FERRY S. & RUBINO J.-L. (1989) - Correspondance entre séquence de Klüpfel et séquence de Vail en système de dépôt carbonaté. *Strata*, 1, 5, p. 9-11.

VAIL P.R., COLIN J.-P., JAN DU CHENE R., KUCHLY J., MEDIAVILLA F., TRIFILIEFF V. (1987) - La stratigraphie séquentielle et son application aux corrélations chronostratigraphiques dans le Jurassique du Bassin de Paris. *Bull. Soc. géol. France*, Paris, (8), III, 7, p. 1301-1321.

Sequence stratigraphy and changes in the ammonite fauna (Upper Jurassic, S-E France)

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ABSTRACT. - Solving the paleontological problem of new taxa appearance needs, among others, to set apart what is due to migrations (this comes to putting the problem in the neighbor's backyard) from what is due to global environmental stresses. Among the possible stresses are changes in relative sea level maybe associated with (or due to ?) climate changes. Environmental changes may be continuously recorded in deep-water polycyclic carbonate series. That is the reason why, in a first step, we have tried to place *faunal turnovers against lithological changes in the subpelagic ammonite-rich series of the Vocontian Trough.* This series was interpreted in terms of relative sea level changes after doing systems tract analysis (Vail et al. 1987) across the carbonate wedge of the French Alpine margin, including shallow-water carbonate banks (see Ferry & Rubino, this volume, for theoretical possibilities). Six basinal depositional sequences have been studied, three in the Oxfordian, three in the Kimmeridgian. The main result is that *either faunal turnovers or simple crises only marked by some disappearances match the boundaries of sequence stratigraphy* Vail-sense. The **deepest changes always occur during the transgressive tract** whose duration may vary depending on sequences. The replacement of the old fauna by the new one is finished when the complete flooding of platforms is achieved. Sea level falls are usually marked by moderate changes in the previous highstand fauna. Changes occur at the same time in other distant regions of western Europe and North Africa.

Figure 1 shows what happened in the Oxfordian. Because individual beds correlate over the whole basin, all ammonite crops have been replaced against the Sederon section given as an example. The strongest turnover is coincidental with the progressive flooding of the first Oxfordian reef on the Jura platform. The sequence boundary we place below the few beds representing the basinal equivalent of the reef is not marked by strong changes. Below, another lowstand tract is represented by a bundle of beds coeval with nodular limestones ("couches à sphérites") on the Jura platform. Such a lowstand tract represents only a relative low within a "regressive" trend climaxing with the instalment of the first reef. Accordingly, the 3rd order transgressive tract of this depositional sequence does not show ammonite changes as strong as for the late Oxfordian flooding. After this flooding, starts another "regressive" trend climaxing with the second Oxfordian reef (Planula zone) (Enay et al. 1988). Within this trend are two 3rd order lowstand tracts represented by two bundles of beds in the Trough and, from bottom to top on the platform, the "Geissberg" beds and the "Calcaires lités". Two small turnovers are recorded within the transgressive tracts of these relative lowstands.

The next strong turnover corresponds with the stepped inundation of the late Oxfordian reef, beginning in the Galar subzone and lasting the whole Platynota subzone of the lower Kimmeridgian. This subzone is marked by faunal innovations coincidental with the parasequences of the transgressive tract. The new fauna is installed at the complete flooding (marly alternation of the lower Hypselocyclum zone). As in the Oxfordian, this flooding is followed by a "regressive" trend in which we individualize two 3rd order lowstand tracts separated by short-lived floodings (more marly levels). It is hard to hierarchize boundaries of minor cycles in this trend and to choose among them that of the 3rd order cyclicity. The first inundation at the basis of the Divisum zone ("vire à Crussoliceras") corresponds to a brutal crisis mainly marked by extinctions, not a real turnover. Appearances were a bit earlier, corresponding to a brief inundation within the Lothari lowstand tract. The next flooding occurred at the basis of the Eudoxus zone. It was not a dramatic event in the lithology, nor a strong turnover in the fauna. Sequence boundaries, as in the Bajocian (see Mouterde et al., this volume), are usually marked by small changes.

Our new analysis of systems tracts differs from the one we proposed two years ago (Ferry & Rubino 1987, Atrops & Ferry 1987). The fact that most of the faunal crisis is within the transgressive tract, and not just after the complete flooding suggests that opening of seeways may not be the main culprit for turnovers. In a general way, cold forms are spotted in S-E France within the transgressive tract too, suggesting that climate coolings, maybe as a result of renewed volcanic activity coincidental with 3rd order sea level rises, may represent most of the environmental stress we are looking for.

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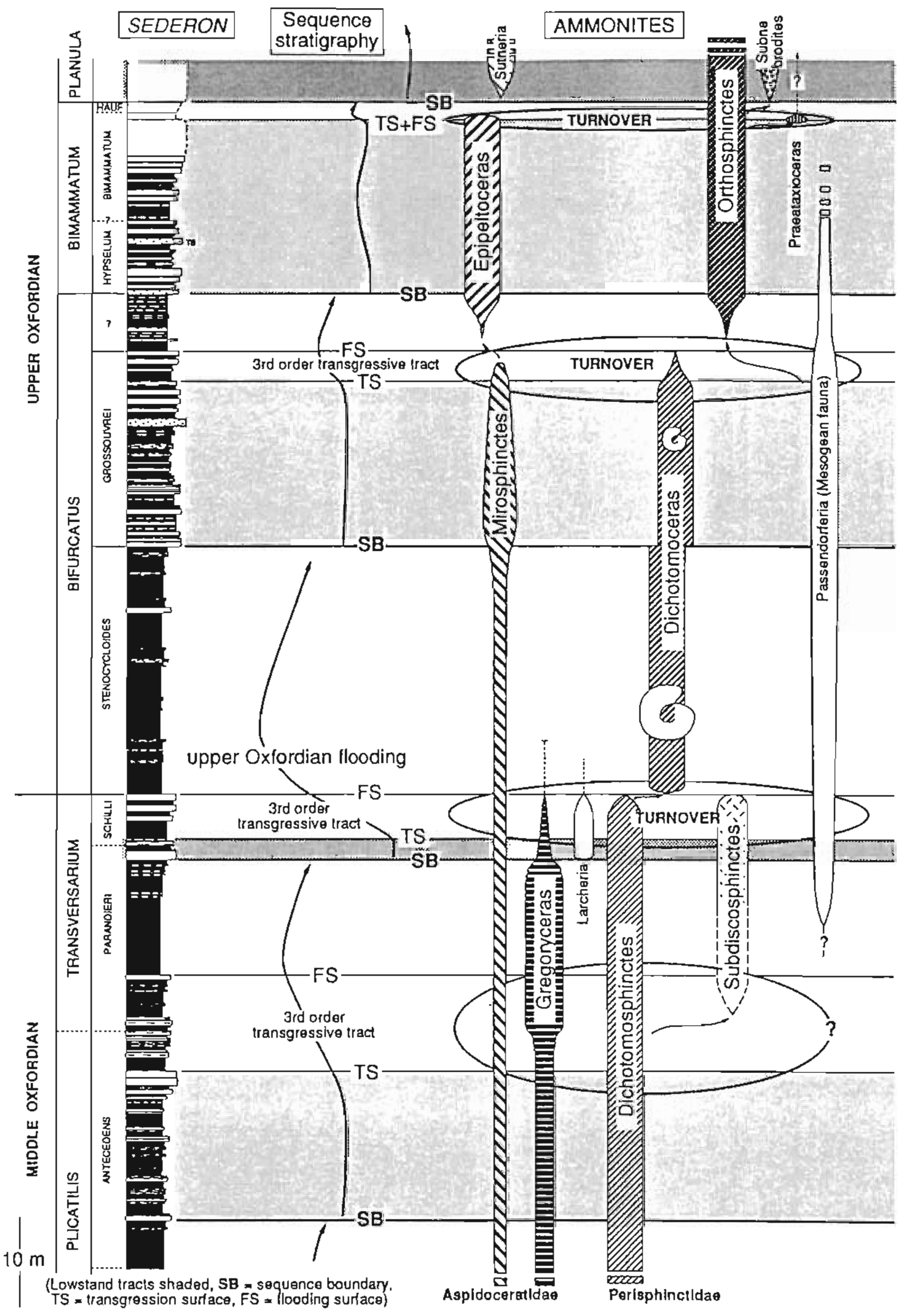
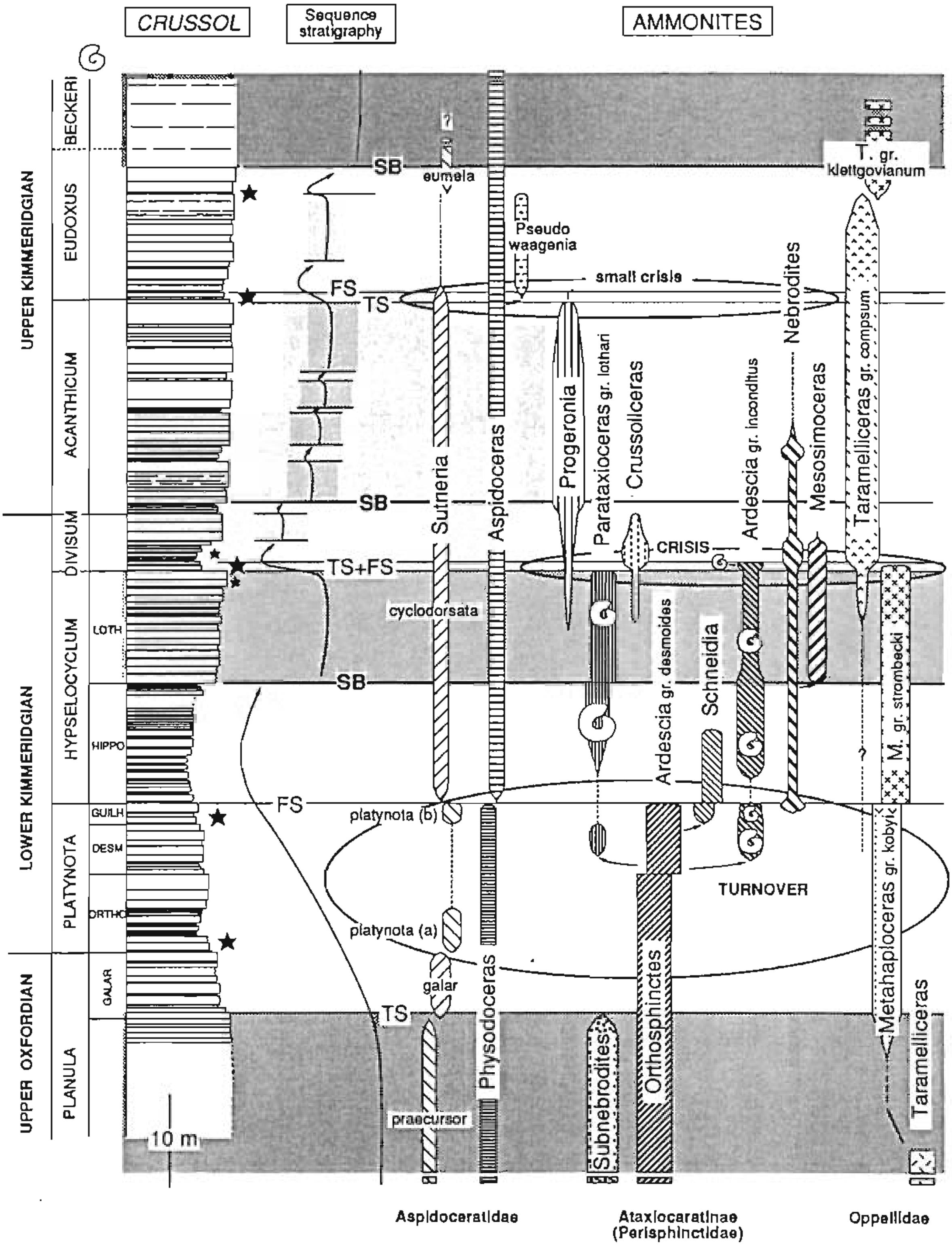


Fig. 1 - Turnovers in sensitive ammonite families in the middle to upper Oxfordian of southeastern France. The Sederon section is given as a key-section for the Vocontian Trough, and is corelated with the composite series of the Jura platform. All beds of the Sederon section can be traced over the whole basin and western border, indicating that there is no bed missing. (SB: sequence boundary, TS: transgression surface, FS: flooding surface.)



(Lowstand tracts shaded, SB = sequence boundary, TS = transgression surface, FS = flooding surface
black stars = arrivals of cold fauna (*Amoeboceras*, *Aulacostephanus* and, to a lesser extent, *Rasenia*)

Fig. 2 - Turnovers in sensitive ammonite families in the uppermost Oxfordian to upper Kimmeriggian of southeastern France. The key-section is the Crussol section in the middle Rhône valley. All beds can be traced over the whole Vocontian Trough, indicating that there is no bed missing. (SB: sequence boundary, TS: transgression surface, FS: flooding surface.)

Contribution à l'étude de la cyclicité sédimentaire Analyse détaillée de l'alternance marno-calcaire : Exemple du Cénomanien des Basses-Alpes (S-E France)

Poster-communication

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RESUME. - L'étude détaillée (analyse quantitative en diffractométrie X, microsonde, microscopie électronique,...) d'une coupe levée au sein de l'alternance marno-calcaire du Cénomanien du Sud-Ouest du bassin vocontien (EYG. 1), conduit à suggérer un modèle pour la genèse de cette série. Les deux points clefs de ce modèle sont :

- le contrôle de la teneur en carbonate par les fluctuations de l'apport terrigène : dilution d'une production biogénique calcitique supposée constante mais aussi effet bio-limitant de la turbidité sur certaines espèces sensibles (Nannoconus) ;
- le contrôle de l'importance de cet apport terrigène par les mouvements relatifs du niveau de la mer (transgression-régression).

La coupe EYG.1 (planche 1), intéressant trois cycles métriques, a été levée au sein de l'ensemble inférieur et moyen marno-calcaire gréseux et glauconieux du Cénomanien affleurant dans le synclinal d'Eygaliers (Sud du Buis). La maille d'échantillonnage serrée (6 cm) autorise une analyse à haute définition.

L'absence de discontinuité de sédimentation à la base des bancs ainsi que l'absence de granoclassement excluent une mise en place de type turbide, que ce soit pour les bancs calcaires ou les ensembles banc/interbanc.

L'absence de structures sédimentaires distinctes sur l'ensemble de la coupe montre qu'il n'y a pas lieu d'envisager de modifications importantes des conditions hydrodynamiques au passage banc/interbanc.

Les carbonates (planche 1) sont formés pour 5 à 20 % par une dolomite néoformée lors d'une diagenèse précoce en milieu réducteur (présence de pyrite), et pour 80 à 95 % par une calcite biogénique (coccolithes, nannoconus, foraminifères planctoniques).

L'alternance marno-calcaire ne résulte pas d'une modification du taux de dissolution des carbonates au passage banc/interbanc dans la mesure où les fossiles sont partout peu corrodés et où il n'y a pas de dépendance lithologique de cette corrosion. Les variations de la composition faunistique au passage banc/interbanc traduisent cependant des changements dans le paléo-environnement océanique. A la différence des coccolithes et des foraminifères planctoniques que l'on trouve indifféremment dans les interbancs marneux et les bancs calcaires, les nannoconus et des spicules de spongiaires (Demosponges) calcitisés ne s'observent que dans les bancs calcaires. La constance du régime hydrodynamique au cours du dépôt de la série EYG. 1 ne permet pas d'attribuer la présence des spicules dans les bancs calcaires à un transport plus intense depuis les biotopes à spongiaires. La présence des spicules traduit donc le développement des éponges lors du dépôt des bancs calcaires ; développement contrarié alors que se déposent les interbancs marneux.

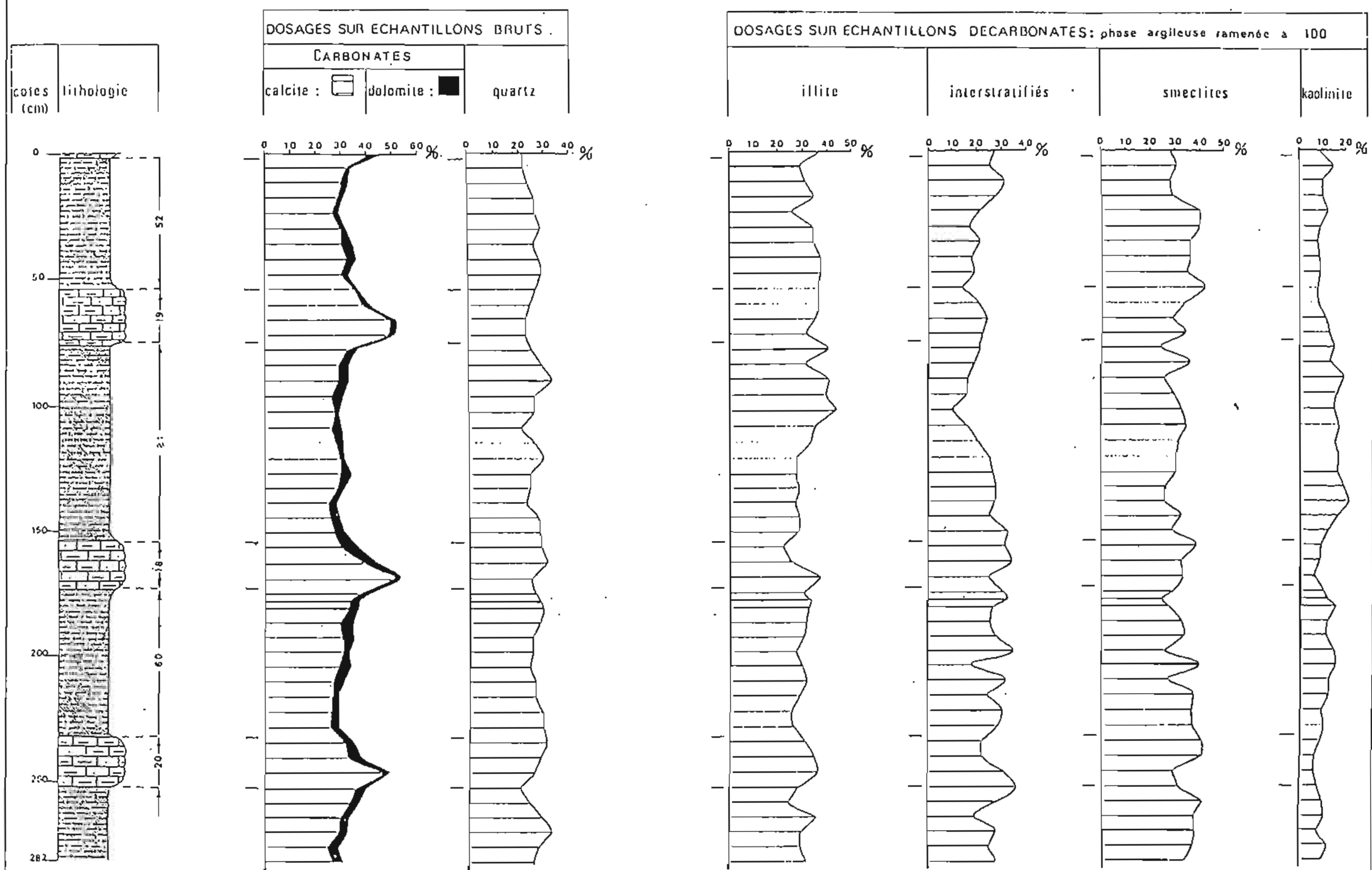
Observée par D. Noël (1968) dans le Crétacé inférieur, l'absence de nannoconus dans les interbancs marneux avait été attribuée au déclin temporaire du groupe consécutif à une importante arrivée de particules fines (argiles) dans le bassin de sédimentation. La turbidité de l'eau jouant le rôle de facteur bio-limitant sur les nannoconus.

Le facteur turbidité joue également un rôle primordial dans l'écologie des éponges. L'alternance marno-calcaire d'EYG.1 pourrait ainsi résulter d'une variation cyclique dans l'importance des apports de sédiments détritiques terrigènes fins qui se déversent dans le bassin. Il n'y aurait alors pas simplement dilution par ces apports de la production biogénique calcitique supposée constante mais un véritable effet bio-limitant sur certaines espèces sensibles, dont les nannoconus qui contribuent pour beaucoup à la phase calcitique.

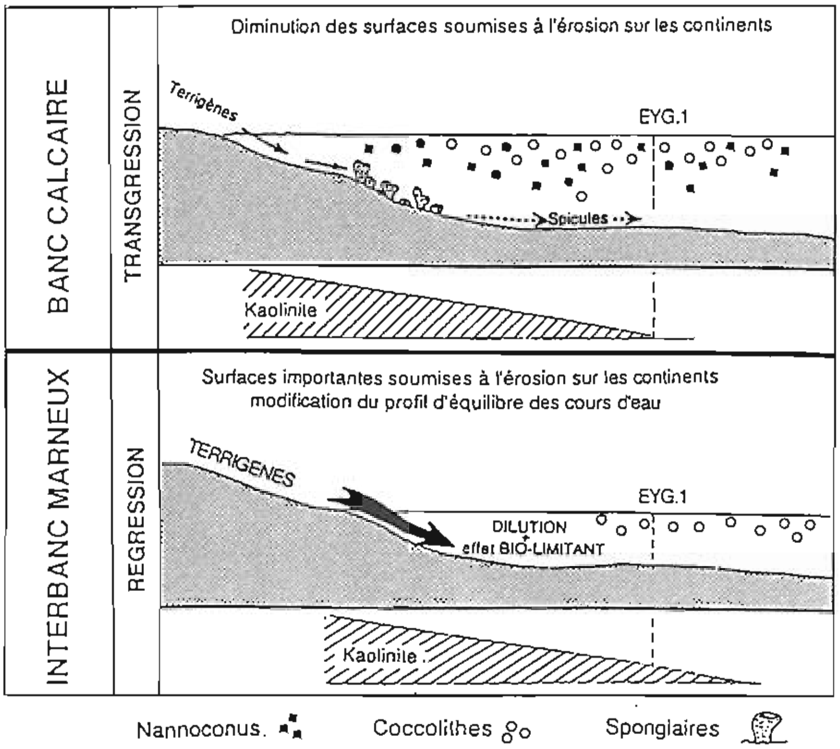
Dans la coupe EYG.1, la kaolinite est sensiblement plus abondante dans les interbancs marneux que dans les bancs calcaires (planche 1). La "grande" dimension de la kaolinite dans le domaine des minéraux argileux (elle atteint souvent 2 µm alors que les smectites varient le plus souvent de 0,1 à 1 µm) fait qu'elle sédimente préférentiellement en bordure des continents (Bausch et al., 1982). Son abondance dans les sédiments à EYG.1 pourrait traduire les variations cycliques de l'éloignement des zones d'apport des matériaux détritiques c'est-à-dire les traces de pulsations du rivage.

PLANCHE 1

LITHOLOGIE et LOGS MINERALOGIQUES d'EYG.1



C'est à ce mécanisme de transgression-régression que seraient associées les pulsions du détritisme. En se retirant, la mer rompt le profil d'équilibre des cours d'eau et découvre des terrains repis par l'érosion, entraînant une importante arrivée dans le bassin de matériaux détritiques terrigènes. A l'inverse, en recouvrant des terres émergées, la mer bloque en grande partie l'action érosive des cours d'eau et diminue la surface soumise à l'érosion.



REFERENCES

BAUSCH, W.M., FASTCHEL, J. & HOFMAN, D. (1982) - Observations on well-bedded Upper Jurassic Limestones. In : Einsele, G. & Seilacher, A. (Eds.), *Cyclic and event stratification*, Springer-Verlag, Berlin, p. 54-62.

NOEL, D. (1968) - Nature et genèse des alternances de marnes et de calcaires du Barrémien supérieur d'Angles (Fosse vocontienne, Basses-Alpes). *C.R. Acad. Sci. Paris*, (D), 266, p. 1223-1225.

Hydrodynamism and sediment distribution by Albian time in the Vocontian domain (S-E France)

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ABSTRACT. - Shelf-basin relationships considered for the Vocontian domain in Aptian-Albian, allow to detect an organization of the deposits that can be explained in a large measure by the evolution of hydrodynamism (controled by the relative sea level changes). Hydrodynamism is acting on transfers of material (erosion, winnowing, deposition) and on chemical exchanges (oxygen, iron, nutrients...) hence various consequences on environment, life, and early diagenesis.

The "Blue Marls", that are hemipelagic sediments of very monotonous aspect, nevertheless display several lithologic units whose facies are characteristic. The basinal succession is more or less continuous. On the shelf, facies are strongly contrasted, but the gaps are numerous and important, and the biostratigraphical data are scarce. In spite of the difficulties for establishing correlations and doing systems tracts analysis across the depositional system, some salient facts appear. The Albian is here choosen as an example. Two episodes may be compared.

The **lower to middle Albian** corresponds to a period of relative lowstand in sea level and of a subsequent rise. The outstanding features are the weakness of currents, the chronic restricted environment, and the deposition of marls with frequent organic-rich layers ("black shales") in the basin and their shelfal equivalents, as glauconite-rich layers, sometimes associated with phosphorites. The syngenetic occurence of some OM-rich layers and glauconite-rich ones may be illustrated by several examples. They appear to represent condensed intervals. In many cases, the only witnesses of such facies are phosphate nodules reworked in younger deposits. Redeposited beds are scarce and quite localized in the basin, particularly as a consequence of a penury in silicoclastic supply on the distal shelf, a domain that is rather favourable to early diagnesis.

The **late middle Albian to early upper Albian** corresponds to a period of relative highstand in sea level. On the shelf, the deposits record the action of a high hydrodynamism ; the detrital material and earlier deposits are swept by currents and reworked as subaqueous bedforms (dunes and sandwaves). Their genesis is attributed (Rubino & Delamette 1985, Delamette 1988) to the influence of an oceanic current : the Tethyan Current (Luyendyk 1972). Nevertheless, other influences are not likely to be discarded. We can still notice that in most cases, the units we can observe at the scale of the outcrop concern the preserved record of several weeks or months of deposition... Sporadic massive sand collapses in the distal part induce the formation of fluxoturbidites. Silty 'pollutions' affect basinal marls and a small wedge of contourite type (?) is formed in the central area. But wide zones are characterized by condensation, omission or erosion that are typical for the shelf edge and slope. The Upper Albian glauconite layer, especially well known in the eastern part of the basin (Cotillon 1971) represents this event. These facts may be ascribed to the direct activity of the oceanic current. On the other hand the souhern part of the basin (Sisteron area) is freely fed by silty-sandy material, and a shelf margin wedge is built.

It has to be noticed that the redeposited sediments are scarce in the basin (redeposited mud layers are only exceptionally evidenced) during the considered stratigraphic interval ; these are mostly fluxoturbidites that have no part in the build up of fan system tracts. Seaward lateral accretion processes (progradation) are quite unconspicuous except for the Sisteron area. Otherwise it can be under lined that, as shown for the late Middle Albian to early Upper Albian, a condensed section or omission surface may be coeval of a shelf margin wedge buildup. Therefore, it can be suggested that a better understanding of the system tracts needs to take into account the importance of material transfers parallel to the shore, and to be integrated in a three dimentional way.

Work partly supported by a French CNRS-INSU grant ("Dynamique et bilans de la Terre, Message sédimentaire")

Eustacy versus tectonics as controlling processes of the Cretaceous sedimentation in Tunisia

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ABSTRACT. - In Tunisia, during the Cretaceous, there was a general grading from the neritic, lagoonal, or continental facies of the Saharan Platform to the open marine and often deep sea environnements of the northern "Sillon tunisien". The main eustatic events correspond to the principal phases of the sedimentary evolution. Irregular subsidence, block tilting, salt mouvements (since the Aptian), and later compressional stress gave complicated patterns of thicknesses and facies in shorter sequences.

The end of the Jurassic corresponds to a relatively high sea level with the wide repartition of Sidi Khalif Shale, highly fossiliferous with Ammonites and Tintinnids (Tithonian to Berriasian).

Valanginian regressive phases are in relation to the transitional to shallow marine Meloussi Formation with northward progradation of the deltaic facies; interbedded sands and carbonates may be due to sea level oscillations or to irregular subsidence and compaction.

During the Hauterivian, a rise in sea level was the cause of the installation of a carbonate barrier (Douleb 101 Dolomite) trapping the fluvial Boudinar Sandstone in the internal zone.

Late Hauterivian and Early Barremian transgression in underlined by a shallow marine sedimentation on the whole Central Tunisia : carbonate and clay of the Bou Hedma Formation overlain by the Sidi Aich Sandstone.

The late Barremian to Early Bedoulian Lower Carbonate Member of the Orbata Formation (Berrani or Bou Labaa Dolomite) has a very wide extension on the Saharan Platform. A slight regressive tendancy associated with the beginning of salt mouvements corresponds to anomalies of facies and thickness, to more internal or restricted environnements, and to local gaps of the Aptian series. This regressive phase reaches its maximum during the Early Albian.

In the northern basins as the "Sillon Tunisien" or the Gulf of Hammamet the Early Cretaceous series are continuously marine ; however the events on the Southern platform supply material giving flysch facies, specially during the Valanginian, Barremian, and Aptian parts of the M'Cherga Formation.

During the Late Cretaceous the general pattern is the same as before, but coarse clastics are very rare after the Upper Albian transgression (Foum el Argoub, Chenini Sandstone). The internal platforms show restricted environments with evaporites. The external shelf is the site of bioclastic or oolithic accumulations and of reef building, mainly by rudistids.

The Central and Southern Tunisia was invaded by the Albian transgression with onlaps on the ramps around the Kasserine Island and the North-South Axis. The maximum of the invasion was completed at the end of the Cenomanian ; then an euxinic environnement gave the thinlaminated, organic-carbon-rich Bahloul Limestone.

Near the base of Santonian or the base of the Abiod Limestone (in the Early Campanian) tectonic mouvements were more active and they resulted in unconformities, gaps, slumps, and reworking.

From Mid-Campanian to Early Maastrichtian, chalky facies invaded the Atlasic and Eastern Tunisia. At this time also there was a very wide extension of the seas on the Saharan platform with connections between the Tethysian margin and Central African troughs.

Middle Triassic carbonate ramp systems in the Catalan Basin, N.E. Spain: facies, cycles, depositional sequences and controls

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ABSTRACT. - The Triassic of the Catalan Basin, eastern Spain, is "Germanic" in character, with Buntsandstein, Muschelkalk and Keuper units, succeeded by the Norian Imon Formation. Carbonate platforms developed in the Lower Muschelkalk (Anisian) and Upper Muschelkalk (Ladinian) and in the Imon. The Muschelkalk platform carbonates are separated by the Middle Muschelkalk evaporites and marls. These platforms were broadly of the carbonate ramp type, with the facies very persistent laterally in the older platform sequence, but much more varied in the younger platform. Small-scale shallowing-upward cycles of various types are a feature of many units in the both the Lower and Upper Muschelkalk. The Lower Muschelkalk has prominent paleokarst horizons and in the Upper Muschelkalk, mud mound-reef complexes are a feature of one stratigraphic domain. Many of the Muschelkalk carbonates are dolomitized, with several types of dolomite distinguishable.

The mid-Triassic strata of the Catalan Basin can be divided into two depositional sequences (fig. 1 and 2), and the systems tracts phylosophy can be applied. Depositional sequence-1 consists of the uppermost part of the Buntsandstein (a lowstand systems tract of lutites, carbonates and evaporites, stratigraphically equivalent to the Röt of the German and North Sea basins) and the Lower Muschelkalk. The latter can be divided into a transgressive systems tract (of onlapping shallowing-upward cycles) and a highstand systems tract of a broadly aggrading-regressive peritidal unit. Depositional sequence-2 consists of the Middle Muschelkalk (a lowstand systems tract of gypsum-anhydrite, marl and sandstone) and the Upper Muschelkalk. The latter can be divided into a transgressive systems tract of onlapping oolites, lagoonal facies, outer ramp cycles, mud mound-reef complexes and stromatolitic grainstone shoals, succeeded by highstand systems tract package of laminated "basinal" dolomicrites to peritidal dolomites. The two depositional sequences are third order cycles which can be interpreted largely in terms of crustal extension followed by regional subsidence. The carbonate platforms developed at times of tectonic quiescence in the Catalan Basin. The metre-scale shallowing-upward cycles may be the result of orbital forcing in the Milankovitch band (they are 4th and 5th order cycles).

This work was in part supported by the CICYT Project n° 0322.

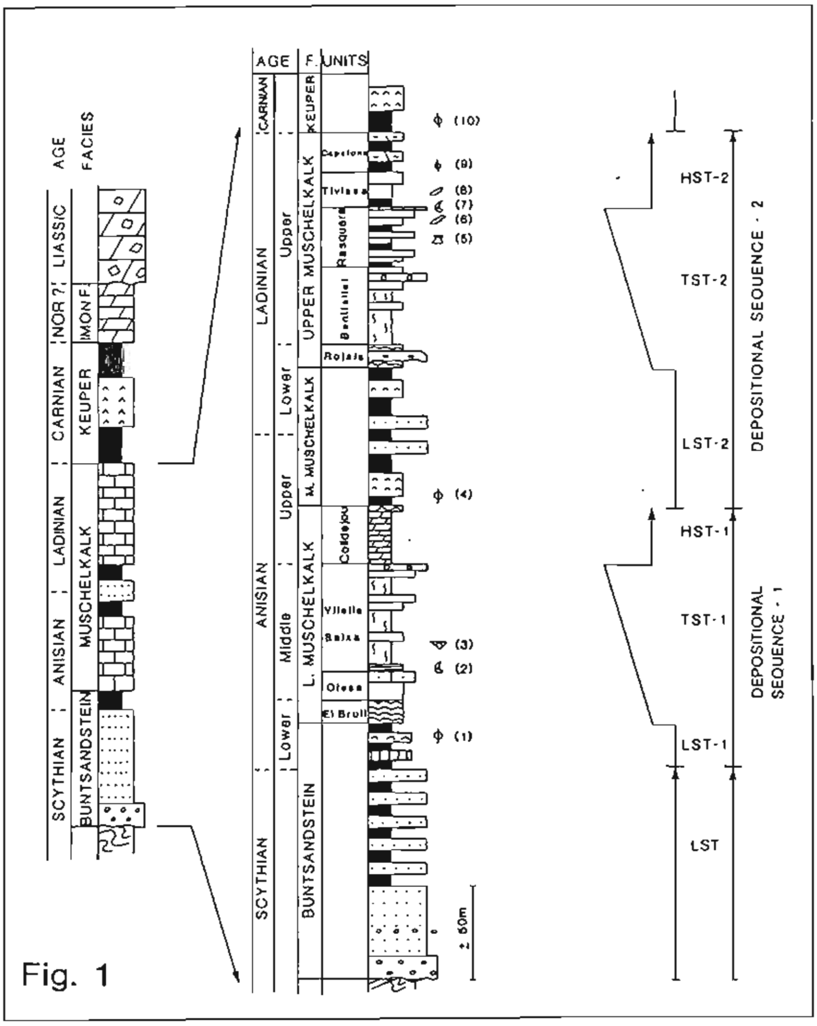
SCYTHIAN
ANISIAN
LADINIAN
CARNIAN
NOR ?
LIASSIC
AGE
BUNTSANDSTEIN
MUSCHELKALK
KEUPER
IMON F.
FACIES
Lower
Middle
Upper
L. MUSCHELKALK
M. MUSCHELKALK
UPPER MUSCHELKALK
F.
UNITS
El Brull
Olesa
Colldejou
Rojals
Rasquera
Tivissa
± 50m
LST
LST-1
TST-1
HST-1
LST-2
TST-2
HST-2
DEPOSITIONAL SEQUENCE - 1
DEPOSITIONAL SEQUENCE - 2

Fig. 1

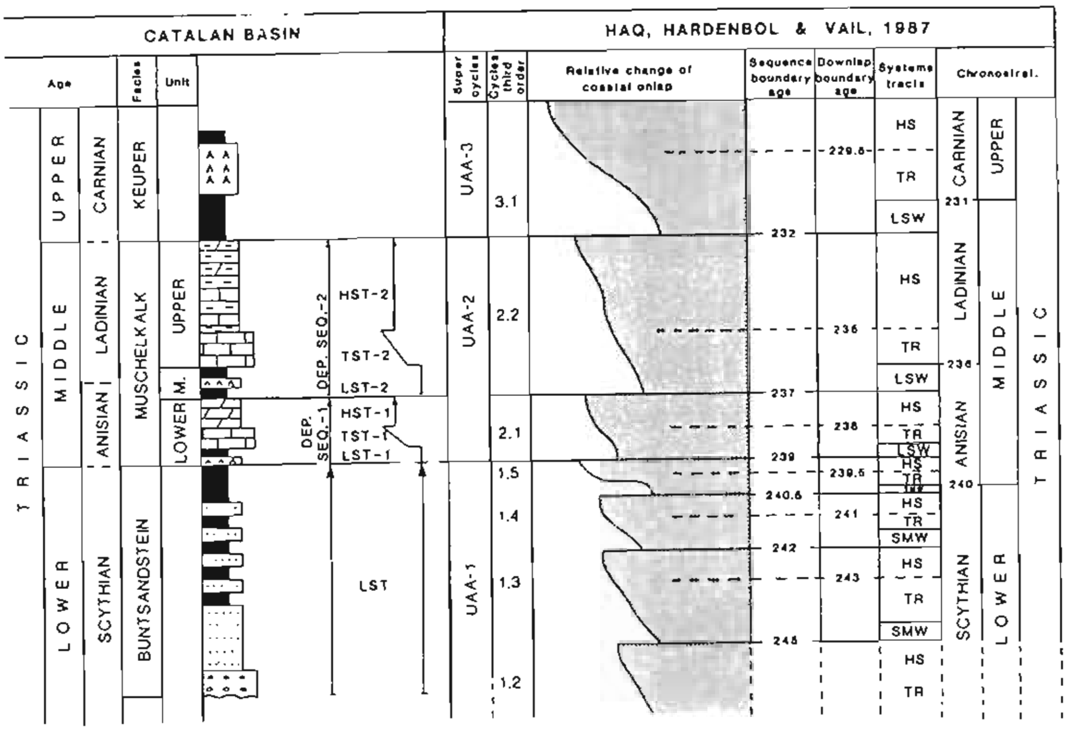
CATALAN BASIN
Age
Facies
Unit
T R I A S S I C
LOWER
MIDDLE
UPPER
SCYTHIAN
ANISIAN
LADINIAN
CARNIAN
BUNTSANDSTEIN
MUSCHELKALK
KEUPER
LOWER
M.
UPPER
DEP. SEQ.-1
DEP. SEQ.-2
LST
LST-1
TST-1
HST-1
LST-2
TST-2
HST-2
HAQ, HARDENBOL & VAIL, 1987
Super cycles
Cycles third order
Relative change of coastal onlap
Sequence boundary age
Downlap boundary age
Systems tracts
Chronostrat.
UAA-1
UAA-2
UAA-3
1.2
1.3
1.4
1.5
2.1
2.2
3.1
245
243
242
241
240.6
239.5
239
238
237
236
232
229.8
HS
TR
SMW
LSW
240
236
231

Fig. 2

Tectonique et eustatisme dans les gisements de bauxite de l'Ariège (Pyrénées, France)

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RESUME. - Du Barrémien à l'Albien moyen, les bauxites de l'Ariège appartiennent aux gradins de la marge européenne, limités par des failles synsédimentaires actives durant la phase de rifting. Les observations faites dans certains gisements montrent que cette situation structurale instable se traduit par le jeu d'accidents en distension ou en compression, des discordances et l'apparition de sédiments tectogènes. Toutefois, cette disposition ne perturbe pas la succession des oscillations eustatiques qui ont contrôlé la formation des bauxites.

I - La tectonique synsédimentaire intra-bauxitique

Les mouvements tectoniques intra-bauxitiques sont particulièrement visibles dans 3 gisements :

1 - Le gisement de la Combe-de-Lé - Des failles normales E-W dans le mur kimméridgien ont été réactivées en failles inverses avec vergence nord durant l'Albien inférieur-moyen, provoquant la discordance de la bauxite moyenne sur la bauxite inférieure et les calcaires à Simplorbitolines inférieurs. La réapparition de ces mouvements à la limite Albien moyen/supérieur explique la discordance des brèches de Marillac (Albien supérieur) sur l'ensemble du gisement.

2 - Le gisement de Bacqué - Présente au mur kimméridgien des failles normales anté-bauxite N110-130° E qui ont ensuite rejoué, durant l'Albien inférieur-moyen, en failles inverses à vergence nord ou sud.

3 - Le gisement de Couchet - Des failles normales, analogues aux précédentes, ont rejoué durant l'Albien inférieur-moyen provoquant : (1) l'apport de blocs du mur kimméridgien incorporés dans la bauxite ; (2) le chevauchement local du mur sur la bauxite.

Les failles normales mises en évidence font partie du réseau d'accidents qui limitaient les gradins de la marge passive européenne. Leur rejeu en compression à l'Albien inférieur-moyen et à la limite Albien moyen-supérieur pourrait annoncer le régime en transpression généralisé de l'Albien supérieur entre les marges européenne et ibérique du domaine Pyrénéen.

II - Contrôle eustatique de la bauxitogenèse

1 - La séquence bauxitique - La bauxitisation apparaît au cours d'une oscillation marine affectant la plate-forme interne.

<u>Transgression :</u> (Haut niveau, dépôt du cortège transgressif)	Argiles ligniteuses et lignites, calcaire urgonien, marnes ou argilites kaolinitques (roche mère de la bauxite). Remplissage des vallées.
<u>Régression :</u> (Bas niveau)	Emersion, bauxitisation des marnes ou argilites kaoliniques, karstification et érosion. Creusement des vallées.

En bordure de la plate-forme le cortège trasnsgressif correspondrait à l'Intervalle Transgressif marneux avec rétrogradation du faciès urgonien et au Prisme de Haut Niveau marneux avec progradation du faciès urgonien. La régression permettrait la mise en place d'un Prisme de Bordure de Plate-forme marneux avec progradation du faciès urgonien.

2 - Superposition de séquences, comparaison avec la courbe eustatique - Dans les gisements étudiés, une dizaine de séquences, plus ou moins complètes selon la localisation sur la plate-forme, peuvent être superposées. Les datations (Foraminifères, malacofaune, pollen et spores) des niveaux calcaires et argileux permettent un bon calage chronostratigraphique. La comparaison avec la courbe eustatique de Haq et al. (1987) montre une bonne correspondance entre les cycles de 3ème ordre et les séquences bauxitiques. Les mouvements tectoniques mis en évidence ne modifient pas l'enregistrement des oscillations sur les gradins les plus internes où toutes les fluctuations eustatiques s'expriment par des horizons bauxitiques plus ou moins évolués.

Eustacy record off Tethyan margins: a new approach through the study of carbonate flux variations in the Tithonian-Aptian section at DSDP Site 534 (Central Atlantic)

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ABSTRACT. - Oceanic environment is more suitable to record messages driven by fluxes of material than do continental margins. Terrigeneous flux is partly controlled by the degree of land-masses drowning by marine fluctuations. The messages of carbonate flux are issued both from margins (for instance through development of carbonate platform systems) and from oceans, through planktonic productivity. The latter depends on climate (temperature and salinity of surface water) related to some extend to eustacy. Consequently, the quest in oceanic realm of eustatic signals seems as promising as on continental margins.

At DSDP site 534 (Central Atlantic) the cored Tithonian-Aptian interval is marked by a decimetric cyclic pattern of deposits where light-colored bioturbated limestones alternate with dark laminated marls (Gradstein & Sheridan 1983). Climatic origin of these alternations is likely (Cotillon & Rio 1984). Accurate biostratigraphy of Early Cretaceous at Site 534 is based on correlations, through cycles, between SE France and Central Atlantic (Cotillon & Rio 1984).

Image processing of black and white core photographs, and correlation between color and Ca CO3

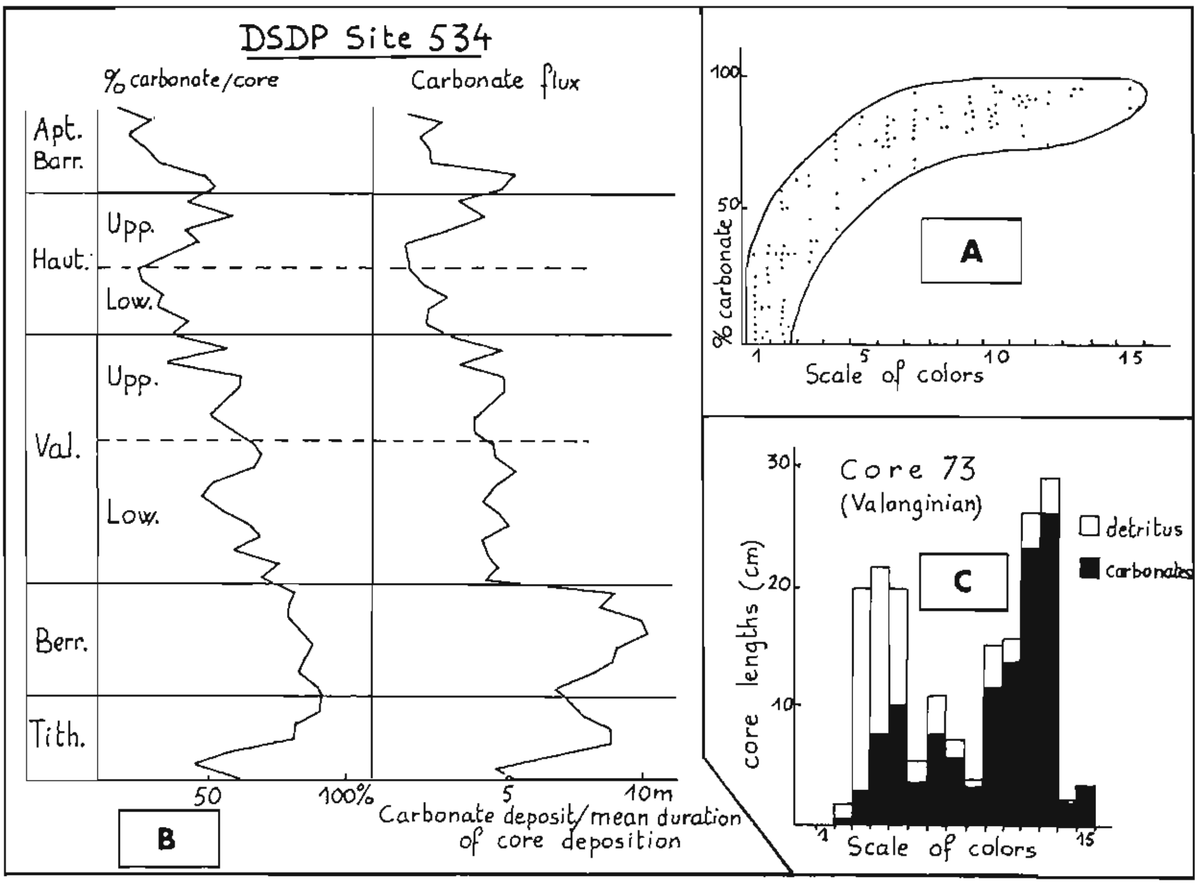

Fig. 1 - Carbonate flux variation through the Tithonian-Aptian interval at DSDP site 534.
A - Relation between carbonate percent and color of sediment.
B - Variations of average carbonate percent per core and of carbonate flux.
C - Fluxes variations within core 73.

content of deposits (fig. 1A) allow to draw a curve of average percents of carbonate in cores, then a curve of carbonate flux variations after correcting values in proportion to sedimentation rate changes from core to core (Cotillon 1985) [fig. 1B]. A weak carbonate dissolution rate or, at least a weak variation of it, is also assumed during the studied interval marked by a great stability of the CCD (Sheridan & Gradstein 1983). The pattern of curves matches the major trends of Tethyan sedimentation from the Tithonian to the Aptian.

The proportions of different colors and of associated carbonates can be precised within each core (fig. 1C). Histograms illustrate a mean calcimetric evolution between two opposite lithologies integrating, for a core, basic variations within component marl-limestone couplets. Through cores representing equal time intervals (correction in proportion to sedimentation rate variations), calcimetric evolutions are those of a mean carbonate flux. In the 51 cores forming Tithonian-Aptian interval, the carbonate flux is composed of several waves expected to be issued from different sources.

Carbonate distribution in the color spectrum of cores may be defined by classical indexes: median, sorting and skewness. Sorting index depends on both the amplitude and the regularity of carbonate flux variation. High indexes characterize broad and polymodal histograms indicating ample and irregular flux variations. Sorting index and number of decimetric marl-limestones cycles per core are positively correlated (r = 0,32 for 50 couples of values) ; then the longer the length of flux variation, the higher is the sorting index. The latter, corrected in proportion to sedimentation rate variations, becomes a speed of carbonate flux variation (SCFV index) [fig. 2B].

It is assumed that a high SCFV index corresponds to a great receptivity of pelagic environment with respect to external forcings such as climate, eustacy, tectonics etc... This condition could be related to low stand marine level periods, when oceanic realm is the closest to emerged continental areas. Conversely, during high stand levels, pelagic environment separated from land-masses by drowned margins acting as buffers, would record damped signals expressed by weaker SCFV indexes.

This interpretation is supported by some significant correlations between the SCFV index and, respectively, the rate of sedimentation (positive correla-

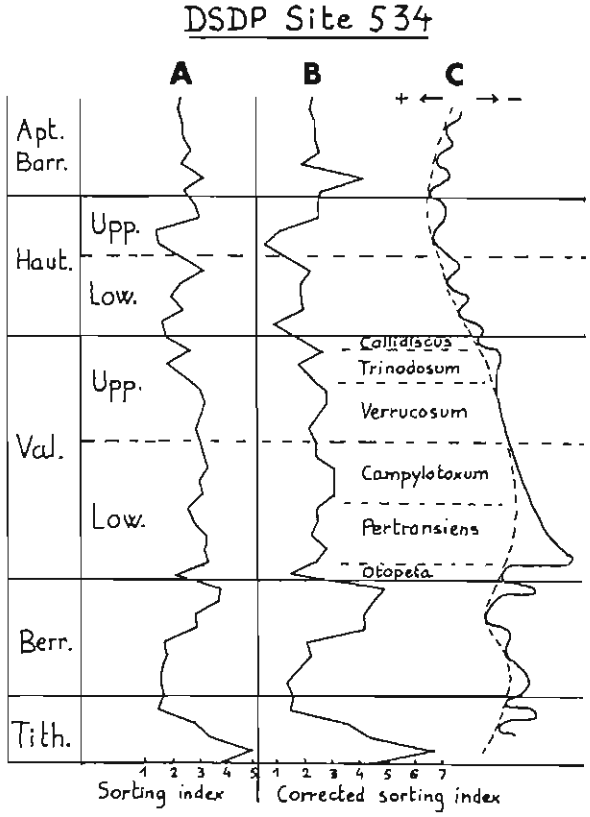

Fig. 2 - An approach for expressing eustatic signal in deep-water deposits.

A - Variation of the sorting index of carbonate distribution in cores.

B - SCFV index curve (Speed of Carbonate Flux Variation) assumed to illustrate sea level fluctuations.

C - Sea level chart of Haq et al. (1987).

tion), the organic carbon content of marly interbeds and the Strontium content of the same layers (negative correlations) [Summerhayes 1981, Arthur et al. 1988, Renard 1987].

On the other hand, the SCFV index is positively correlated with carbonate flux and negatively with amounts of primary clay minerals and with the number of redeposited layers in cores. The following interpretation is deduced : low stand marine levels would coincide with a prevailing carbonate sedimentation on oceanic bottom, with smectite-rich clay mineral associations and with a lowering of redeposition.

A first comparison between SCFV index curve and eustatic curves of Haq et al. (1987) evidences major disparities for two intervals: Tithonian-lower Berriasian and Aptian (fig. 2).

This research of eustatic signal in deep environments is just starting and still tentative. The SCFV index curve must be found again in other sites, with the same main characters, before becoming a reliable tool. Its signification has to be supported by geochemical data mor systematic and numerous than yielded by DSDP routine analysis. Biological data are also required. SCFV index curves drawn and compared at various oceanic sites, confronted with eustatic and coastal onlap ones may help to a better display of eustacy participation to marine oscillations.

REFERENCES

COTILLON P. (1985) - *Bull. Soc. Géol. Fr.*, 8, I, &, p. 59-68.
COTILLON P. & RIO M. (1984) - *Init. Rpts. DSDP*, v. 77.
GRADSTEIN F.M. & SHERIDAN R.E. (1983) - *Init. Rpts. DSDP*, v.76.
HAQ B.U. et al. (1987) - *Science*, 235, p.1156-1167.
RENARD M. (1987) - *Mém. Géol. Univ. Dijon*, 11, p.125-142.
SUMMERHAYES C.P. (1981) - *A.A.P.G. Bull.*, 65, 11, p.2364-2380.

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The Cenomanian-Turonian oceanic anoxic event (CTOAE) on the northwestern Tethyan margin

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ABSTRACT - Sedimentary and biological crises have been pointed out around the Cenomanian-Turonian boundary in many epicontinental basins and on the margins of the Atlantic, Tethyan or Pacific oceans. This period is usually marked by a major discontinuity, a sedimentary break or a low sedimentation rate. It has been regionally recorded in several successive laminated layers rich in marine organic matter: the black shale horizons (BSH) of the CTOAE. Our purpose today is to settle the successive steps of the sedimentation and the main oceanographic perturbations recorded around this event, in two distinct areas (fig. 1) of the European Tethyan margin : the Pyrenean-Provençal trough which was in connection with the northern Atlantic Ocean, and the Vocontian basin which represented the western end of the Alpine sea in connection with the Tethys.

In the central and eastern parts of this basin (fig. 1), the Cenomanian-Turonian boundary (Archaeocretacea zone) is evidenced by several BSH forming a regional stratigraphic level of a few meters thick: the **Thomel level** (fig. 2). Above a sedimentary break, the decimetric BSHs (about 2 % of Total Organic Carbon) usually alternate with bioturbated, organic-matter-poor marly layers (about 0.5 TOC %). Such cyclic fluctuations, already observed in the Atlantic Ocean, have been considered as a consequence of variations in the sedimentary inputs (organic, as well as carbonates or terrigeneous) together with changes of the redox conditions in the deeper part of the water column. They mainly consist here in a periodic decrease in the benthonic activity into the sediment and in a better preservation of the well-hydrogenated and amorpheous organic-matter from oxidation. During the deposition of the BSH, the carbonated planctonic microfauna is also rarefying : only keeps living some thiny and globular morphotypes of surface-dwelling foraminifera, while the large and keeled morphotypes disappear. This selective preservation of the smaller forms allows to set aside the hypothesis of a drastic carbonate dissolution during the post-mortem test drop. According to numerous authors, the worldwide disappearance of the genus *Rotalipora*, was the result of a rising oxygen minimum zone (OMZ) arresting the process of gametogenesis in the deeper water planctonic foraminiferid. The abrupt extinction of the last species : *R. cushmani* (Morrow) is evidenced just above the sedimentary break, at the basis of the first BSH of the Thomel level (fig. 2). In the deeper and central parts of the eastern basin where this level consists of an alternation of bioturbated layers and BSHs, the OMZ reached only periodically the basin floor. This rhythmicity is not observed on the northern and southern margins of the basin, where the anoxic conditions prevailed permanently. These rythmic variations in the redox conditions were mainly controlled by fluctuations in the thickness of the OMZ, while the spatial distribution of these BSHs delineated the paleogeographic and structural features of the basin (fig. 1).

Litho- and biostratigraphic correlations have been established between this basin and shallower areas of the Provençal domain unaffected by anoxia (fig. 2). Several episodes in the sedimentary record are distinguished :

1 - During the Cushmani zone, subpelagic to hemipelagic sediments were deposited in the Vocontian basin and on the slope of the southern Provençal trough, while the shallow-water rudist-bearing carbonate facies developped on the platform (unit A). A first sedimentary break (unit B) occurs in the both domains at the top of this zone.

2 - Above this hiatus, the Archaeocretacea zone may be subdivided as follows:
- the basis corresponds to the abrupt extinction of *R. cushmani* and to the deposition of the BSHs (unit C) in the Vocontian basin only ;
- when the sedimentation renews everywhere, it is represented by mainly bioclastic deposits, small rudist banks on the southern platform, calcispher-rich hemipelagic limestones on its southern flank, and an alternation of marls and subpelagic limestones, with silty turbidites at the top of beds (unit D) in the northern Vocontian Trough;
- a new sedimentary break occurs, expressed in the Provençal domain by a hard-ground of regional extent on the platform and a soft-ground on the slope ;

- the upper part of the zone is recorded in the basin by the deposition of the last four BSHs of the Thomel level (unit F), while the omission continues in the Provençal area.

3 - The Helvetica zone corresponds to the deposition of a subpelagic carbonate series in the Vocontian basin, of marls and slumps on the slope, and of glauconitic and marly hemipelagic limestones on the whole Provençal platform (unit G).

In summary, two main periods of BSH deposition in the deeper part of the basin are expressed by two major discontinuities in the shallower areas. The first marks a backward shift of rudistid reefal patches as a result of a first step in the fini-Cenomanian sea level rise (top of the Cushmani zone). The second one marks the complete drowning of the Provençal platform (during the Archaeocretacea zone).

According to numerous authors, a global eustatic control - evidenced here as two transgressive pulsations - should be at the origin of the initiation of the OMZ. These oceanographic modifications may have improved both the circulation of the epireic water-masses, the flowing of high-salinity and dense waters in the deep areas, a reduction of vertical exchanges, and then the initiation of a deep and fluctuating OMZ.

The world-wide CTOAE began here during the late Cenomanian (top of the Cushmani zone) and ended in the early Turonian (basis of Helvetica and Nodosoides zones) when the global sea level reached its highest Mesozoic stand, at the end of the third order eustatic cycle UZA 2.5.

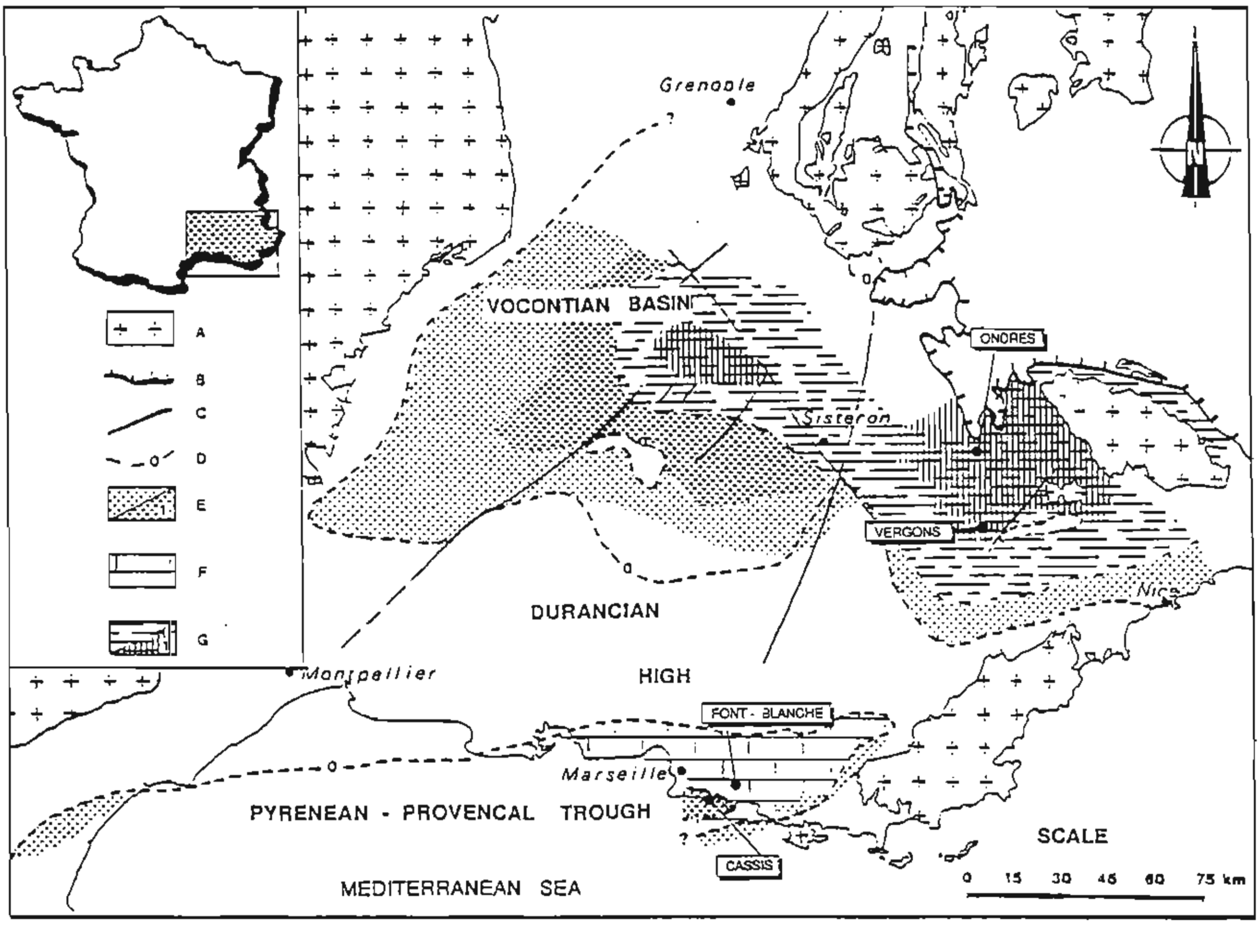

Fig. 1 - The Vocontian basin and the Pyrenean-Provençal trough. Facies map of Cenomanian deposits (after Philip et al. 1984). (A) : basement ; (B) : Pennic thrust front ; (C) : Cretaceous faults ; (D): isopach 0 meter ; (E) : channelized sands, sanstones and sandy-bioclastic limestones with shallow-water fauna (E1) : sandy-glauconitic facies ; (F) : rudist-bearing limestones of the southern Provençal platform ; (G) : marls and marly limestones with ammonites and planktonic foraminifera ; (G1) : black shales (Thomel level).

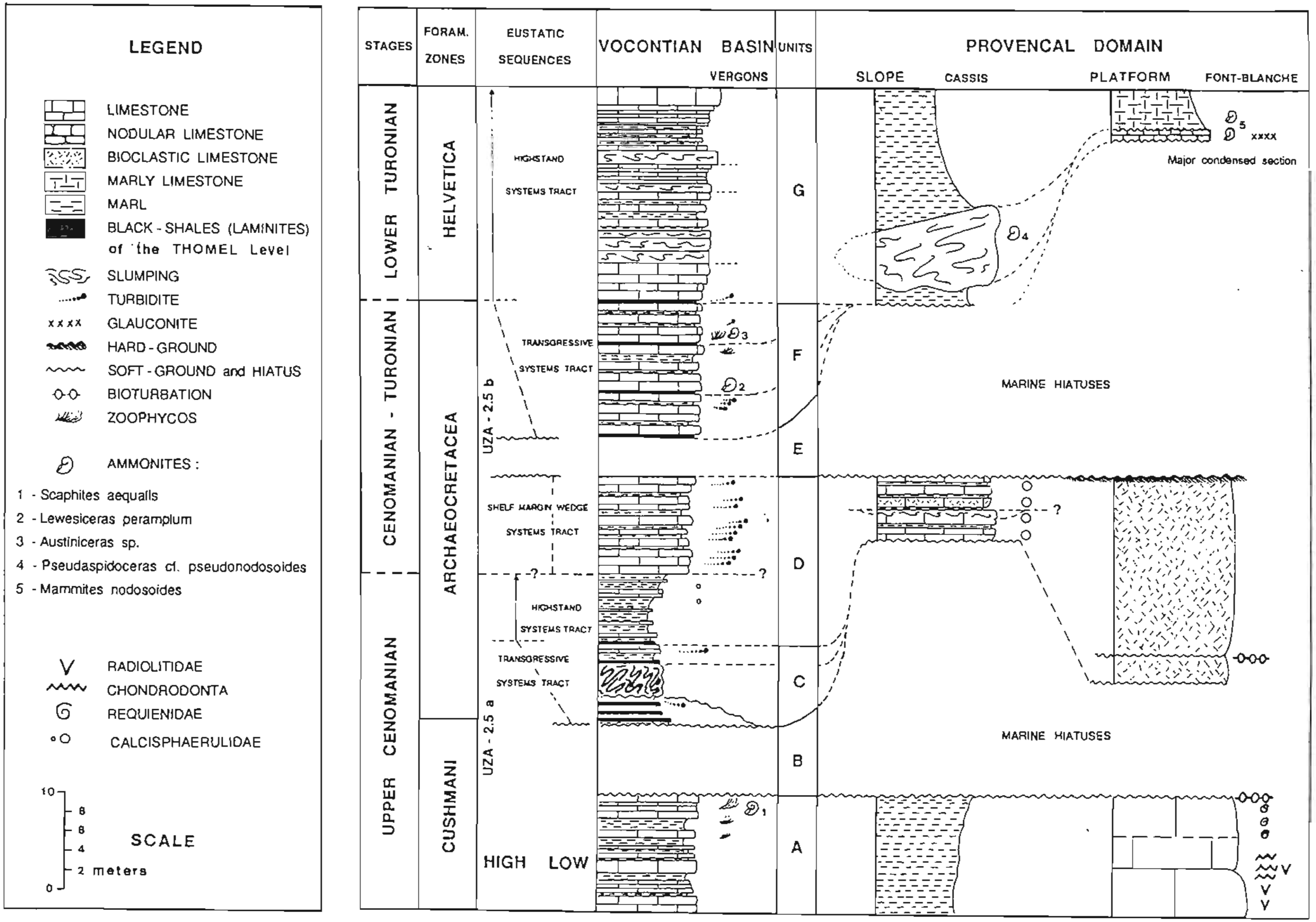

Fig. 2 - Litho- and biostratigraphic correlations between the Provençal domain and the Vocontian basin at the Cenomanian-Turonian boundary, and interpretation in terms of systems tracts.

Clays minerals as a tool in recording eustatic fluctuations Example of Cretaceous to Eocene pelagic sediments from the Umbria-Marche basin (Italy)

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ABSTRACT. - Clay mineral assemblages of Albian to Eocene pelagic carbonate sediments deposited in the Umbria-Marche basin have been studied in four well-known sections already described from litho- bio- and magneto-stratigraphy. A good calibration in comparison with eustatic curves of Haq et al. (1987) is therefore available. The sections are located near Gubbio and Furlo : "Bottaccione" just to the North of Gubbio, "Furlo Upper Road", "Furlo Flaminia" and "Furlo Pietralata" near Furlo.

From Albian to Eocene, three formations can be distinguished :

- the "Marne a fucoidi" (Aptian/Albian) are mainly composed of black organic carbon-rich and light-green or red shales and marlstones. The clay mineral assemblages are mainly composed of illite, chlorite, random illite/smectite mixed-layers and smectite. From the base to the top of the formation the proportion of smectite increases at the expense of the other clay species ;
- the Scaglia Bianca (Cenomanien/Lower Turonian p.p.) is composed of white and greenish-grey well-bedded micritic limestones. The clay mineral assemblages are largely dominated by smectite (80-95 %) associated with illite and random illite-smectite mixed-layers ;
- the Scaglia Rossa (Turonian p.p. to Eocene) is represented by pink to red micritic and marly limestones. Smectite is still the more abundant clay species, but in comparison with the underlying Scaglia Bianca, the illite amount increases. In addition, small amounts of chlorite and kaolinite appear sporadically in Turonian to Campanian sediments and become ubiquitous from the Ventricosa zone (Campanian) upwards.

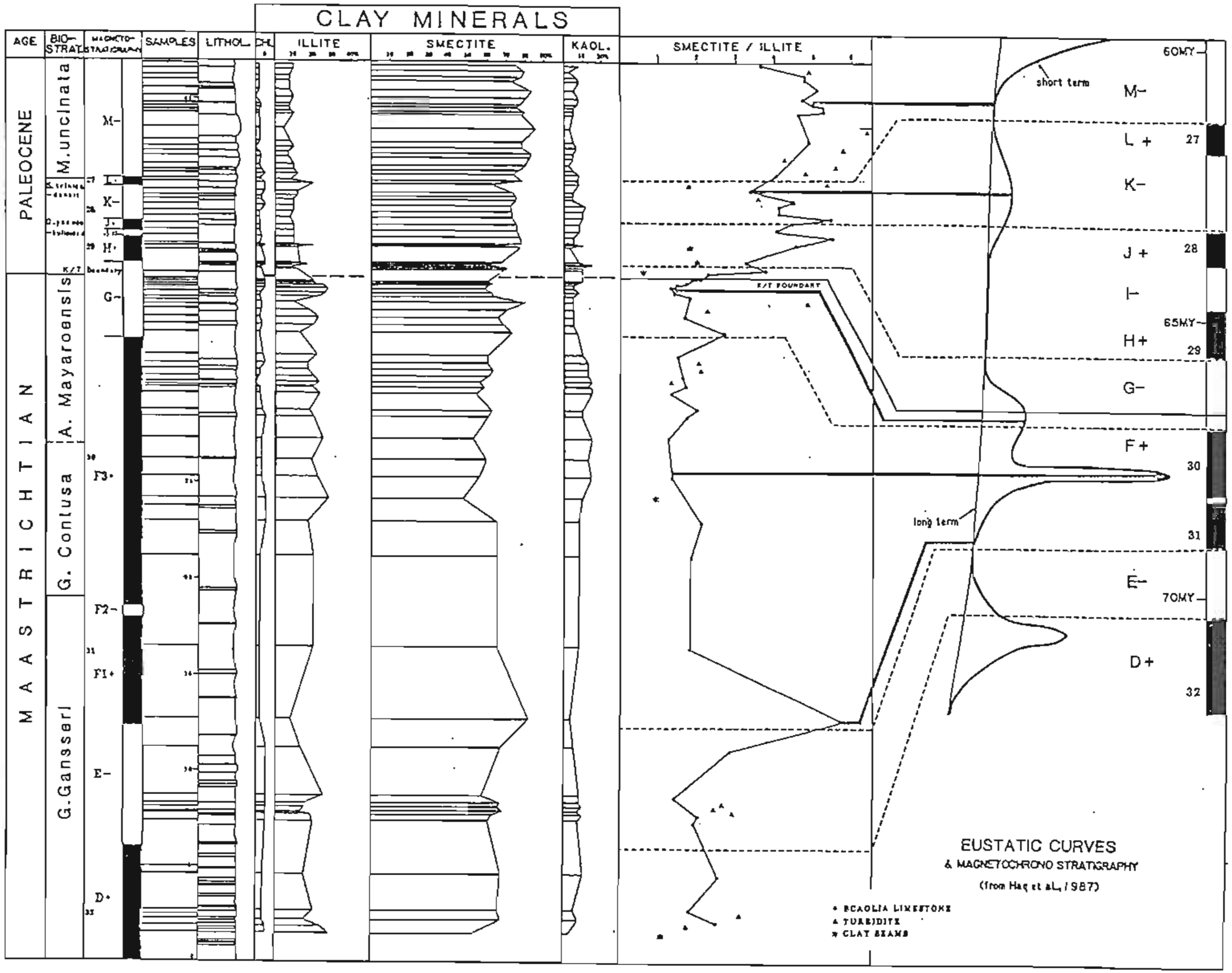
We focused on the relative variations in the percentages of smectite and illite in the clay fraction of pelagic limestones. These variations can be easily expressed by the smectite/illite ratio (Sm/I) which is measured on X-ray traces after glycolation. Sm/I corresponds to the ratio between the height of the 17-18 Å peak of smectite and the height of the 10 Å peak of illite after glycolation.

Relationship between clay mineral assemblages and long-term eustatic fluctuations

The long-term eustatic curve is compared with the evolution of Sm/I from Albian to Eocene sediments of the Bottaccione section. A rough correspondence occurs between the long-term eustatic curve and average values of Sm/I. Relative lowstands of sea level (e.g. Albian) are characterized by clay mineral assemblages rather rich in illite and/or chlorite and kaolinite, whereas highstands of sea level (e.g. Cenomanian) present a clay sedimentation dominated by smectitic minerals. As long-term eustatic fluctuations are namely due to variations in the activity of oceanic ridges, this may suggest that the more smectitic clay sedimentation during highstand of sea-level periods could partly result from volcanic derived-smectite. Alternativaly, as illite, chlorite and kaolinite settled in proximal areas in comparison with detrital smectites, periods of rising sea level resulting in increasing distance from emergent source areas lead to a more smectite-rich sedimentation.

Relationship between clay mineral assemblages and short-term eustatic fluctuations

On the sections studied in the region of Furlo, a very dense sampling of Campanian to Paleocene sediments allows the comparison between Sm/I and short-term eustatic cycles. On the three studied sections which are partly synchronous, a good correspondence appears between Sm/I and transgression/regression cycles. Transgressions are characterized by highest average values of Sm/I than regressions (fig.). This relationship could be due to differential settling processes of clay minerals leading to the preferential deposition of illite, chlorite and kaolinite in proximal areas, and to the transport of smectites in more distal areas. From this example it appears that eustatic cycles can be indirectly recorded by clay assemblages of pelagic sediments.



Example of correspondence between eustatic curves and Sm/I on the Pietralata section (Furlo).

Deep-water microbial biostromes, depositional sequences, and sea-level fluctuations: the Upper Jurassic of the western Subalpine margin (S-E France)

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ABSTRACT. - A number of microbially-generated carbonate deposits have been recognized through the Jurassic of the Tethyan margins. The deep-marine constructs (below the fair-weather wave base) include thrombolite bioherms, sponge bioherms, mud-mounds and stromatolite-bearing biostromes (Dromart and others, in press). On this paper there is specifical concern with the microbial biostromes and their occurrence within depositional sequences which compose the Upper Jurassic of the western Subalpine basin.

The microbial biostromes consists of fine-grained carbonates in form of oncolites plus stromatolite knobs and columns. Microbial crusts required hard substrates (pebbles, ammonite shells) for growth, and in turn are indirect evidence of rapid lithification on depositional floors. Internal lamination of microbial elements reflects rhythmic accretion, in association with a low sedimentation regime. These microbial forms cause the rubbly/nodular-like appearance of the deposits that closely resemble Ammonitico-Rosso lithofacies. In summary, microbial deposits reflect condensed horizons.

The microbial biostromes developed below a shelf-edge, in epibathyal-slope environments. They formed upon narrow, gently-dipping terraces, at depths of a few hundred meters (Dromart, 1989)

Such microbial limestones recur throughout the Upper Jurassic of the western Subalpine Basin (Ardèche area). The host-series is made up of thin- to thick interbedded shales and fine-grained carbonates which were deposited in a fore-shelf/slope setting. The calcareous material consists of a mixture of planktonic tests together with platform-sourced products (Dromart, 1989). The Upper Jurassic of the area is about 300 m thick, and reliable age assignments are based on ammonite biostratigraphy (Elmi, 1967; Atrops, 1982 and 1984 ; Cecca, 1986 ; Dromart, 1986).

Of particular importance here is the position of the condensed horizons, in the form of microbial limestones, within depositional sequences and the subsequent effect it has on sequence interpretation in terms of systems tracts and sea-level fluctuations.

The basic ideal lithologic succession recognized throughout the interval - Mid-Oxfordian-Mid-Tithonian - is shown in figure 1 together with interpretation of the deposits in terms of systems tracts according to the new concepts of sequence stratigraphy.

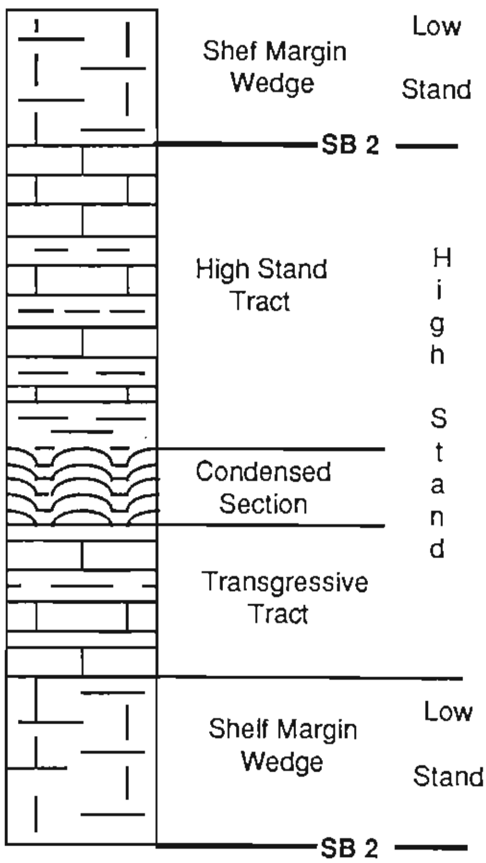

Fig. 1 - Ideal sequence of the Upper Jurassic in the western Subalpine Basin, and interpretation in terms of systems tracts and sea-level fluctuations.

The microbial limestones are assumed to make up the Condensed Section. Sequence boundaries are of type 2 because no erosional surfaces has been evidenced and no lowstand wedge (LSW) developed in the adjacent basin. The massive carbonates are believed to compose a shelf margin wedge (SMW) and to mark the sea-level low stand because 1) these deposits pinch out towards the basin ; 2) they may be enriched in coarse platform-derived debris (uppermost Kimmeridgian), relative to under- and overlying carbonates ; and 3) they are time-equivalent of coral-reefs (late Mid-Oxfordian, latest Oxfordian, and latest Kimmeridgian) which were successively restricted to the shelf edges of the adjacent Jura carbonate shelf (Enay and others, 1988: Bernier, 1984). It should be stressed that the type-2 SB defined here does not correlate with Klüpfel sequence boundaries which would appear above the massive carbonates.

On the basis of such interpretations, the diagram of systems tracts for the Upper Jurassic of the Ardèche area has been compiled in figure 2. It should be mentioned that a type-1 SB is thought to occur in Tithonian carbonates because of an extensive development of limestone breccias together with significant evidence of major erosion.

Comparison with diagrams released by Haq and others (1987) dicloses minor discrepancies for the interval - Oxfordian-E.Kimmeridgian - (? matter of time-calibration) that pass into substantial ones for the interval - L.Kimmeridgian-Tithonian -. In contrast, the succession proposed here is perfectly consistent with the sea-level curve presented by Hallam (1989) even though original method and data are quite different.

Jurassic microbial biostromes intercalated with outermost-shelf/slope fine-grained deposits (i.e. "Ammonitico Rosso", "Calcaires grumeleux" lithofacies) appear to be reliable markers of transgression maxima (Condensed sections). Of specific interest is the possible accurate calibration through times of the sea-level rises because these deposits usually are rich in ammonites.

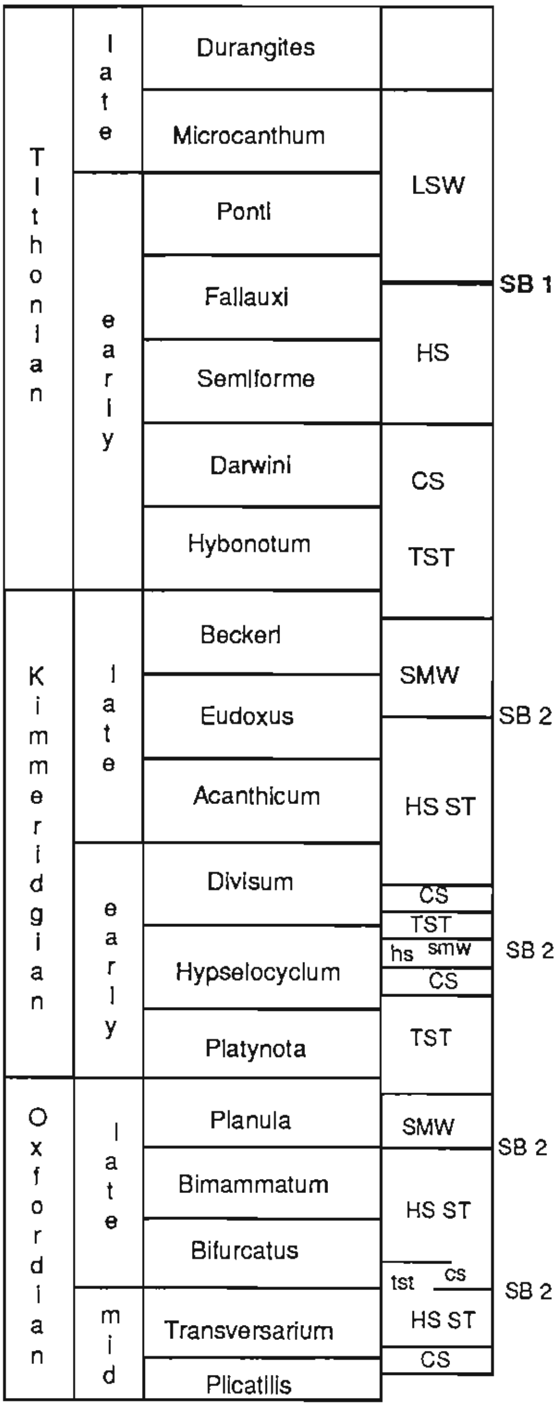

Fig. 2 - Calibration of systems tracts and sequence boundaries for the Jupper Jurassic of the western Subalpine Basin.

REFERENCES

ATROPS, F. (1982) - *Doc. Lab. Géol. Lyon*, 83, 463 p.
ATROPS, F. (1984) - In Synth. géol. S-E France, *Mém. B.R.G.M.*, 125, p. 244-249.
BERNIER, P. (1984) - *Doc. Lab. Géol. Lyon*, 92, 730p.
CECCA, F. (1986) - Unpub. Thesis, Lyon I.
DROMART, G. (1986) - Unpub. Thesis, Lyon I.
DROMART, G. (1989) - *Palaeogeogr., Palaeoclim., Palaeoecol.*, 69, p. 23-43.
DROMART, G., GAILLARD, C. & JANSA, L. (in press) - In Phanerozoic Stromatolites II (C. MONTY, ed.). Springer Verlag.
ELMI, S. (1967) - *Doc. Lab. Géol. Lyon*, 19, 507 p.
ENAY, R., CONTINI, D. & BOULLIER, A. (1988) - *Eclog. geol. Helv.*, 81, 2, p. 295-363.
HAQ, B.U. et al. (1987) - *Science*, 235, p. 1156-1167.
HALLAM, A. (1988) - In *SEPM Spec. Publ.*, 42, p. 261-273.

Eustacy and rift tectonics: the western Alps and south-east basin of France across the Triassic-Liassic boundary

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ABSTRACT. - The sedimentary sequences of Late Triassic-Early Liassic age in SE France and the Western Alps have several lithologic boundaries which can be traced over a major part of this area. The detailed study and correlation of more than 35 sections along several profiles in various directions lead us to interpret some of these lithological boundaries as sequence boundaries (sensu Haq et al. 1987). Some additional data show the (at least local) overprint of synsedimentary tectonics, so that this area is likely to have experienced a competition between global eustacy and more or less local rift tectonics around the T/J boundary, which gave birth to the following sedimentary sequences :

Lower sequence : it is transgressive upon various very shallow to emersive platform carbonates and terrigenous deposits of Norian age. It gave only Rhaetian fossils, such as the foraminifera *Triasina hantkeni*. In the eastern area (internal and external zones of the Western Alps ; part of Provence), this sequence is made of shallow marine clayey limestones and marls, grading upward into tidal carbonates. Its thickness increases eastward while facies becomes more openly marine. In the Western area (western edge of the South-East Basin), the sequence is reduced in thickness and affected by continental terrigenous influx. This sequence is missing upon part of the Dauphiné domain, which corresponds to an area affected by some short-lived early-rift volcanism in the Latest Triassic. Tectonic disturbances are minor on the studied area (most of the crustal extension occurs farther in the East, i.e. Lugano graben in the Southern Alps). The shallowing upward organisation of the sequence and its widespread distribution appear to be a response to a relative sea-level rise. Since a very similar sequence of the same age has been drilled on the northwestern passive margin of Australia (ODP leg 122, see fig. 1), this relative rise is better explained by a global sea-level change than by some local tectonic subsidence.

Upper sequence : the deposits of this sequence which is dated early to late Hettangian, overstep the maximum areal extension of the lower one and show stronger marine influences. The basal boundary does not show a very sharp sedimentary break, and may correspond to a "type 2" sequence boundary sensu Haq et al. (1987). The lowstand facies, of early Hettangian age, still have some geographic homogeneity, whereas the highstand facies (middle to upper Hettangian) are highly differentiated across the studied area due to extensional tectonics. Local small-scale synsedimentary faults are observed, and the distribution and the composition of the sedimentary bodies are partly guided by some crustal lineaments active at that time, either parallel or transverse with respect to the future Ligurian ocean. The paleostress setting which has been reconstructed in some places indicates a transitional state between the Triassic and the Liassic (emplacement of syn-rift Tethyan extension). Although the sedimentary organisation of the upper sequence is coherent with the depositional model of Haq et al. (1987), the tectonic context of the incipient rifting in the Earliest Liassic is a major obstacle to evidence some global eustatic events from these data. Nevertheless, the basal transgression (early Hettangian) is the most likely to have been generated by a global event since most of the observed Hettangian tectonics is junger.

Such a study enlights the interplay between extensional tectonics and global eustacy, which are evidently acting together at some peculiar periods of the Earth's history. In the case of the T/J boundary, a widespread magmatic activity is also noticed on various extended continental crust areas (Central Atlantic margins, Morocco, Spain, western Alps, NW Australian margin, etc.). The link between the extensional deformation of the marginal domains and global sea-level rise such as documented in that study tends to support the models which ascribe global sea-level changes to the formation of passive margins and changes in the area/age distribution of the ocean floor (Heller & Angevine 1985), instead of those involving fluctuations in oceanic spreading rates.

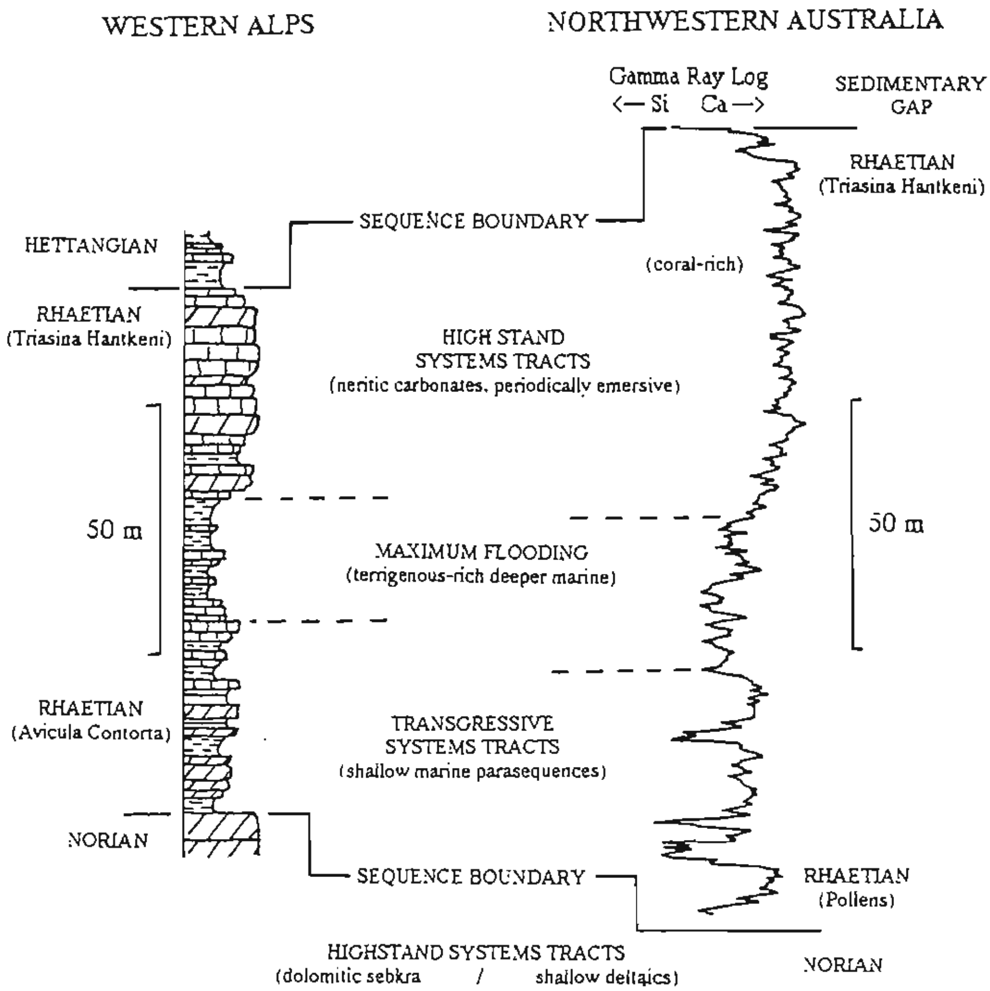

Fig. 1: the sedimentary sequences of Rhaetian age show similar features on different distant margins. This documents a Rhaetian global eustatic event.

Fig. 1 : The sedimentary sequences of Rhaetian age show similar features on different distant margins. This documents a Rhaetian global eustatic event.

Hard-ground and condensed horizons (Liassic and Cretaceous, Swiss Mediane Nappe): a story of differentiated subsidence and sea level change

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ABSTRACT. - Hard-grounds and condensed horizons characterize two intervals (Mid Liassic and "Mid Cretaceous") in the stratigraphy of the Mediane Nappe. This unit belongs to the alpine front ranges but was deposited on the northern flank of the Briançonnais paleogeographic realm. The study of this anomalous beds clarifies the respective roles of tectonics, eustacy and sediment supply at these times of basin evolution.

Petrographic analysis shows coexistence of phosphate, calcite, glauconite, silica, goethite and hematite, and pyrite. Geochemical analysis reveals early diagenetic lithification of these horizons (oxic and suboxic zones), which prooves conditions of low sediment supply. The liassic condensed horizons occur in the northern part of the basin, whereas the Albian to Cenomanian ones are localized in the southern zone. This paleogeographical pattern is a consequence of the geodynamic evolution. Whereas the liassic sediments (up to 500 m thick) register extensional tectonics, "Mid-Cretaceous" deposits (up to 80 m thick, starved basin) suffer the effects of a first alpine inversion. Sinemurian-Pliensbachian and Albian-Cenomanian condensed horizons, precisely dated by ammonites and planctonic foraminifera, occur within storm-deposited sediments. Two decompacted and restored North-South transects illustrate basin evolution.

The spacing of these beds within the studied series indicates individual sedimentary sequences of n x 106 years duration. Compared with other sequences and their duration, this suggests long term tectonic phenomena. These condensed or mineralized deposits, present at two distinct times and location in constrasting geodynamical contexts, but with analogous cyclic periodicity, show a similar cause : this is the same balance of accomodation potential and sediment supply.

Climatic-eustatic mixed control on carbonate deposition (Mesozoic, S-E France).

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ABSTRACT. - Framed and progressively refined over the last decade, the depositional model of margin sediments of P. Vail and Exxon geologists rapidly proved an invaluable tool for basin analysis through a sequence stratigraphy new way. It remains to know how it may apply to carbonate series which were until now described Klüpfel-way (stacked shallowing-up marl/limestone rhythms of platforms) by most European geologists. Adaptating the new way of doing sequence stratigraphy comes after all to know the *exact significance of the Klüpfel discontinuity* (KD) atop of carbonate rhythms, i.e. if it is coincidental or not with the sequence boundary (SB) Vail-way, and, if yes, over the whole depositional system or not. This comes to know if the KD is a flooding surface everywhere or not. A correct answer cannot be given without studying a complete depositional system, like, for instance, the one outcropping in French Subalpine Ranges (Vocontian Trough and adjacent platforms). Figure 1 shows the basic field facts that have to be taken into account, especially the pervasiveness of the Klüpfel sequence (KS) from the shallow to the deep. How this fact may fit into the wandering of systems tracts across the margin as in the Vail and coll.'s model above ?

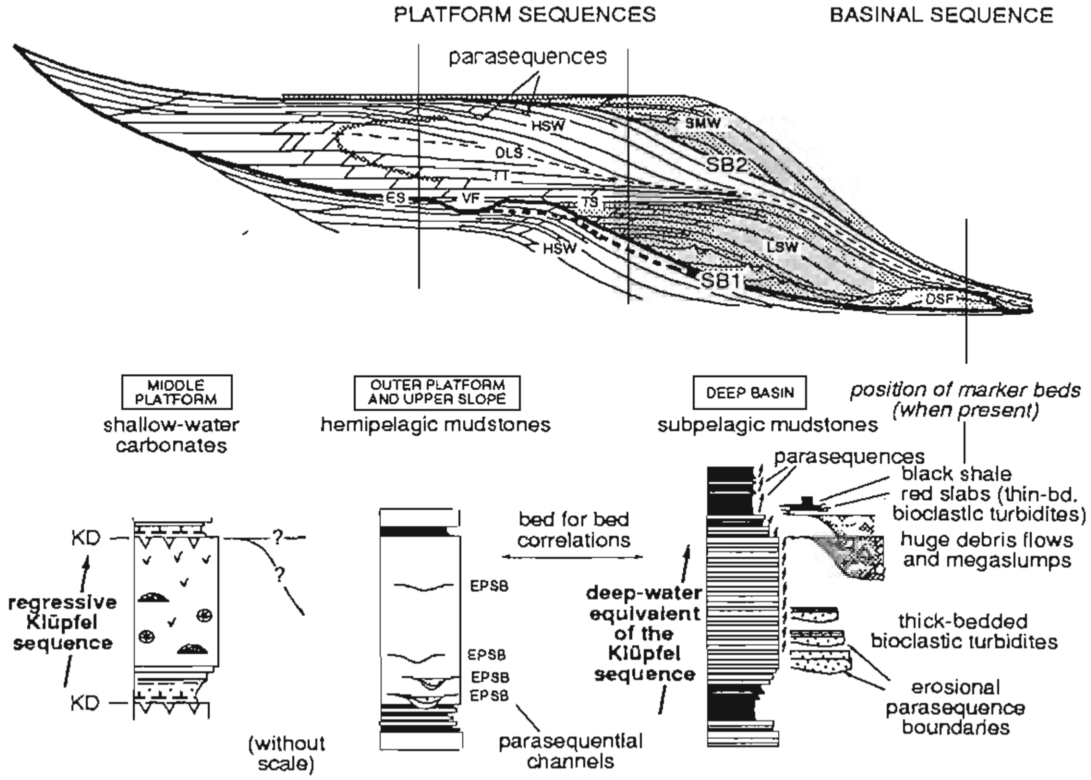

Fig. 1 - Platform-to-basin carbonate Klüpfel sequences (3rd order cyclicity of Haq et al. (1987). KD: Klüpfel discontinuity. The basinal sequence shown here is of the SA-type. Throughout the Mesozoic depending on the relative importance of marls versus limestones in this basinal sequence, the basic SA-type shifts between the SM-type (only a few beds atop) or the SC-type (thin marls at base). The stacking of SM-, SA- and SC-type sequence is not random ; it builds up the second order cyclicity (Ferry & Rubino 1987).

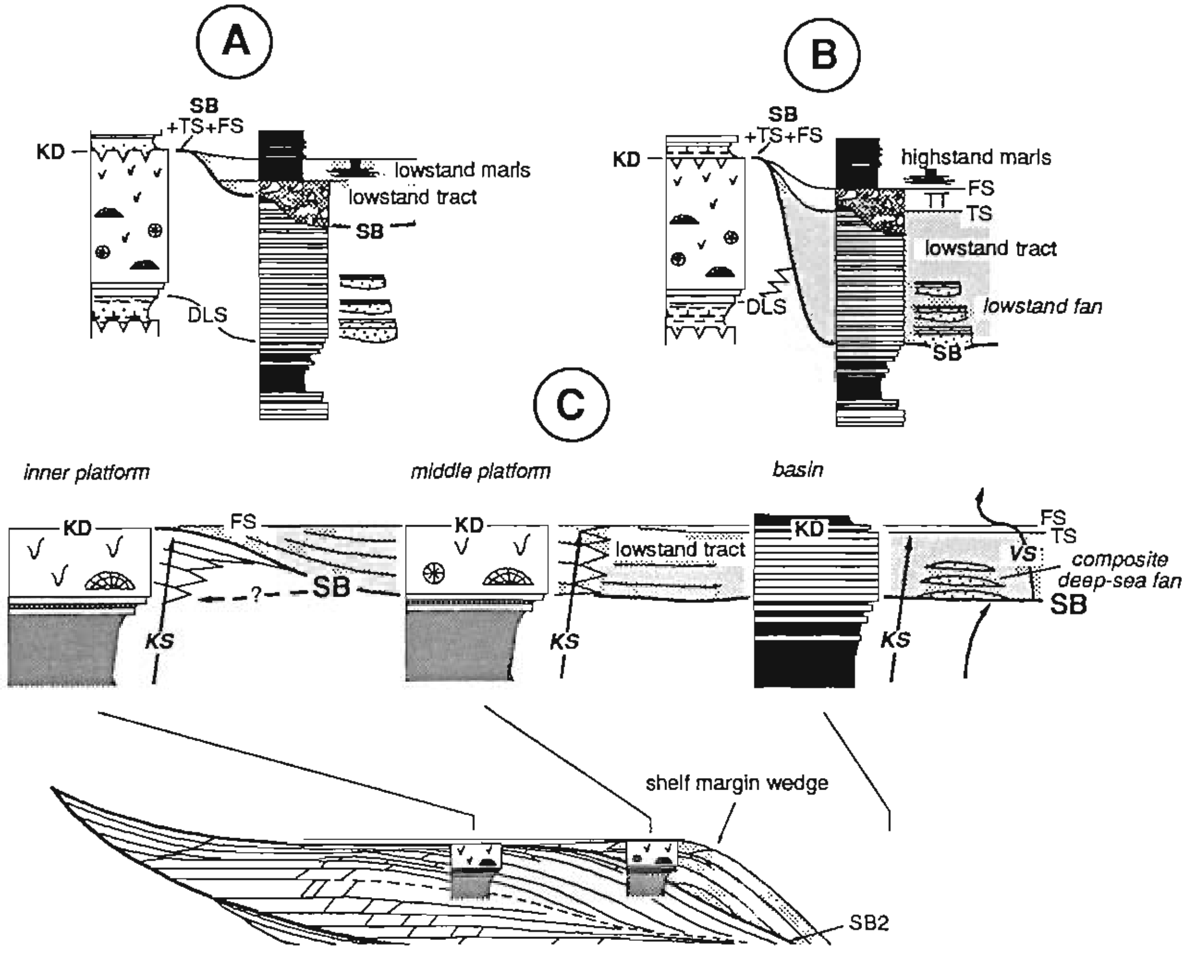

Fig. 2 - The three possible ways of drawing the sequence boundary across the carbonate depositional system.

There is three possible solutions (fig. 2). In A, platform carbonates are late highstand deposits coeval with the basinal mudstones of the upper part of the deep-water equivalent of the KS. The SB should be an emersion surface on shallow-water carbonates. There is then no other room for placing a lowstand tract in deep water than in the basal marls of the next basinal KS. The huge slump or debris flow deposits often found atop of basinal KSs then represent an equivalent of the lowstand fan of the model. The shift of the deep-water bed-scale limestone-marl alternation toward pure marls may be explained by the drop in both the periplatform ooze supply (exposed, unproductive platform) and a climatically-driven drop in the supply of planktonic carbonate. Eustacy here, if existing, may thus be glacio-eustacy, given what is known in the Quaternary on carbonate deposition in the deep ocean. It was the solution we favored two years ago (Ferry & Rubino 1987a, 1987b, 1988).

Solution B does not change the interpretation of platform deposits. But because the strongest bioclastic supplies (turbidites) in the deep area are always within the lower part of limestones of the basinal KS, one may think that they represent the lowstand fan. The often sharp transition, if not erosional nature of the contact between marls and limestones in the KS, either on the slope or even in deep-water is another argument for placing the SB below the basinal limestones rather than at their top. If so, the debris flows represent the collapse of the late lowstand tract during the transgression. This solution should probably be discarded in most, if not all, cases. First, bed-for-bed platform to basin correlations prevent the SB from cutting across the system (fig. 1 above). Second, we think it would be difficult for the cemented carbonates of the exposed platform to feed a thick lowstand mudstone wedge basinward.

We are thus inclined toward solution C that would be expected for most of the lowstand tracts, that are of the shelf margin wedge type, i.e. placing the SB **below** both the basinal and (the whole ?) platform upper part of the KS. This solution fits the fact that there is the same number of KSs in shallow and deep water. We have never found any additional prograding lowstand wedge on slopes. *What may occur is the nesting of some prograding Klüpfel wedges in canyons* having functioned for a while at a given place on the margin. Such a setting may mimic a prograding lowstand wedge. But the type-1 SB becomes a type-2 SB some ten kilometers away. If we are correct, the progradation of the shallow-water carbonates on the platform at the third order level is mainly due to the drop in relative sea level that forces *the downwardshift of parasequential lowstand tracts*. The SB would then be the most difficult surface to place in the depositional system. It would have to be choosen among a set of parasequence boundaries within the downwardshift, i.e. somewhere within the marl-limestone transition in the platform KSs. Bioclastic turbidites do not build up a true fan. They are emplaced as a consequence of *parasequential sea level changes in the Milankovitch frequency band within the 3rd order lowstands*. The transition between limestones and the marls of the next KS is thus the transgressive tract in the basin. It usually pinches out on the platform (amalgamation of the transgression and the flooding surfaces), except where red-brown, cross-bedded crinoidal (oolitic) limestones represent this transgressive tract resting on reef or lagoonal facies. This solution better fits the correlations we make in the whole depositional system of the Alpine margin, including the epicontinental sea of the Paris Basin.

If solution C should be choosen in all sequences as we think, then the climate cooling we need for explaining the drop in planktonic carbonate (see above) is coincidental with the transgression, not with the lowstand. As a supporting evidence, it should be mentioned that arrivals of "cold" ammonites in S-E France are almost always in what we call transgressive tracts in the basinal series (fig. 3). Eustatic sea level changes, if really existing, cannot thus be glacio-eustatic but *tectonic in origin, already at this cyclicity order*, which may be confirmed by the position of the many evidences of tectonic activity atop of platform Klüpfel sequences (fig. 3). **This comes to know who is right after all, either Klüpfel with his tectonically-driven periodic floodings of platform (tectonic collapse or uneven subsidence) or Vail and coll. with their eustatic overprint on a roughly steady subsidence rate.** It should be first emphasized that only worldwide correlations can prove that local sea level curves match one another, and that there is really eustatic sea-level changes at the 3rd cyclicity order, rather than deformations of the geoid. Second, the fact that 3rd order curves may match one another does not imply discarding some kind of middle frequency tectono-eustacy. This would suppose that the whole Earth may "breathe" a way that must be better understood than now.

The basic problem we will have to face in the coming years, to be sure, is to understand the **"boundary problem" that arise when studying superimposed cyclicities carbonate deposits.** At one end, in the Milankovitch frequency band, and for this reason, cycles are thought to be driven by glacio-eustacy (see the "PACs" of Goodwin & Anderson, 1985). At the other end, the tectonic signature is usually suggested (see Vail & Eisner, this volume).

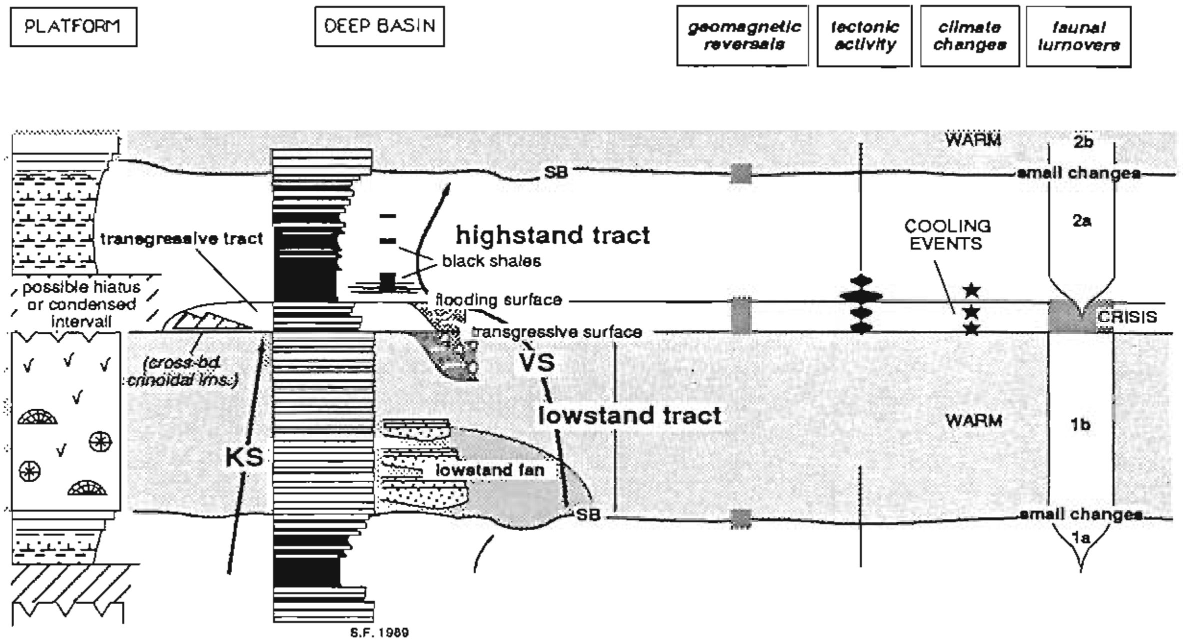

Fig. 3 - The basic relationship between the carbonate sequence Klüpfel-way (KS), and according to our way of doing systems tract analysis in the sense of Vail and coll. across the carbonate wedge. The resulting sequence is the VS (Vail sequence) which is, for us, always outphased with the KS. (SB = sequence boundary)

Study done under a French CNRS-INSU grant ("Dynamique et bilans de la Terre, Message sédimentaire")

A revision of the Mesozoic sea level chart of Haq et al. (1987) from the carbonate wedge of the French Alpine margin.

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ABSTRACT. - On the basis of the interpretation of platform-to-basin sequence relationships given elsewhere (Ferry & Rubino, this volume), a checking of the sea level chart of Haq et al. (1987) has been done in the ammonite-rich subpelagic series of the Vocontian Trough on the Alpine margin. The basic fact taken into account is that there is a full correspondence between all platform subsequences, sequences and megasequences and their deep-water equivalents (that is to say from the 5th to the 2nd cycle order of Vail and coll.). Such a relationship suggests that a basic rule governed the carbonate depositional system across sequence hierarchy. But it does not allow to know if sequence boundaries (SB) are of the type 1 or the type 2, mainly because of morphological or tectonic problems that will be examplified. SB Vail-sense are thus simply placed against the ammonite biozonation. Selected sections platform-to-basin correlated have been choosen in order to define systems tracts in all sequences composing the Mesozoic series (Lias to Campanian).

On platforms immediately surrounding the Vocontian Trough, 3rd order carbonate lowstand tracts, either as reefs or oolitic shoals or fine-grained hemipelagic mudstones depending on the degree of 2nd order flooding (fig. 1), are stacked one upon another, with only a few intervening marls. These marls develop mainly in outer platform settings and in the deep basin. Their thickness is maximum at the shelf edge. They progressively thins in distal parts of the basin. Farther in the East or the South, in inner Alps, it becomes increasingly difficult to spot the depositional sequences within homogeneous calcareous formations like the "Maiolica" for example, which is time-equivalent with the expanded Tithonian-lower Aptian series of the Vocontian Trough. That is the reason why this expanded Vocontian series is a basic section for at least stratigraphically positioning the main surfaces defined in the model of Vail and coll. This can be easily done when the sedimentation in the Trough is made of a bed-scale limestone-marl alternation. When shallow-water carbonate ramps spreaded over the margin (i.e. through 2nd order lowstand tracts) like in the Late Jurassic or at the end of the Neocomian, the deep-water sedimentation was shifted toward the dominence of limestones. Then, localizing 3rd order sequences is not easy in deep-water carbonates. The same problem occur at 2nd order floodings that induce a marl shift in the alternation of the Trough. Then, the high-frequency signal (roughly 20 k.years) fades away into homogeneous marls. That is the reason why depositional sequences are entirely represented by marls and so hard to spot. That is the case within Bathonian to lower Oxfordian "Terres Noires", or within Gargasian-Albian "Blue Marls" for instance. Outer platform deposits then give better results than basinal ones.

The second order sequence boundary is as difficult to place within the downwardshift of 3rd order lowstand tracts as in the downwardshift of parasequences in the 3rd order sequence (see Ferry & Rubino, this volume). As interesting as for 3rd order transgressive tracts, it can be shown that 2nd order rises in relative sea level were not of constant duration. *The curve is never a sinusoid*, neither at the 3rd order hierarchical level, nor at the 2nd order one. The Late Dogger 2nd order transgressive tract encompass the depositional time of three 3rd order sequences, two in the upper Bajocian and another in the lower Bathonian. The Gargasian rise in relative sea level was a very much faster event spanning the depositional time of a mere subsequence (the thin marly subsequence at the end of the lower Aptian).

The curve presented here show many discrepancies, major and minor, with the chart of Haq et al. (1987). More comparisons in carbonate settings world-wide will show if our analysis of the depositional system of S-E France is correct or not, and if there was really eustacy in the past, outside glacial periods.

Study done under a French CNRS-INSU grant ("Dynamique et bilans de la Terre, Message sédimentaire")

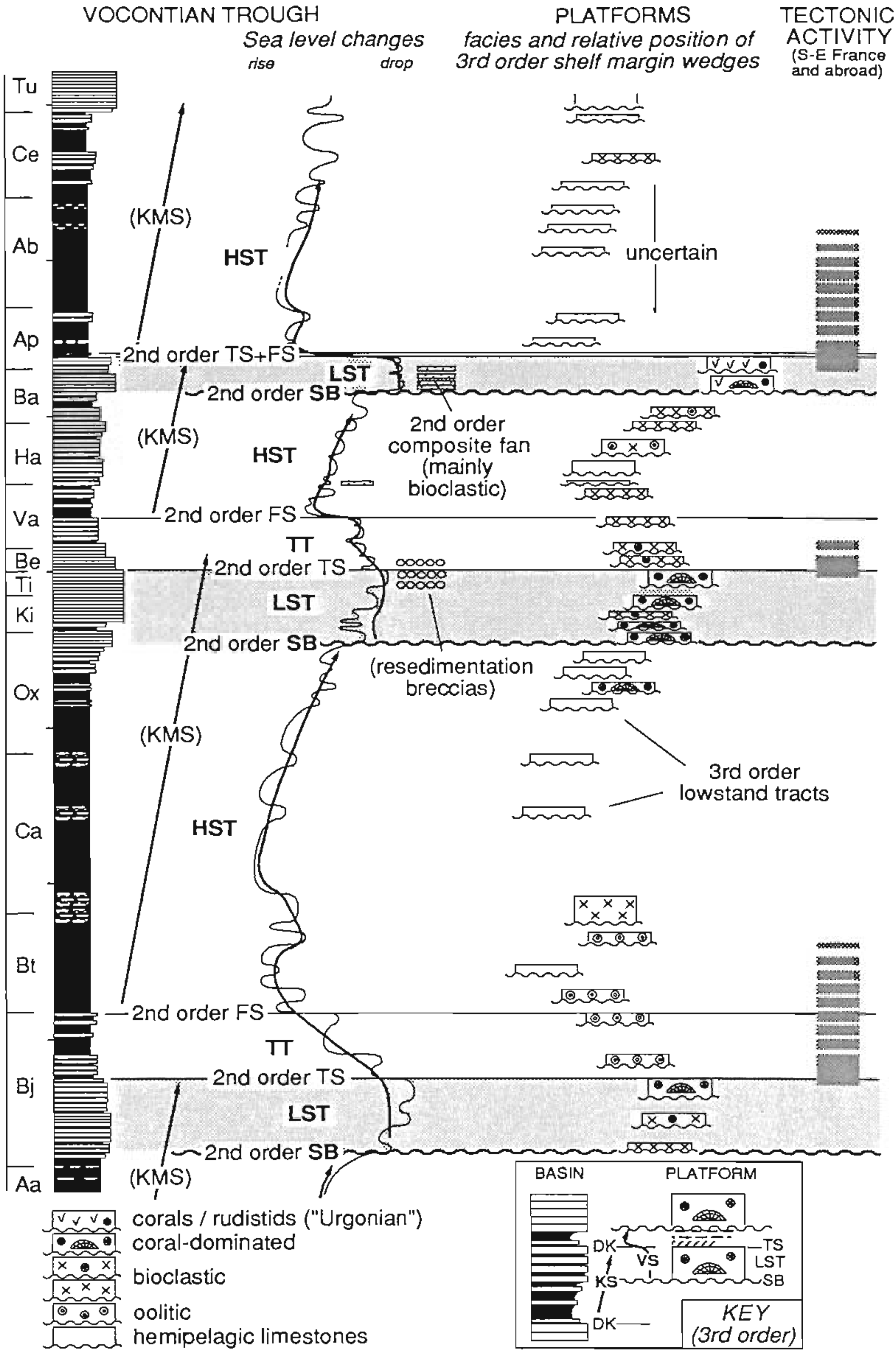

Fig. 1 - Arrangement of third order platform lowstand tracts versus their deep-water equivalents in the Vocontian Trough (Dogger to Turonian) showing the approximate position of second order sequence boundaries and transgressive tracts. Note that, as for 3rd order cycles, the Klüpfel megasequence (KMS) is phased out with the second order depositional sequence.

Enregistrement de l'eustatisme par les systèmes sédimentaires bathono-callovo-oxfordiens de Bourgogne

Eustacy recorded by Bathonian to Callovian sedimentary systems of Burgondy, France

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RESUME. - Les systèmes sédimentaires bourguignons s'étageant entre le Bathonien supérieur et l'Oxfordien moyen résultent de l'intégration logique d'un certain nombre de séquences de dépôt dans un contexte général de montée relative du niveau marin sur une plate-forme. Les systèmes sont séparés par des discontinuités majeures, de valeur au moins régionale, tandis que les séquences de dépôt le sont par des discontinuités de valeur plus locale. Systèmes et séquences sont les réponses, à des échelles différentes, à des débordements puis à des reculs de la mer. Ils constituent un "message sédimentaire" permettant de faire la part entre le contrôle eustatique général et le rôle de la tectonique locale. Systèmes et séquences sont replacés dans un cadre biochronologique aussi précis et détaillé que possible dont on a essayé d'évaluer le degré d'incertitude (Floquet et al. 1989).

Le **premier système**, d'âge Bathonien supérieur à Callovien inférieur (ordre d'un million d'années) et d'une épaisseur totale de 12 à 16 m, a été dénommé *Pierre de Dijon-Corton* (fig. 1). Il est composé de corps sédimentaires mis en place selon des séquences de dépôt séparées par des discontinuités corrélables à travers la région d'étude. Ces séquences sont métriques (de moins de 1 m à plus de 3 m) et ne représentent certainement que des périodes très brèves de sédimentation séparées par de longs intervalles de temps. Leurs témoins sont par exemple des signes d'altération, biologiques avec perforations, mécaniques avec des érosions, diagénétiques avec les surfaces durcies et avec la stratigraphie des cimentations et des recristallisations. Ce sont également les resédiments tels les reprises en base de séquence, les infiltrations à leur sommet et les corps sédimentaires allochtones en position latérale.

Une séquence complète comprend des faciès initiaux d'approfondissement et d'ouverture sur le large, des faciès médians de milieux calmes et ouverts de mer étendue, des faciès terminaux variés de milieux plus superficiels pouvant atteindre l'émersion. La plupart des séquences sont incomplètes avec absence soit des faciès initiaux d'approfondissement (non déposés ?) soit des faciès terminaux de faible profondeur enlevés par érosion.

L'ensemble du système est compris entre deux discontinuités majeures appelées D1 et D2. Il traduit sur 200 km l'évolution d'une plate-forme à paléotopographie persistante de haut-fond bordé distalement par des rampes carbonatées. Pendant cette période on assiste à un grand mouvement transgressif avec débordements de plus en plus marqués de la mer qui génèrent une succession d'aggradations sédimentaires centripètes de plus en plus accentuées. Il en résulte un net rétrécissement de la partie proximale de la plate-forme.

Le **deuxième système**, d'âge Callovien inférieur (environ 1,5 million d'années) et d'une épaisseur de l'ordre de 10 mètres, est appelé *Pierre de Ladoix* (fig. 1). Il est aussi agencé en séquences de dépôt qui peuvent également présenter un terme inférieur micritique argileux ou marneux et un terme supérieur calcarénitique oolitique et bioclastique, couronné par une surface durcie, encroûtée et perforée. Mais, du fait de la disposition souvent lenticulaire des corps sédimentaires, leurs continuités et liaisons latérales sont plus difficiles à suivre sur de grandes distances. Les discontinuités qui limitent les séquences paraissent mouler les morphologies des corps sédimentaires sous-jacents ou dériver des figures d'érosion. La lenticularité des corps sédimentaires pourrait être due à une différenciation plus forte de la paléotopographie de la plate-forme (facteur tectonique local ?).

L'organisation interne des séquences est toujours liée aux variations de la tranche d'eau avec initialement des faciès micritiques plus ou moins argileux d'approfondissement, suivis de faciès de dunes sableuses oolitiques et bioclastiques dont la formation et la migration sont générées par la stabilisation de l'épaisseur de la tranche d'eau marine.

Ce deuxième système est limité par des discontinuités majeures appelées D2 et D3.

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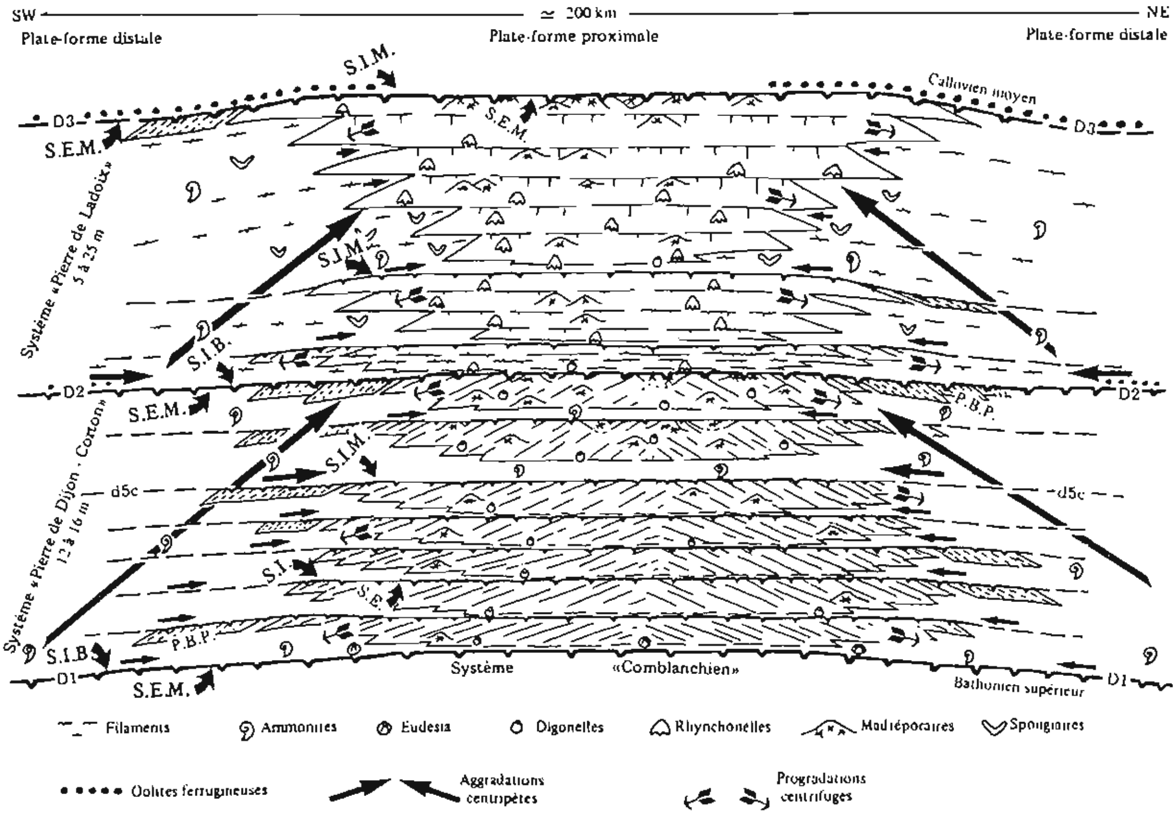

Fig. 1 - Esquisse théorique de l'agencement des systèmes "Pierre de Dijon-Corton" et "Pierre de Ladoix" ainsi que de leurs séquences, suivant une coupe orientée Sud-Ouest à Nord-Est le long de la bordure sud-orientale du Bassin parisien. Approfondissements et aggradations centripètes ; diminution de profondeur et progradations centrifuges. SE : Surface d'érosion (M = majeure), S.I. : Surface d'inondation (M = majeure, B = basale), P.B.P. : Prismes sédimentaires de bordure de plate-forme proximale (positions hypothétiques). Le découpage en séquences continues (7 pour le premier système, 3 pour le second) ne reflète que les événements majeurs ayant affecté les plates-formes. Il n'est pas tenu compte des subdivisions locales des séquences en sous-séquences ni des phénomènes d'érosion qui auraient supprimé certaines séquences et provoqué des diminutions d'épaisseur parfois considérables des systèmes. D'après Floquet et al. (1989).

Theoretical arrangement of the "Pierre de Dijon-Corton" and "Pierre de Ladoix" systems and sequences. Section SW-NE along the south-eastern border of the Paris Basin. Deepening and onlap, shallowing and progradation. S.E. : Erosion surface (M = main), S.I. : Flooding surface (M = main, B = basal), P.B.P. : Shelf margin wedge (hypothetical position). The 7 continuous sequences of the first system and the 3 of the second one show only the major events which occurred on the platforms (e.g. erosions are not considered). After Floquet et al. (1989).

Les systèmes sédimentaires ultérieurs, d'âge Callovien moyen à Oxfordien moyen (7 millions d'années), au nombre de 5 ou plus sont très irréguliers. Sur la partie proximale de la plate-forme, ils peuvent manquer ou sont à l'état de lentilles ou de niveaux discontinus d'épaisseur décimétrique à métrique. Ils renferment de nombreux horizons à oolites ferrugineuses et sont séparés par des surfaces de discontinuité durcies, ferruginisées.

Dans ces systèmes les contrastes sont plus accentués : approfondissements et baisses du niveau marin plus forts, exondations proximales plus prononcées, débordements en relation avec des événements majeurs retrouvés à travers toute l'Europe occidentale, courants plus actifs... Certains corps sédimentaires bioclastiques, présents sur les bords de la plate-forme pourraient être le résultat d'une exportation du matériel bioclastique depuis les zones proximales érodées jusqu'à des zones distales plus profondes (prismes de bordure de plate-forme proximale mis en place lors des bas niveaux marins relatifs).

En conclusion, l'enchaînement de ces systèmes sédimentaires et des séquences qui les composent, reflète l'évolution d'un haut-fond dont la partie proximale est épisodiquement mise en eau puis remblayée par la sédimentation jusqu'à émersion possible. L'eustatisme lié à l'évolution de la Téthys semble être le moteur des approfondissements qui conduisent aux aggradations centripètes des faciès et milieux de plate-forme distale. Les remblaiement sédimentaires lors de la stabilisation dans l'acquisition des hauts niveaux marins relatifs entraînent les progradations centrifuges des faciès et des milieux de plate-forme proximale superficielle à fort hydrodynamisme. De plus, il est possible, surtout à partir du deuxième système, que des manifestations tectoniques locales accentuent les effets des baisses du niveau marin relatif et par conséquent les progradations et les érosions.

REFERENCE

FLOQUET M., LAURIN B., LAVILLE P., MARCHAND D., MENOT J.-Cl., PASCAL A. & THIERRY J. (1989) - Les systèmes sédimentaires bourguignons d'âge Bathonien terminal-Callovien. *Bull. Centres Rech. Explor. Prod., Elf-Aquitaine*, 13, 1, p. 133-165, 20 fig., 2 tabl., Boussens.

Communautés à brachiopodes et discontinuités dans le Bathonien-Callovien de la plate-forme bourguignonne

Brachiopod assemblages and discontinuities in the Bathonian-Callovian of the Burgundy platform, France

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RESUME. - Des travaux récents ont réinterprété les formations carbonatées du Jurassique moyen de la plate-forme bourguignonne (SudEest du Bassin de Paris) en termes de stratigraphie séquentielle (Floquet et al. 1989). Au Bathonien supérieur - Callovien inférieur, deux principaux systèmes sédimentaires superposés ont été reconnus qui ont valeur de cortèges : système *Pierre de Dijon-Corton* et système *Pierre de Ladoix*. Les quarante mètres d'épaisseur environ de ces systèmes sont découpés en multiples séquences de comblement séparées par des discontinuités. Parmi celles-ci, deux ont été considérées comme majeures à l'échelle régionale : D1, à la base du premier système et D2 séparant les deux systèmes. Ces interprétations doivent cependant tenir compte de contraintes qui tiennent, d'une part aux conditions d'affleurement et d'autre part, au grand nombre de discontinuités observables. Cette multiplicité nécessite leur hiérarchisation. Les systèmes étudiés affleurent en deux bandes de terrains, éloignées de presque 100 km. S'il est possible, dans chaque région, de suivre les formations de coupe en coupe, en revanche, les séries diffèrent d'une région à l'autre ; ces différences entravent les corrélations et le suivi dans l'espace des discontinuités. De ce fait, le modèle proposé souffre d'incertitudes, la position de certains corps sédimentaires étant généralement déduite et non directement observée. D'autre part, les critères sédimentologiques immédiats ne permettent pas de reconnaître d'éventuelles superpositions de discontinuités. Pour être confirmé, le modèle de la plate-forme bourguignonne doit donc être confronté à l'ensemble des arguments sédimentologiques, diagénétiques et paléontologiques. L'analyse qui suit est celle de la contribution des faits biologiques à cette synthèse.

La relation entre les mouvements eustatiques de grande ampleur et les coupures fauniques, en particulier chez les ammonites, est maintenant établie (Gabilly et al. 1985, Atrops & Ferry 1987). Le fait a été montré également chez les bivalves au Jurassique (Hallam 1976) : des écosystèmes entiers peuvent être totalement renouvelés. Ainsi, les modifications bathymétriques, l'évolution d'un cortège sédimentaire et les changements dans la composition des faunes peuvent être recherchés de pair. Les relations entre modifications des composantes biologiques et sédimentaires à cette échelle supposent que l'analyse ne soit pas seulement réalisée au rang des seuls taxons mais à celui des communautés.

Les communautés benthiques des systèmes sédimentaires de la plate-forme bourguignonne comportent toujours un groupe de brachiopodes dominant à côté de bivalves et gastéropodes faiblement représentés. Dans le système Pierre de Dijon-Corton, quatre communautés ont ainsi été reconnues (fig. 1) : communauté à *Cererithyris nutiensis*, communauté à *Lotharingella gremifera*, communauté à *Digonella divionensis*, communauté à *Burmirhynchia latiscensis*. Chaque communauté est identifiée sur des critères qualitatifs (composition taxonomique) et possède un spectre quantitatif propre (Figure). Les communautés se remplacent au cours du temps (remplacements r1, r2, r3) par modification de la proportion des taxons mais sans remise en question de la composition taxonomique globable. Cependant, d'un système à l'autre, les modifications sont brutales, marquées par la disparition de la totalité des brachiopodes auxquels succèdent de nouvelles espèces, inconnues antérieurement sur la plate-forme. Ces renouvellements plaident pour l'existence d'événements majeurs capables de modifier radicalement les communautés.

Outre les corrélations entre les deux régions, la confrontation du modèle à l'évolution des communautés (remplacements) et des renouvellements fauniques a contribué à la hiérarchisation des discontinuités. D1 et D2 séparant les deux systèmes sont associées à des renouvellements de communautés, ce qui confirme leur valeur de discontinuités majeurs à l'échelle de la plate-forme. Cependant, des renouvellements importants ont aussi été mis en évidence au-dessus de discontinuités considérées comme mineures (d5c) et posent le problème de leur valeur (limite de système ou limite de paraséquence ?). Entre ces renouvellements fauniques, les remplacements ponctuent l'évolution des communautés. Ils s'effectuent le plus souvent, non pas au niveau des discontinuités mineures, mais dans les termes médians des séquences. D'après les données sédimentologiques, ils interviendraient donc pendant les périodes de tranche d'eau maximale. Dans le

système Pierre de Dijon-Corton, la séquence orientée de communautés est générale à l'échelle de la plate-forme. Elle a permis d'identifier les séquences sédimentaires et de montrer un net mouvement transgressif à la base du système. La reconnaissance des communautés, de leur remplacement et des renouvellements apportent ainsi des arguments pour la définition, et la compréhension des systèmes sédimentaires. L'interaction des composantes biologiques (communauté) et sédimentaires donne au système une cohérence qui permet sa caractérisation.

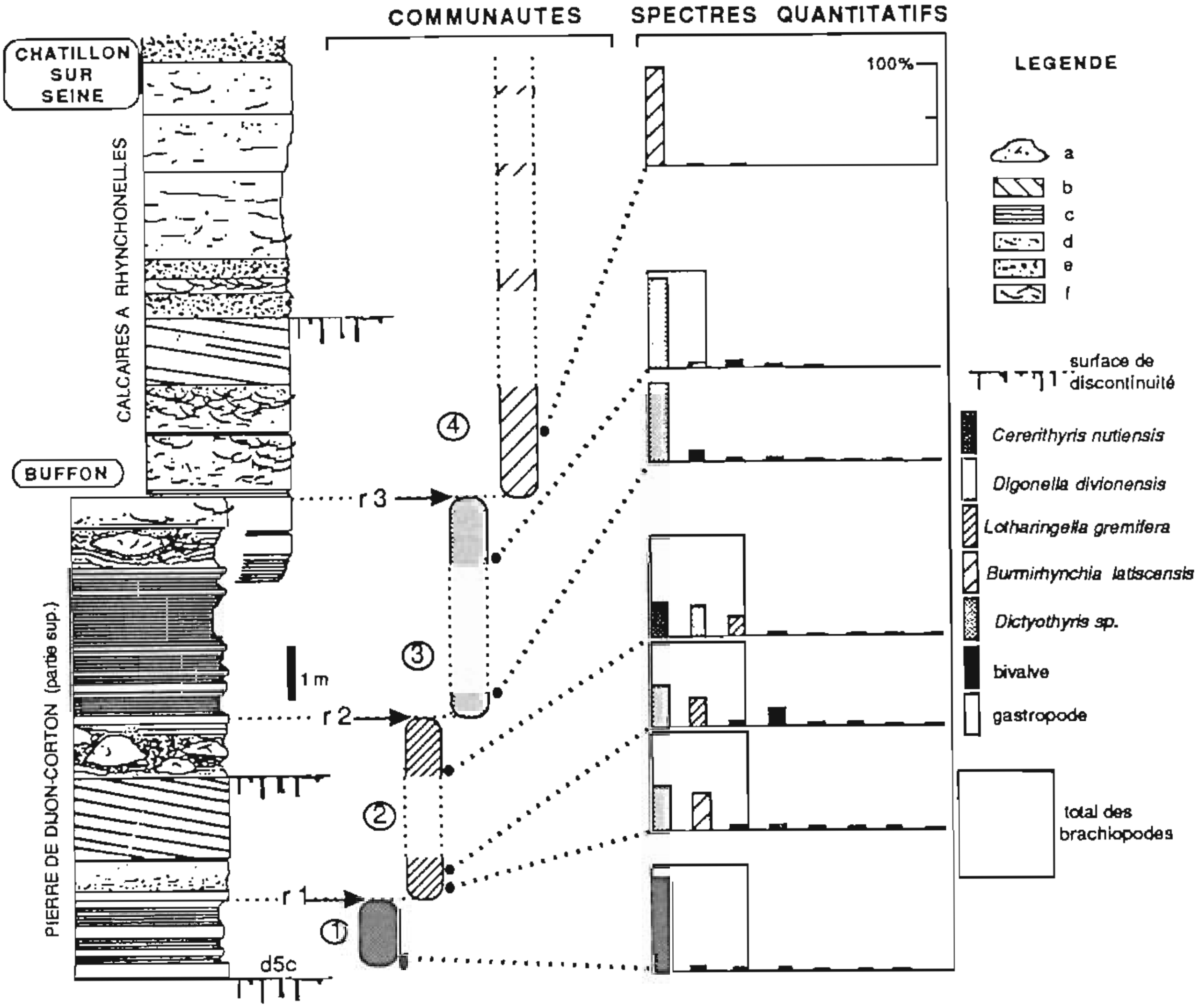

Fig. 1 - Enchaînement des communautés à brachiopodes dans la partie supérieure du système Pierre de Dijon-Corton et les Calcaires à Rhynchonelles. a : madréporaires, b : calcarénite à litages obliques, c : micrite et micrite argileuse, d : calcaires bioclastiques, e : calcaires à oncoïdes, f : lumachelles à *Burmirhynchia latiscensis*. 1 : communauté à *Cererithyris nutiensis*, 2 : communauté à *Lotharingella gremifera*, 3 : communauté à *Digonella divionensis*, 4 : communauté à *Burmirhynchia latiscensis*. r1, r2, r3 : remplacements de communautés.

Influence of eustacy on the organic facies of the Berriasian stratotype at Berrias (Ardèche, France)

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ABSTRACT. - The Berriasian stratotype consists essentially of muddy carbonates deposited on an external platform. The ca. 30 m thick section is biostratigraphically well-dated by ammonites and calpionellids (Busnardo et al. 1965 ; Le Hégarat & Remane 1968 ; Le Hégarat 1980, and see fig. 1). Some fifty palynologically prepared samples yielded organic residues rich enough to study the quantitative distribution of organic matter (palynofacies).

The following organic constituants were distinguished : gelified humic fragments (inertinite, vitrinite), other miscellaneous fragments (woody, peloidal, filaments), pollens and spores, dinoflagellate cysts and foraminifera linings. Additional parameters were also considered : size, shape and degree of degradation of continental fragments number of species and types (proximate, proximo-chorate and chorate) of dinoflagellate cysts. Variations in the composition of this palynofacies usually result from changes in the depositional environment. Together with sedimentological and biostratigraphic data, these variations may be interpreted in terms of sequence stratigraphy and results may be compared (fig. 1) with the global sea-level chart of Haq et al. (1987).

Three important sedimentological breaks allow to subdivide the type section into four intervals (fig. 1) : the base of bed 143 (Le Hégarat 1965) is an erosive surface terminating a poorly-bedded interval of marly limestones without macrofauna (break 1). In this lowermost interval, bed 139 is the only outstanding continuous bed and its sub-planar base could also be an erosive surface. The interval above the sedimentological break 1 is a well-bedded carbonate section truncated at the top by a breccia (bed 150), the base of which is strongly erosive (break 2). This breccia is overlain by another well-bedded carbonate interval up to bed 188, where the high concentration of macrofauna and pyrite nodules seems to indicate a condensed section (break 3). The uppermost part of the section becomes more argillaceous and grades into the Valanginian marls (base of the Otopeta subzone at bed 198).

In these four intervals, the distribution of organic matter leads to an environmental interpretation summarized on the lefthand side of fig. 1 by an unscaled curve showing oscillations between distal and proximal conditions. This curve can be tentatively translated into sequence stratigraphy systems tracts and correlated with the global sea-level chart of Haq et al. (1987). When doing so, one must keep in mind the discrepancy existing in the correlation between calpionellids and ammonites zonations. That shown for the Berrias type section is the latest interpretation of R. Busnardo and G. Le Hégarat (personal communication).

There is good correlation between sedimentological break 2 at Berrias and sequence boundary 131.5 m.y. On both sides of this boundary, palynofacies show an increase towards more marine conditions, which correspond to the high stand systems tract of the eustatic curve. In the lowermost part of the section, the base of bed 139 seems to fit best with sequence boundary 134, although an alternative interpretation cannot be excluded. In the uppermost part of the section, the rapid transition to more distal conditions near the base of the Otopeta subzone correlates with the Valanginian transgression terminating at 127.5 m.y. on the eustatic curve. Correlations in the Picteti-Callisto subzones are less straightforward. The inferred sequence boundary at the base of the Picteti subzone (bed 180) can be correlated with that at 129 m.y. on the eustatic curve. Two interpretations are proposed for sedimentological break 3 : that showing a sequence boundary (128.5 m.y.) coincidental with a transgression surface is preferred, because organic matter indicates the underlying interval (beds 180 to 187) to be a complete, low-amplitude sedimentary sequence comparable to that spanning the interval 129 to 128.5 m.y. on the eustatic curve. In this case, organic matter would show the existence in the Berrias section of an extra sedimentary sequence below the base Valanginian.

REFERENCES

BUSNARDO, R., LE HEGARAT, G. & MAGNE, J. (1965) : Le stratotype du Berrasien. *Mém. Bur. Rech. Géol. Min.*, 34, 5-33.

HAQ, B.U., HARDENBOL, J. & VAIL, P.R. (1987) : Chronology of fluctuating sea levels since the Triassic. *Science*, 235, 1156-1166.

LE HEGARAT, G. (1965) : see BUSNARDO et al. (1965).

LE HEGARAT, G. (1980) : Le Berriasien. *In* : Les étages français et leurs stratotypes. *Mém. Bur. Rech. Géol. Min.*, 109, 96-105.

LE HEGARAT, G. & REMANE, J. (1968) : Tithonique supérieur et Berriasien de la bordure cévenole. Corrélation des Ammonites et des Calpionelles. *Geobios*, Lyon, 1, 7-70.

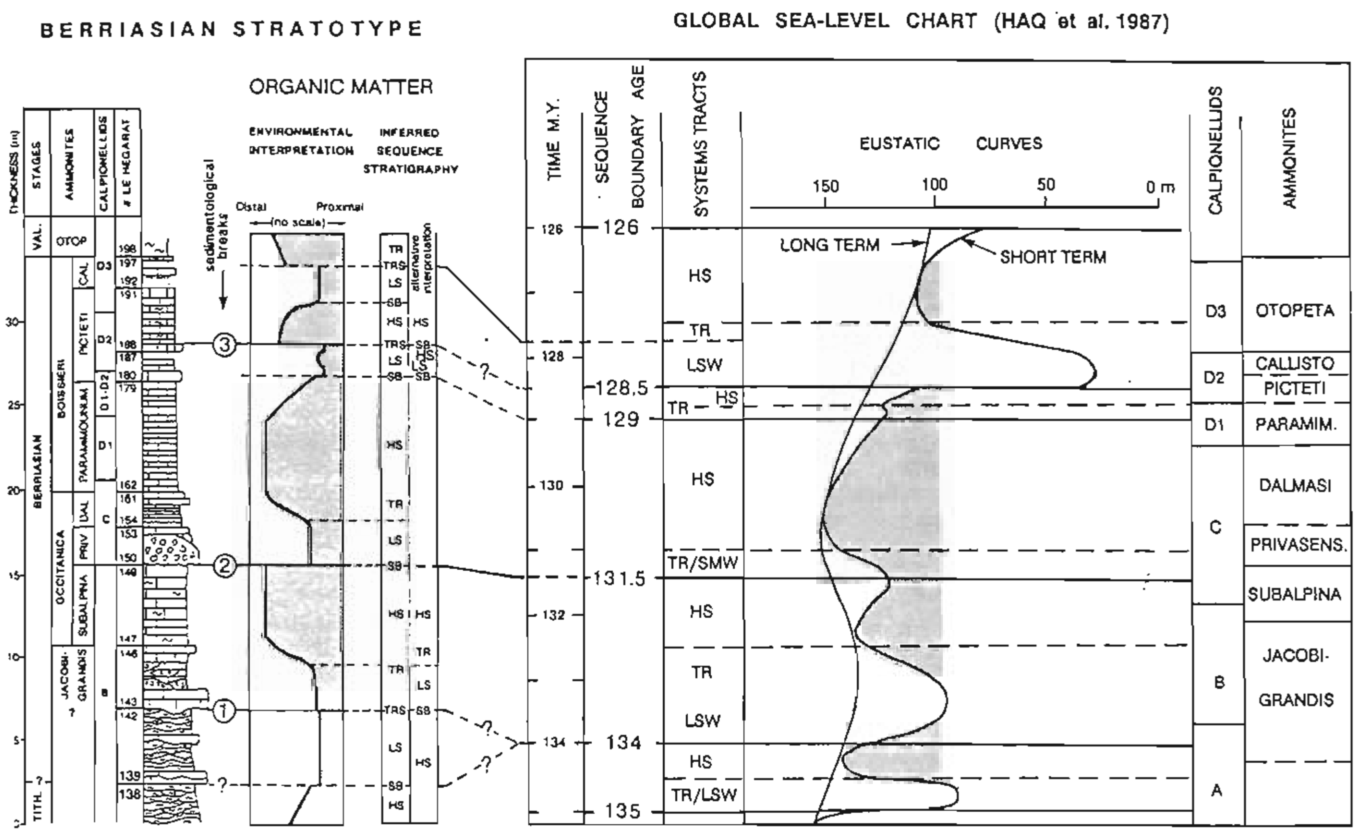

Fig. 1 : Environmental interpretation and inferred sequence stratigraphy derived from the composition of organic matter in the Berriasian stratotype. Tentative correlation with the global sea-level chart of Haq et al. (1987). Abbreviations of systems tracts as in Haq et al. (1987): SB = sequence boundary, TRS = transgression surface.

Séquences eustatiques et cyclicité dans le Crétacé moyen du Bassin Parisien

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RESUME. - Au cours du Crétacé moyen, le domaine épicontinental anglo-parisien enregistre une large transgression au cours de laquelle il devient le siège d'une sédimentation pélagique circalittorale -la craie- passant latéralement à des dépôts clastiques de plate-forme infratidale et prélittorale sur la bordure du Massif armoricain. Les enchaînements sédimentaires horizontaux et verticaux sont assez précisément datés sur des bases fauniques. La stratigraphie séquentielle propose un modèle interprétatif qui permet de préciser la dynamique des dépôts et des discontinuités. Du Cénomanien inférieur au Turonien moyen, la modulation de la transgression obéit à 4 cycles eustatiques de 3ème ordre (Haq et al. 1987).

Agencement des systèmes biosédimentaires et des discontinuités

Vers l'Ouest du Bassin parisien, les cortèges de dépôts s'agencent de la manière suivante :

*** cycle UZA - 1.7 (fin Dispar-Mantelli-Dixoni p.p.) :** Sur la plate-forme armoricaine, développement d'un Cortège Transgressif (Glauconie à *O. vesiculosa*) puis d'un Prisme de Haut Niveau (Marnes de Ballon) ; les Sables de Lamnay sus-jacents prennent valeur de Prisme de Bordure de Plate-forme avec apparition d'une discontinuité terminale sous faible tranche d'eau (Hardground Théligny). Dans le bassin normand, ce cycle est enregistré dans la Craie glauconieuse de St. Jouin avec des discontinuités profondes de condensation internes (HG St. Jouin et Bruneval) et sommitale (HG Rouen).

*** cycle UZA - 1.8 (fin Dixoni-Rothomagense-Jukes-brownei) :** Sur la plate-forme, CT et PHN des Craies de Théligny - Marnes de Nogent-le-Bernard - Sables du Mans ; PBP des Sables du Perche avec discontinuité terminale peu profonde (HG Duneau). Vers le bassin, CT, PHN et PBP enregistrés dans la Craie de Rouen avec discontinuités - niveaux condensés.

*** cycle UZB - 2.1 (Guerangeri-Geslinianum p.p.) :** Deux cycles mineurs y sont distingués.

2.1.a : Sur la plate-forme, PHN des Marnes à *O. biauriculata* des Sales à *C. obtusus* inférieure ; discontinuités internes de condensation (HG Antifer) et terminale (HG Antifer 2).

2.1.b : Sur la plate-forme, PHN des Sables à *C. obtusus* supérieurs avec Surface d'érosion sommitale (SE Mézières) ; dans le bassin, Craie à *A. plenus* supérieure avec discontinuités profondes et condensations (HG Antifer 3).

- cycle UZB - 2.1. (Juddii - Coloradoense - Nodosoides - Woolgari p.p.) : Sur la plate-forme, CT de la Craie à *T. carantonensis* scellant la cicatrice de ravinement qui peut tronquer la totalité de l'épisode 2.1 ; PHN de la Craie à *I. labiatus* ; vers le bassin, craie à *I. labiatus* s.l. avec discontinuités terminales (HG Tilleul 1-2).

Un certain nombre de *discontinuités* apparaissent ainsi à la limite des différentes séquences. Une même discontinuité présente une évolution diagénétique précoce très différente suivant le domaine considéré. Sur la plate-forme, les hardgrounds résultent d'une cimentation de matériel quartzeux et bioclastique par précipitation de carbonate sous une très faible tranche d'eau ; en milieu de bassin, les hardgrounds représentent un épisode de dissolution-recristallisation affectant une biomicrite pélagique à profondeur plus importante et précédant un niveau de condensation.

Enregistrements sédimentaires cycliques en domaine pélagique

La série crayeuse de Normandie offre plusieurs exemples de faciès alternants selon un motif cyclique dont l'épaisseur varie entre 0,30 et 1,00 m.

L'alternance liée aux bandes diagénétiques de silex est très bien exprimée au sein des séquences du Cénomanien, Turonien supérieur, Coniacien et Santonien. Les coupes de St. Jouin ou Sandouville présentent environ 50 cycles craie-silex pour le Cénomanien inférieur (25 m) et 30 pour le Cénomanien moyen-supérieur (15 m). Compte-tenu de la durée du Cénomanien (5 ± 1 Ma) et des lacunes ou condensations, ces cycles peuvent correspondre à des épisodes d'environ 40 000 ans. Cette périodicité est conforme à celle reconnue dans le Cénomanien de l'Ile de Wight pour des rythmes marne-calcaire (Hart 1987). La zone à *Jukesbrownei* de Normandie montre d'ailleurs la superposition à la même échelle de ces deux types d'alternance.

Dans le Coniacien inférieur de St. Pierre en Port, l'alternance *craie bioturbée à silex-craie noduleuse* a la même fréquence.

En absence de silex (Turonien inférieur-moyen de Senneville ou Etretat), une rythmicité peut être soulignée tantôt par des *bancs noduleux* ou *à flammes marneuses*, tantôt par une *bioturbation* alternativement dominée par les *Thalassinoides* ou *Zoophycos* et les *Chondrites*.

L'enregistrement de ces types de cyclicité disparaît latéralement avec une baisse ou une augmentation du taux de sédimentation.

Réponse des foraminifères bathyaux aux oscillations eustatiques et corrélation avec les séquences de dépôt: analyse dans le Valanginien-Hauterivien du bassin vocontien (S-E de la France)

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RESUME - Une maille serrée d'observations (au niveau des interbancs marneux) et des comptages en série dans les alternances marno-calcaires pélagiques du Crétacé inférieur vocontien ont permis de mettre en évidence des évolutions cycliques, à différentes échelles, de la composition des associations de foraminifères. Une corrélation de ces variations avec les oscillations eustatiques est pressentie.

1 - Evolution à long terme : Du Valanginien à la base du Barrémien, les associations de foraminifères évoluent dans le sens d'un enrichissement et d'une diversification avec prépondérance des formes calcaires. La fraction supérieure à 250 m d'abord constituée quasi exclusivement de Nodosariidés (Lenticulines essentiellement), s'enrichit en agglutinants quartzeux, puis en agglutinants à test calcaire (Dorothia, Spiroplectinata) et en Spirillines. Dans la fraction comprise entre 100 et 250 m, dominée par des agglutinants quartzeux, se développent progressivement les Spirillines, les formes porcelanées et surtout les agglutinants calcaires (Valanginien) ; puis les agglutinants quartzeux sont supplantés par les formes calcaires, Spirillines principalement, mais aussi petits agglutinants et rotalidés (Conorotalites, Gavelinella), le changement majeur se situant à l'Hauterivien inférieur. A l'Hauterivien supérieur, les foraminifères planctoniques apparaissent puis prolifèrent.

Pour l'ensemble de cette période, la courbe eustatique donnée par Haq et al. (fait état d'une tendance transgressive générale, avec un maximum à la limite Hauterivien-Barrémien. Il apparaît donc que la diversification croissante et l'enrichissement en formes calcaires, qui sont plus ou moins indépendants du faciès, coïncident avec une élévation continue du niveau marin.

2 - Evolution à court terme : La même évolution des associations se retrouve à une échelle plus fine, celle des séquences de 3ème ordre sensu Vail et surtout celle des paraséquences d'ordre inférieur. Ces séquences sont caractérisées par une base à dominante calcaire et un sommet plus argileux (Jacquin et al., 1989). On constate que le peuplement est proportionnellement plus pauvre en bas de séquence, tandis qu'en haut de séquence, il est plus abondant, de plus grande taille au niveau de maintes espèces et plus diversifié, surtout au sein des formes calcaires (par exemple, plus de gros agglutinants quartzeux et de Spirillines au sommet des séquences au Valanginien inférieur ; plus de Dorothia, plus de Spirillines, des gros agglutinants calcaires, des formes porcelanées et des Nodosariidés plus variés au Valanginien supérieur ; plus d'agglutinants calcaires et de rotalidés à l'Hauterivien). A partir du Barrémien et à l'Aptien, des phénomènes d'anoxie viennent perturber cette dynamique. Si les variations quantitatives (abondance) peuvent s'expliquer par un effet de condensation lié à une réduction du taux de sédimentation dans les niveaux à dominante marneuse, les variations qualitatives (augmentations de taille) doivent correspondre à une dynamique propre au peuplement, indépendante du faciès.

L'évolution à long terme des associations pouvant être corrélée avec une élévation continue, non contestée, du niveau marin, on peut donc interpréter les évolutions à court terme - qui sont similaires - de la même manière. Or les tendances à court terme se calquent sur le découpage reposant sur les concepts de la stratigraphie séquentielle (sensu Vail). Ainsi se trouve confirmé le fait qu'en domaine de bassin les bases de séquences, à dominante calcaire, correspondent aux périodes de bas niveau relatif (lowstand system tracts), et les sommets de séquences, à dominante plus argileuse, aux périodes de haut niveau marin relatif (transgressive and highstand systems tracts).

Il ressort de cette étude, pour la période du Valanginien-Hauterien :

- une analogie des évolutions à long terme (supercycles) et à court terme (paraséquences) de la composition des associations de foraminifères ;

- une confirmation, par le biais des foraminifères, de la validité du découpage séquentiel sensu

Vail en domaine de bassin ;

- corrélativement, la possibilité d'utiliser (dans certaines limites) les foraminifères pour interpréter les cortèges sédimentaires de bassin ;

- l'évidence que les foraminifères bathyaux, sans être tout à fait indépendants du faciès, ont ressenti, même sous une épaisse tranche d'eau, les effets des variations relatives du niveau marin : les dépôts de haut niveau relatif renferment les associations proportionnellement les plus riches, les plus diversifiées et les plus calcaires.

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The eustatic control over carbonate pelagic sedimentation on submarine plateaus

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ABSTRACT. - In the last years the increasingly improved concepts of sequence stratigraphy of Vail and coll. have provided an invaluable tool for all people working on problems of sedimentary basin analysis. The application of these principles seems to fail on particular kinds of carbonate series that is to say "neither shallow nor deep", typically eondensed pelagic sediments deposited on isolated submarine plateaus. Even if quantitatively minor on a world-wide scale, such rock complexes are widespread and important in the Mesozoic series of Western Tethyan passive continental margins.

In these settings sedimentation rates are very low, being due to the particle by particle settling of planctonic organisms, and omission surfaces are frequent. As a consequence of this virtually uniform sedimentation, rock units are very thin, laterally extensive and the growth of the plateau s completely aggradational. All the geometric and sedimentological criteria commonly used on shelf-slope sediments in order to distinguish depositional sequences are completely lacking.

Nevertheless a complex interaction between sea-level changes and sedimentation may be recognized. In completely pelagic depositional systems, in fact, the prime controlling factor is current activity which is linked to the overall ocean circulation pattern and, in turn, to eustatic variations. The more intense the idrodynamic regime, the more winnowed the sediments, frequent the hiatuses and intense the early submarine cementation. Conversely quieter movements of bottom water prevent reworking and early lithification, allowing a better preservation of fine-grained sediments.

A representative example of this model is to be found in the Rosso Ammonitico Veronese of Southern Alps (NE Italy). This Jurassic formation may be subdivided into three units :

- the lower one is massive and characterized by bored and iron-stained intraclasts which show the importance of early cementation. At the top bioclastic grainstones prevail, with mineralized hard grounds ;
- the middle one is made up by thin and planar beds of non-nodular mudstones and wackestones ;
- the upper one has a typical nodular structure due to selective early cementation but is almost devoid of intraclasts and mineralized omission surfaces.

The comparison between such series and Vail's charts of sea-level changes reveals some meaningful correlations. The deeply winnowed and mineralized sediments of the lower unit may be connected to the marked falls of sea level during Upper Bathonian and Lower Callovian, while the onset of micritic, non nodular sedimentation of the middle unit precisely corresponds to the Upper Callovian rapid rise of sea level and in particular to a maximum flooding surface of major importance.

The very peculiar pattern of sedimentation in Rosso Ammonitico Veronese, highly condensed and discontinuous, does not allow exact correlations with all the rise and falls events. In the light of the foregoing considerations, however, it is envisaged that, after the definition of a detailed biostratigraphic framework, depositional sequences may be recognized also in this settings : they will be bounded by lowstand-induced omission surfaces and possibly characterized by less winnowed, micrite-richer parts corresponding to sudden rises in sea level (condensed sections).

Liassic mineralized ammonite-bearing beds: a record of episodic deposition in the western Swiss Prealps

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ABSTRACT. - Depositional sequences of middle Liassic age (Sinemurian and Pliensbachian) of the Western Swiss Prealps, are preserved in the Medianes Nappe, which came from the Northern continental margin of the Tethys. They show mineralized beds occuring within different facies associations. These were related to contrasted basin morphology at the time of their deposition. This part of the Tethyan margin was characterized by regional differential subsidence (individual blocks measured less than 50 km), controlled by growth faults which were active since Rhaetian times.

Although thin (between 0,10 m to 0,50 m), the mineralized beds commonly contain several distinct faunal horizons stacked one upon another. The different outcrops we have studied have allowed us to recognize fourteen biostratigraphical horizons. They are the Resupinatum horizon of the Semicostatum zone, the Meridionalis and Glaber horizons of the Obtusum zone, and the (Quenstedti), Raricostatum, Boehmi, Meigeni and Insigne horizons of the Raricostatum zone from the Sinemurian. The Pliensbachian is represented by the Jamesoni horizon of the Jamesoni zone, the Alisiense and Crassum horizons of the Ibex zone, the Stockesi and Depressum horizons of the Margaritatus zone and the Spinatum horizon of the Spinatum zone. During the 15 millions years of the Sinemurian and Pliensbachian times, sediment thickness (when present) varies from 30 m and 50 m in the North to 200 m in the South. Mineralized beds are absent in the South, where only the lower part of the succession is preserved below a Late Jurassic unconformity. All of the previously cited horizons contain fauna which constitute in general a homogenous entity. They show affinities with North-West Europe, and comprise rare close endemic taxa or ubiquous taxa.

Petrographical and geochemical analyses of these beds show different phases of mineralization within an early diagenetic environment (phosphates, glauconite, amorphous silica impregnated with iron oxydes, hematite, calcite and, locally pyrite interlayered with these previous minerals). Reworked clasts of the same composition also occur and some Ammonites have corroded upper surfaces.

In conclusion, data indicates that deposition was episodic. The record of several successive horizons does not mean that deposition was continuous. Sediment accumulation was ponctuated by discontinuities recorded within the mineralized beds ; and the succession of : erosive surface, reworked clasts, mineralized beds ; may be interpreted in terms of fluctuations of relative sea-level. Besides, this part of the Northern continental margin suffered extensional tectonics, and the regional physiographical context, well established by the complex liassic basin morphology, is in agreement with the faunal affinities with the North-West Europe at that time.

Sea level changes and ammonite turnovers in the Bajocian of the Vocontian Trough (S-E France)

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ABSTRACT. - On the basis of the interpretation of the Vocontian basinal series in terms of systems tracts proposed by Ferry & Rubino (this volume), both middle (Humphriesianum zone) and upper Bajocian (Subfurcatum zone) sea level rises lasted the depositional time of four to five parasequences (about 4 to 5 hundred k-years ?). The second one is known as a strong transgressive event in Europe, and is marked in the Trough by mudstones both finer-grained and more marly on the average than in the lower to middle Bajocian below. On the Jura platform, the pattern of carbonate banks changed accordingly from an extensive reefal platform to oolitic shoals scattered on highs of the drowned banks. Changes in the ammonite fauna in the mudstones of the Trough do not occur at random. We have mixed the earlier work of Pavia in the Digne sections with newly-found ammonites. *Most of the change is concentrated in both cases in what is interpreted as the basinal equivalent of the transgressive tract*, using the terminology of Vail and coll. (1987). Such a tract that is often lacking or condensed, or represented by barren bioclastic limestones on platforms where most of the change cannot thus be studied in detail. The sequence boundaries (sea level falls) are marked by smaller changes. In both cases, *the turnover is achieved at what is interpreted as the maximum flooding surface.*

Figure 1 shows what happened during the upper Sauzei sea level fall and subsequent rise. Fauna is scarce within the limestones representing the sea level lowstand so that it is hard to know in this case if the disappearance of *Emileia* and *Bradfordia* really occurred at the sequence boundary or above. There is no agreement about the possible filiation between these genus and, respectively, *Chondroceras* and *Stegoxyites*. If such a filiation is correct, the replacement cannot be precisely placed but seems to start with the last parasequence of the lowstand tract and continue throughout the transgressive tract. The most prominent turnover is within the Sonniniidae. Some *Sonninia* are quoted in Spain and Morocco with the first *Dorsetensia* so that the replacement is thought to occur at the beginning of the rise in sea level rather than earlier. At Digne, the first *Dorsetensia* occur in the first transgressive parasequence marked by thicker marly interbeds. The lower boundary of the subzone given by Pavia in this section has thus no real ground and would rather be placed above, i.e. coincidental with the transgressive surface TS. Within the *Stephanocerataceae* changes are more difficult to spot with enough accuracy and are plagued by nommenclatural problems. The first *Stephanoceras* appear within the last parasequence of the lowstand tract and develop in the transgressive tract.

What is clear in this example is that the small turnover is finished at the maximum flooding surface, just below the highstand marls. There is some relationship between the low intensity of this faunal turnover and the modest sea level rise at the basis of the Humphriesianum zone. This elevation of relative sea level corresponds to thin marls separating two episodes of reefal carbonate deposition on the Jura platform.

The second example (fig. 2) is a basic case study from which the pattern of faunal turnovers may be extracted and found again in other sequences (see Atrops & Ferry, this volume). The sequence boundary is placed at the basis of a bundle of more limy parasequences that are time-equivalent with the second Bajocian reef of the Jura platform. This "surface" is marked only by small changes affecting the previous highstand fauna. Some first appearances are spotted within the parasequences composing the lowstand tract but changes occur faster in those composing the transgressive tract. The rise in sea level is marked by the extinction of the Stephanoceratidae and by a bloom of new forms belonging to the Perisphinctidae, some short-lived, other more durable. As in the previous example, the turnover is finished when the complete flooding of nearby platforms is achieved.

Because what is known here seems coeval with what is known elsewhere, the *basic problem to be addressed is to understand the mechanism of appearances*. One cannot always escape through invoking migrations. What is interesting is that the turnover seems to have proceeded by *steps coincidental with parasequences in the Milankovitch frequency band*. Solving the above question requires more heavy field work in statistically studying faunal assemblages bed-by-bed, including marly interbeds.

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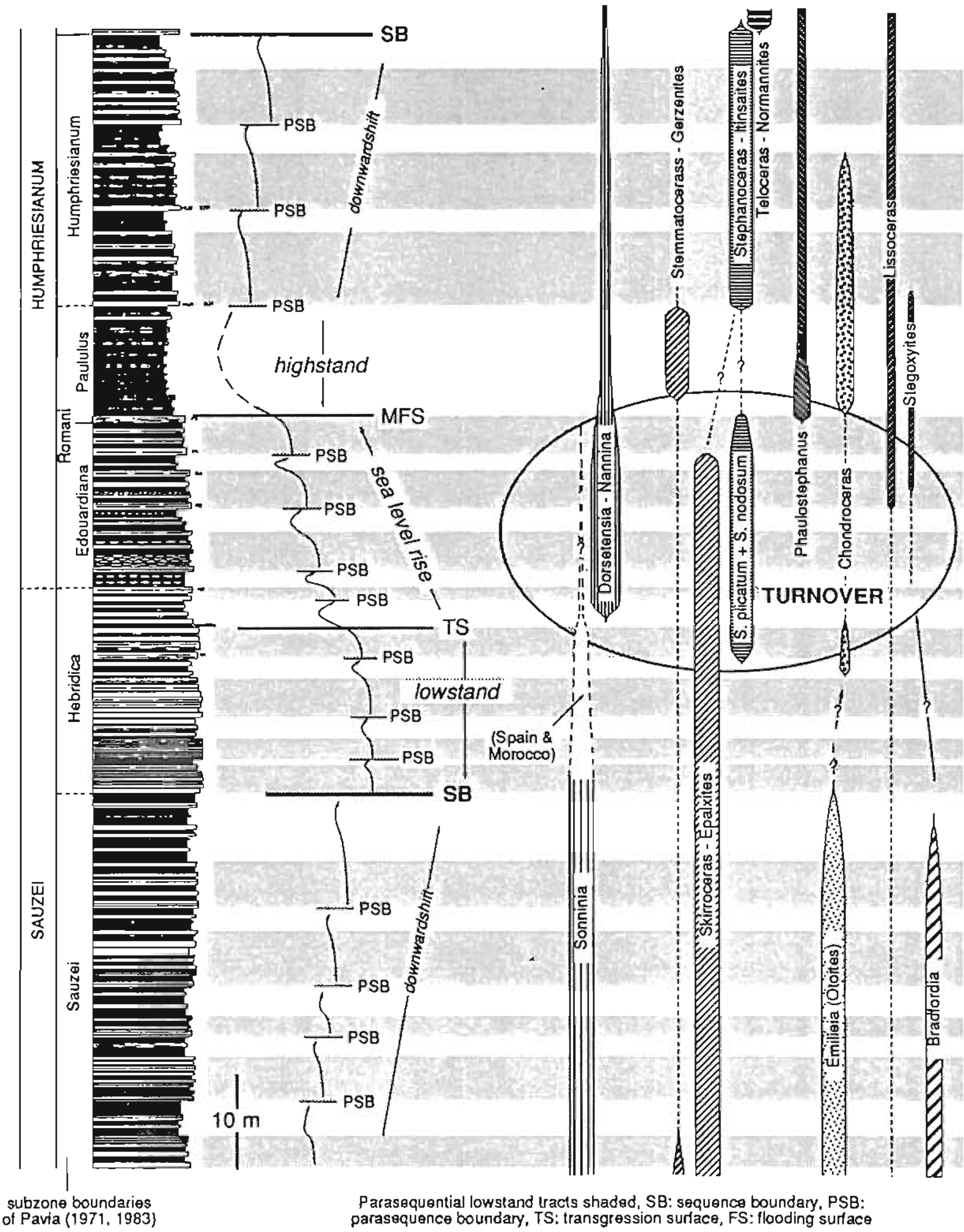

Fig. 1 - Vertical repartition of some ammonite genus before and after the late Sauzei fall in relative sea level, spotted in the basinal hemipelagic limestone-marl alternation of the Vocontian Trough near Digne, S-E France. Repartition mainly based on earlier work of Pavia. Interpretation of the hemipelagic series in terms of systems tracts (Vail and coll.'s sense) from platform to basin correlations. SB: sequence boundary, PSB: parasequence boundary, TS: transgression surface, MFS or FS: maximum flooding surface.

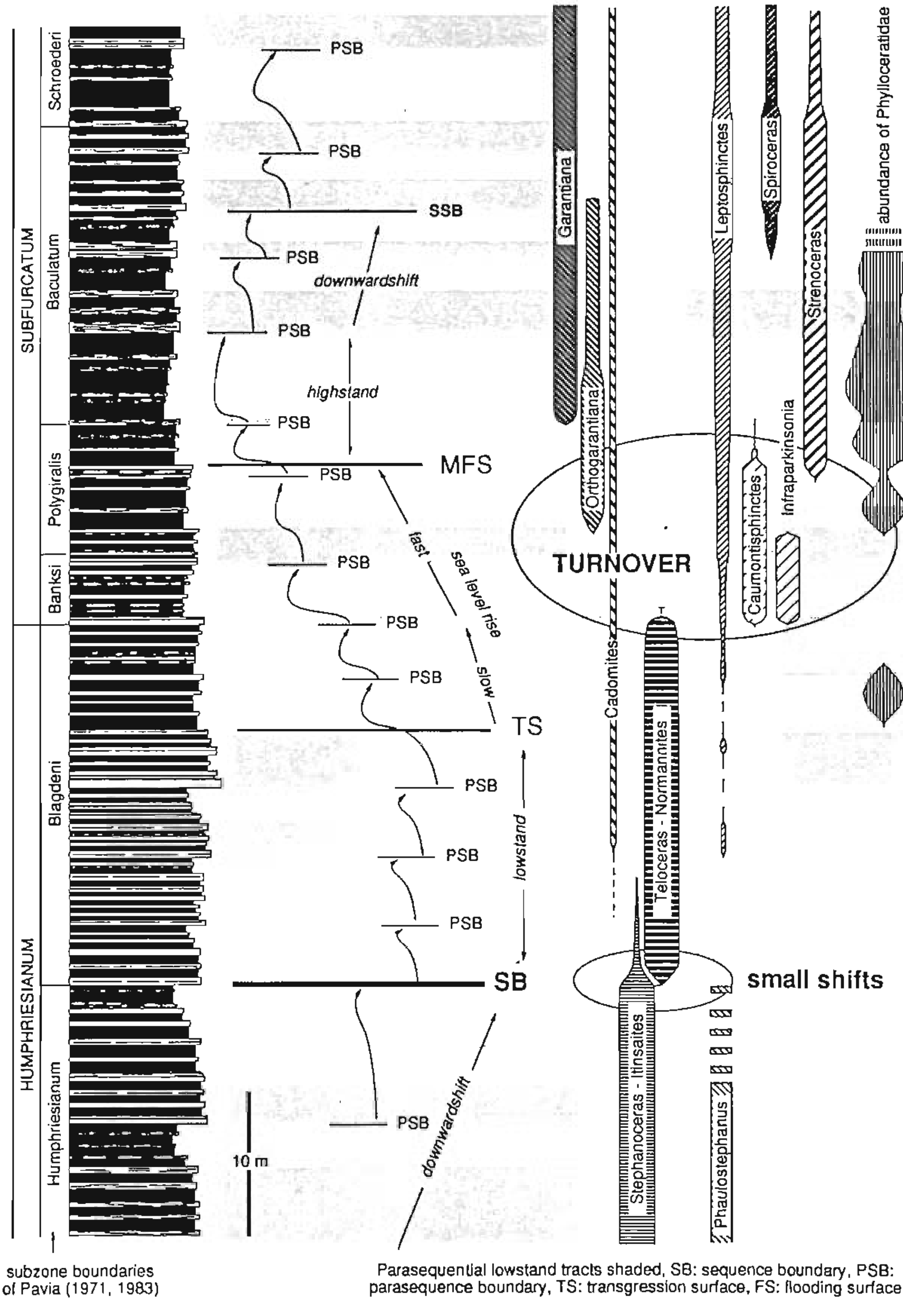

Fig. 2 - Vertical repartition of some ammonite genus before and after the late Humphriesianum fall in relative sea level, spotted in the basinal hemipelagic limestone-marl alternation of the Vocontian Trough near Digne, S-E France. Repartition mainly based on earlier work of Pavia. Interpretation of the hemipelagic series in terms of systems tracts and significance of abbreviations as on fig. 1.

Séquences de dépôt et cycles eustatiques de troisième ordre dans les alternances calcarénites-radiolarites du Jurassique de la Nappe de Balagne (Corse)

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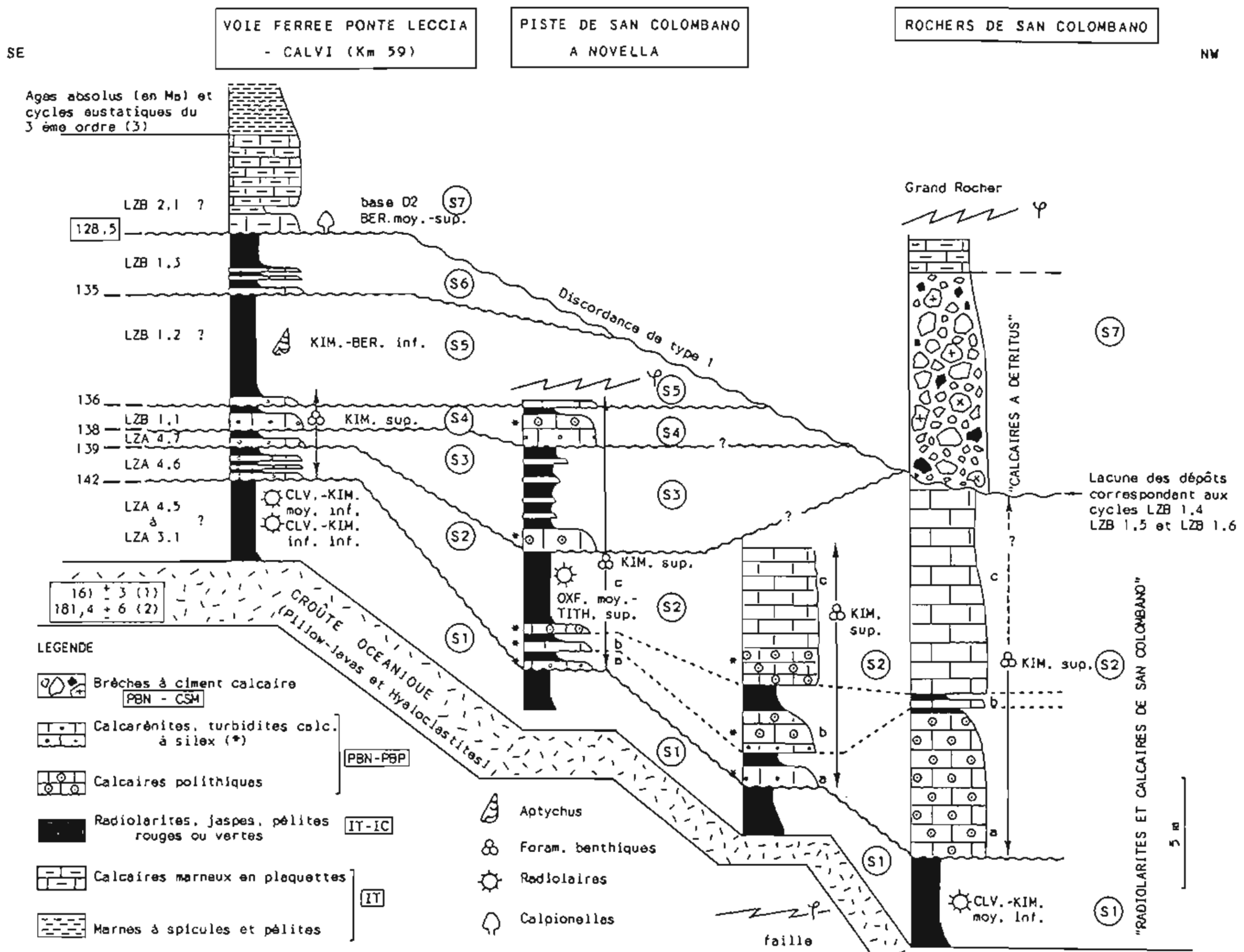
RESUME - Dans les unités allochtones d'origine orientale (Cima de Mutereno, San Colombano) constituant la Nappe de Balagne (Corse du Nord), la série sédimentaire jurassique s'étage du Callovien au Tithonique et repose sur une croûte océanique datée entre 181 et 161 MA. Cette série (fig.) s'articule à Cima de Mutereno en 6 séquences, S1 à S6, au plus décamétriques. S1 ne comporte que des radiolarites (de Wever et al. 1987) et correspond à une condensation de l'ensemble des cycles de 3ème ordre allant de LZA3-1 (Callovien inférieur) à LZA4-5 (Kimméridgien inférieur) difficilement séparables dans cette zone profonde du bassin à forte vacuité. Les autres séquences, S2 à S6, toutes granodécroissantes et rétrogradantes, ont valeur de séquences de dépôt au sens de Vail et al. (1987). Elles débutent par des



(1) Ohnenstetter et al. (1981); (2) Beccaluva et al. (1981); Haq et al. (1987)

calcarénites à silex et oolithes marquant le Prisme de bordure de Plate-forme (baisse brutale du niveau de la mer induisant l'érosion des carbonates plus proximaux et la resédimentation des Foraminifères benthiques et des Dasycladales) et s'achèvent par des radiolarites et/ ou des pélites interprétées comme les témoins d'un intervalle transgressif situé sous la CCD, à faible taux de sédimentation et concentrations microfaunistiques. Les discontinuités interséquences sont de type 2. On peut respectivement corréler les séquences S2 à S6 avec les cycles de 3ème ordre LZA4-6, LZA4-7, LZB1-1, LZB1-2 et LZB1-3 (intervalle Kimméridgien-Portlandien). Une septième séquence de dépôt S7, toujours à caractère rétrogradant, marque le début du Crétacé (cycle LZB2-1, Berriasien sous-zone D2) et constituée par la succession calcaires à Calpionelles (Intervalle Transgressif)/marno-calcaires et pélites (Prisme de Haut Niveau), se localise en général plus haut sur la plate-forme que les séquences précédentes. A San Colombano par contre, S7 se dépose plus en aval et début par une discontinuité érosive de type 1 (185,5 MA) jalonnant des accumulations de calcaires à détritus (Prisme de Bordure de Plate-forme ou Cône Sous Marin ?) consécutives à une baisse importante du niveau de la mer au-delà de la limite de la plate-forme induisant l'érosion du socle émergé (granites, roches métamorphiques) et des dernières séquences jurassiques antérieures (S3 à S6).

REFERENCES

de WEVER P., DANELIAN T., DURAND-DELGA M., CORDEY F. & KITO N. (1987) - *C.R. Acad. Sci. Paris*, t. 305, Sér. II, p. 893-900.

VAIL P.R., COLIN J.P., JAN DU CHENE R., KUCHLY J., MEDIAVILLA F. & TRIFILIEFF V. (1985) - *Bull. Soc. géol. France*, n° 7, t. ", p. 1301-1325.

Problem of eustatic 3rd order depositional sequence recording during transgressive supercycle Example of Albian carbonate/clastic mixed deposits of S-E France

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ABSTRACT. - On mature passive margins, when subsidence rate is steady, it seems probable that eustatically-driven 3rd order depositional sequences (DS), that were primarily defined in this context, must be recorded in the deep basin as well as on the shelf.

Detailed studies have been carried out on the Albian of South-East France, a region which belongs to the northern margin of the Tethys. It seems that recognition of all depositional sequences is more problematic than the conceptual model of Vail and coll. suggests it, especially in outer shelf settings, or even in the deepest parts of the basin during particular time intervals.

In the Vocontian Trough, all major DS of middle to upper Albian can be easily recognized on the basis of sandy turbidite systems (type 1 fan systems) that are emplaced at the basis of the sequences (Rubino 1984, 1988). But minor events as those occurring during early to middle Albian (106 and 103 m.y.) cannot be evidenced. Even the maximum floodings of these sequences canot be defined, because the series, made of dark marls, show numerous black shale layers that probably represent a parasequential signal rather than a sequential one (Breheret & Delamette 1988). This interval coincides with the first oceanic anoxic event (OAE1) which clearly indicates a worldwide transgressive event. Consequently, using available sedimentological data, biostratigraphical markers and basin-wide correlations, only 5 DS can be correlated with the sea level chart of Haq and others (1987).

On the surrounding shelves, things are really more complex. Schematically, there is three main types of sections: a) condensed or highly condensed, b) mixed, and c) sandy.

- *Condensed series* occur in eastern Provence, on the southeastern edge of the basin (Castellane and Nice subalpine arcs). They consist of 10 to 20 m thick glauconitic sandstones interbedded with phosphatic layers or nodular, silty and glauconitic limestones bearing polyzonal ammonite assemblages. Erosional surfaces occur within this thin formation, especially under phosphatic lag deposits.

Highly condensed series are common on the far northern edge (Helvetic domain) (Delamette 1986) and also in Provence. Thicknesses are less than 5 m. Facies bear phosphated stromatolites, iron crusts and glauconite. Some erosional surfaces have been found and related to sequence boundaries (Delamette 1988) but in these series, lower and part of middle Albian usually form an homogenous unit.

- *Mixed series* like those occurring on the drowned Barremian carbonate platform of the Vercors area (northern edge of the Vocontian Trough) consists of a basal condensed interval (representing lower to middle Albian) overlain by thick, cross-bedded units of glauconitic sandstones bounded by erosional surfaces.

- *Sandy series* occur on the western edge of the Trough (Rhodanian shelf) and also on the southwestern one (northwestern Provence). They form homogenous cross-bedded sandy units bounded by three erosional surfaces. A late Albian age is proved for the two upper units. The lower one is not dated. These sandy series are overlain by silty marls and burrowed silty limestones of latest Albian age (Vraconian). These sandy units, that bear a high content of glauconite and sometimes show a basal transgressive lag, are interpreted as *stacked transgressive system tracts* of middle to late Albian age. Depending on places it is possible to evidence 3 or 4 depositional sequences. In all cases lower to middle Albian deposits seem to be missing.

Interpretation : when putting toghether all data from shelves sections, a maximum of four DS can be recognized. By comparison with the Vocontian series, at least one sequence is missing. By comparison with the chart of Haq et al., three DS are in fact missing if the chart is right. How explaining these discrepancies ?

A first explanation may be the presence of a highly condensed interval on shelves representing early to middle Albian, that is to say in the basin the OAE1, as a consequence of a rapid transgression at the basis of UZA-1 supercycle. As a consequence, one may think that the minor sea leval fall (106-103 m.y.) has given minor deposits restricted to the inner shelf,

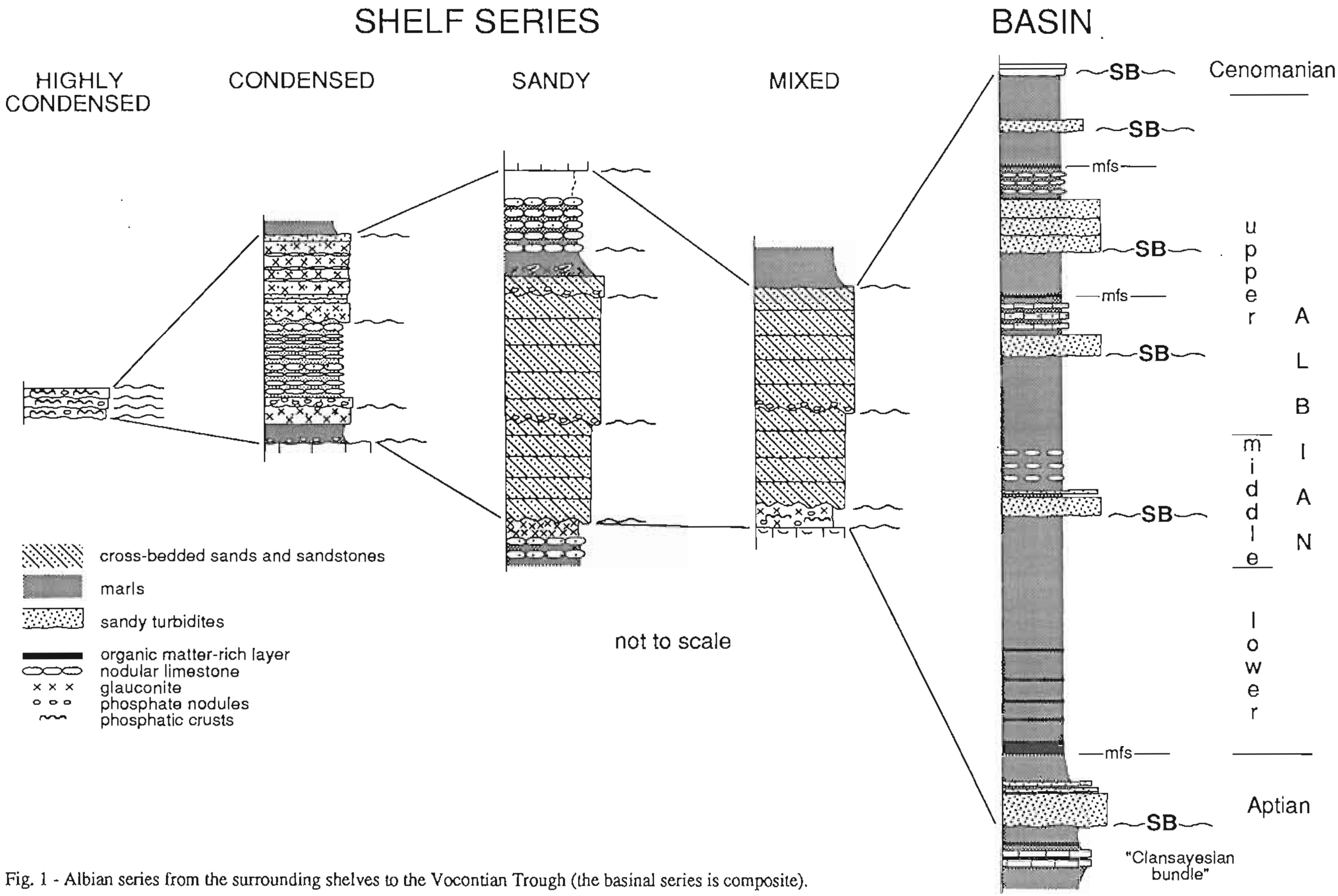

Fig. 1 - Albian series from the surrounding shelves to the Vocontian Trough (the basinal series is composite).

without siliciclastic input reaching the platform edge and the slope.

The second point that may be emphasized is the possibility of a complete reworking of the thin highstand lag deposit when later sea level falls reached the shelf edge. The emplacement of subsequent transgressive tracts wiped out these thin deposits.

A final point is trying to understand, if the interpretation of cross-bedded units as transgressive tracts is correct, why there is neither highstand or lowstand deposits preserved on the shelves. The best explanation involves tectonism. It is during Albian time that the African plate starts moving northward. Consequently, a regional uplift occurred, that created the so-called Durance Isthmus in the South. During this uplift, space available for sediment was created only during the transgressive period of third order cycles because eustatic sea level rise is then faster than uplift. Through the stillstand, as in the lowering phase, erosion dominates.

REFERENCES

BREHERET J.-G. & DELAMETTE M. (1988) - *GéoTrope*, v.1, p. 74-83.
DELAMETTE M. (1988) - *Publ. Dpt. Géol. Paléont. Univ. Genève*, 315 p.
HAQ B.U. et al. (1987) - *Science*, v. 235, p. 1156-1167.
RUBINO J.-L. (1988) - *GéoTrope*, v.1, p. 52-73.

Stratigraphie séquentielle du Malm et du Crétacé sur la marge orientale de la plaque ibérique. Causes tectoniques et eustatiques.

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RESUME. - La sédimentation sur la marge orientale de la plaque ibérique (Ibérie) pendant le Malm et le Crétacé inférieur s'est produite dans six bassins principaux, constituant des golfes de la Téthys. Ces bassins perdent leur individualité paléogéographique à partir de l'Albien, lorsque la sédimentation s'étend et les seuils paléogéographiques deviennent moins actifs.

Sur quatre cents kilomètres, le long de la côte orientale de la péninsule ibérique, nous pouvons reconnaître six bassins : 1) Salou-Garraf, 2) Perello, 3) Maestrat, 4) Oliete, 5) Aliaga-Penyagolosa, 6) Albacete. Il s'agit de bassins nés d'un rifting intra-continental et occupés par une mer épicontinentale. Parmi ces bassins, celui du Maestrat correspond à la zone où la sédimentation mésozoïque a été la plus active (jusqu'à 6500 m d'épaisseur).

La série sédimentaire du Malm et du Crétacé dans le bassin du Maestrat (jusqu'à 4750 m d'épaisseur), est constituée principalement de carbonates marins d'eau peu profonde, avec des intervalles de carbonates d'eau plus profonde. Les épisodes de sédimentation silico-clastique et les carbonates d'eau douce se trouvent normalement limités aux secteurs marginaux du bassin ; cependant, ils peuvent présenter des déplacements très remarquables vers le centre du bassin.

Nous avons caractérisé quatre épisodes dans l'histoire de la subsidence tectonique du bassin du Maestrat : 1) Permien supérieur-Oxfordien, 2) Kimméridgien-Hauterivien, 3) Barrémien-Albien inférieur et 4) Albien moyen-Sénonien. Chaque épisode commence avec une forte augmentation de la vitesse de subsidence et continue avec une diminution progressive de cette vitesse, jusqu'à des valeurs très réduites. Nous avons observé des vitesses de subsidence tectonique du socle à l'air libre élevées pendant le Kimméridgien et le Barrémien (43 m/MA). Ces vitesses diminuent progressivement jusqu'à 10 m/MA dans l'Hauterivien et dans l'Albien inférieur. Cette évolution est attribuée à une alternance de périodes de rifting et de subsidence thermique. Ces épisodes contrôlent le développement des séquences de dépôt.

Nous avons réalisé une analyse stratigraphique séquentielle qui a permis de caractériser dix-sept séquences de dépôt pour l'intervalle Oxfordien-Sénonien. Ces séquences sont limitées par des discontinuités (discordances et/ou disconformités). Chaque séquence constitue un prisme sédimentaire qui se termine en biseau vers les bords du bassin et recouvre progressivement (onlap) les discontinuités de la limite supérieure des séquences de dépôt précédentes.

La limite basale des diverses séquences de dépôt est caractérisée par une des situations suivantes:

1) Exposition et érosion d'une partie importante de la plate-forme, avec déplacement du biseau marginal d'eau douce vers le bassin et, ensuite, invasion de la plate-forme par des matériaux silico-clastiques (par exemple: séquences de dépôt du Valanginien inférieur, séquence de dépôt du Valanginien supérieur). 2) Exposition et érosion d'une partie importante de la plate-forme avec latérisation (par exemple : séquence de dépôt du Barrémien basal). 3) Exposition avec érosion et invasion de la plate-forme par des apports silico-clastiques importants (par exemple : séquence de dépôt de l'Aptien inférieur, séquence de dépôt de l'Albien moyen, séquence de dépôt de l'Albien supérieur-Cénomanien moyen) ou 4) Exposition et érosion limitées aux secteurs les plus marginaux de la plate-forme.

Les cortèges sédimentaires de bas niveau (LST) peuvent être formés par des importants dépôts deltaïques ; c'est le cas de la séquence de dépôt de l'Aptien inférieur.

Les cortèges sédimentaires transgressifs (TST) de chaque séquence de dépôt peuvent être plus ou

moins développés en fonction de l'espace créé par la subsidence.

Les cortèges sédimentaires de haut niveau (HST) peuvent présenter des progradations très remarquables ; c'est le cas de la séquence de dépôt de l'Aptien supérieur, qui atteint les 5 kilomètres de développement horizontal.

La corrélation des dix-sept séquences de dépôt entre les différents bassins s'avère difficile. Ceci est attribué à l'influence de la tectonique (rifting), par moments plus importante que l'influence de l'eustatisme, sur la sédimentation..

Use of depositional sequence boundaries as deformation markers : depositional sequence sets and fold-and-thrust systems in the Cretaceous South-Pyrenean foredeep basin

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ABSTRACT. - Tectonic analysis and sequence stratigraphy (in the sense of Vail, 1987) are combined in order to interpret thrust propagation in space and time. Sequence boundary mapping leads to the construction of isochrone maps (fig. 1) in which time-lines are calibrated in million years (Ma). This procedure reveals the geometrical and chronological relation-ships between tectonic structures and depositional sequence sets, and also allows to estimate the chronology and the timing of tectono-sedimentary processes.

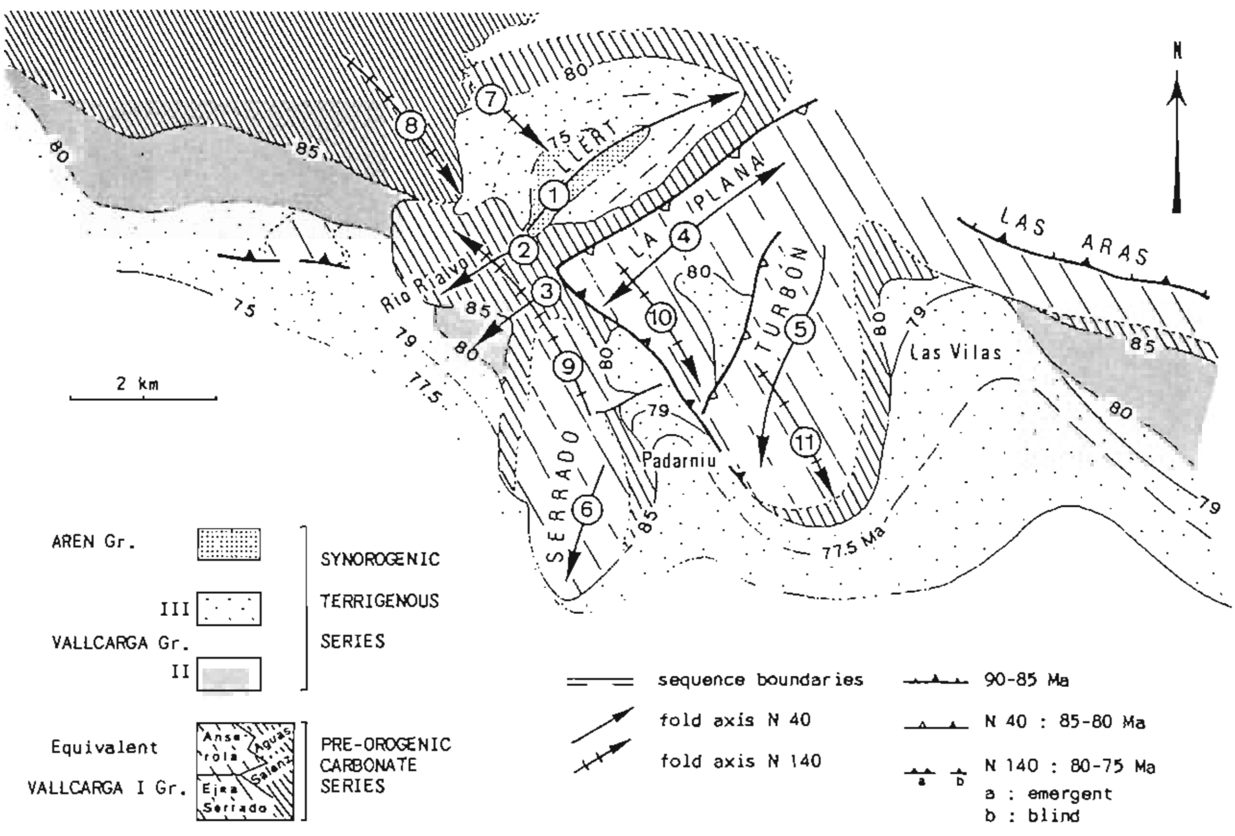

Fig. 1 - Depositional sequence sets and fold-and-thrust systems in the Turbón area.

This method leads to the characterization of a Cretaceous foredeep basin (in the sense of Bally 1980) in the South Central Pyrénées (fig. 2). This perisutural basin includes : i) a preorogenic carbonate ramp dipping northwards towards the megasuture axis; ii) four clastic wedges bounded by major regional unconformities. Each unconformity marks the transition to the new foredeep regime, and the depotcenter migration signs the fold-and-thrust sequence propagation starting from the latest Turonian (90 Ma).

Fold-and-thrust systems are correlated with depositional sequence sets (acting time span : about 5Ma). The time of displacement along the thrust surfaces and the time of fold building are measured with reference to the age of the sequence boundaries involved in the tectonic structures (acting time span : about 1 Ma). In this foredeep four depositional sequence sets

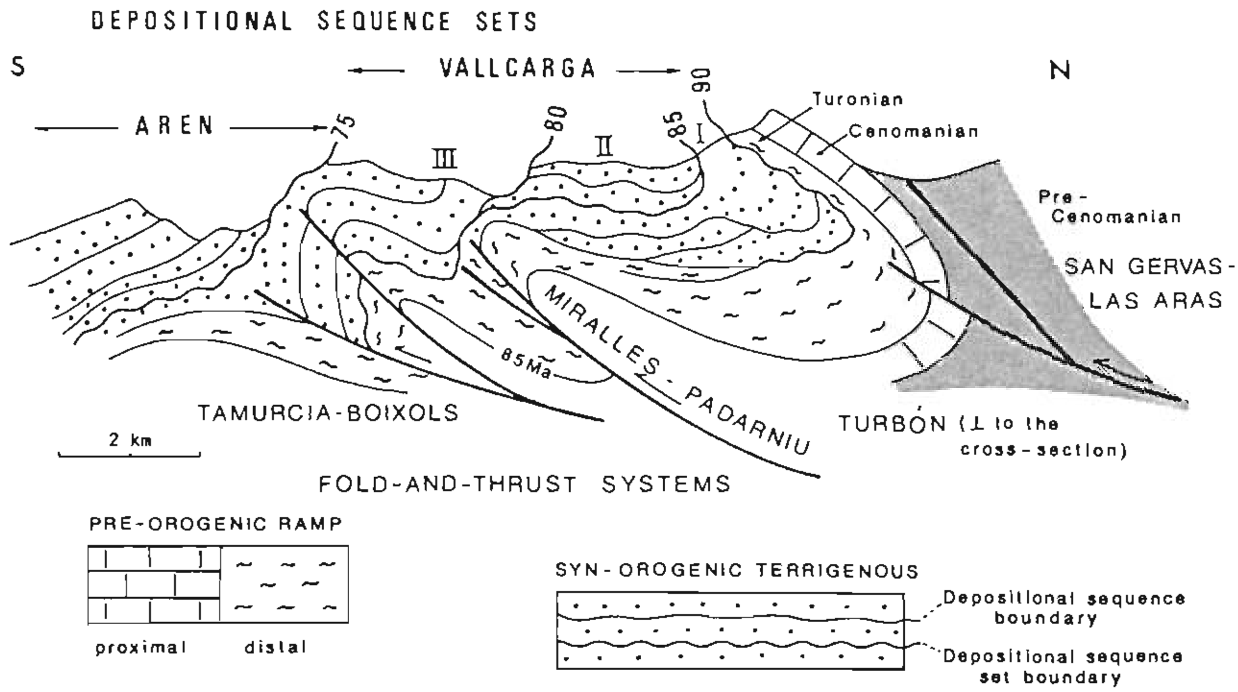

Fig. 2 - Depositional sequence sets - fold-and-thrust systems relationships in the South-Pyrenean foredeep (Noguera Ribagorzana valley).

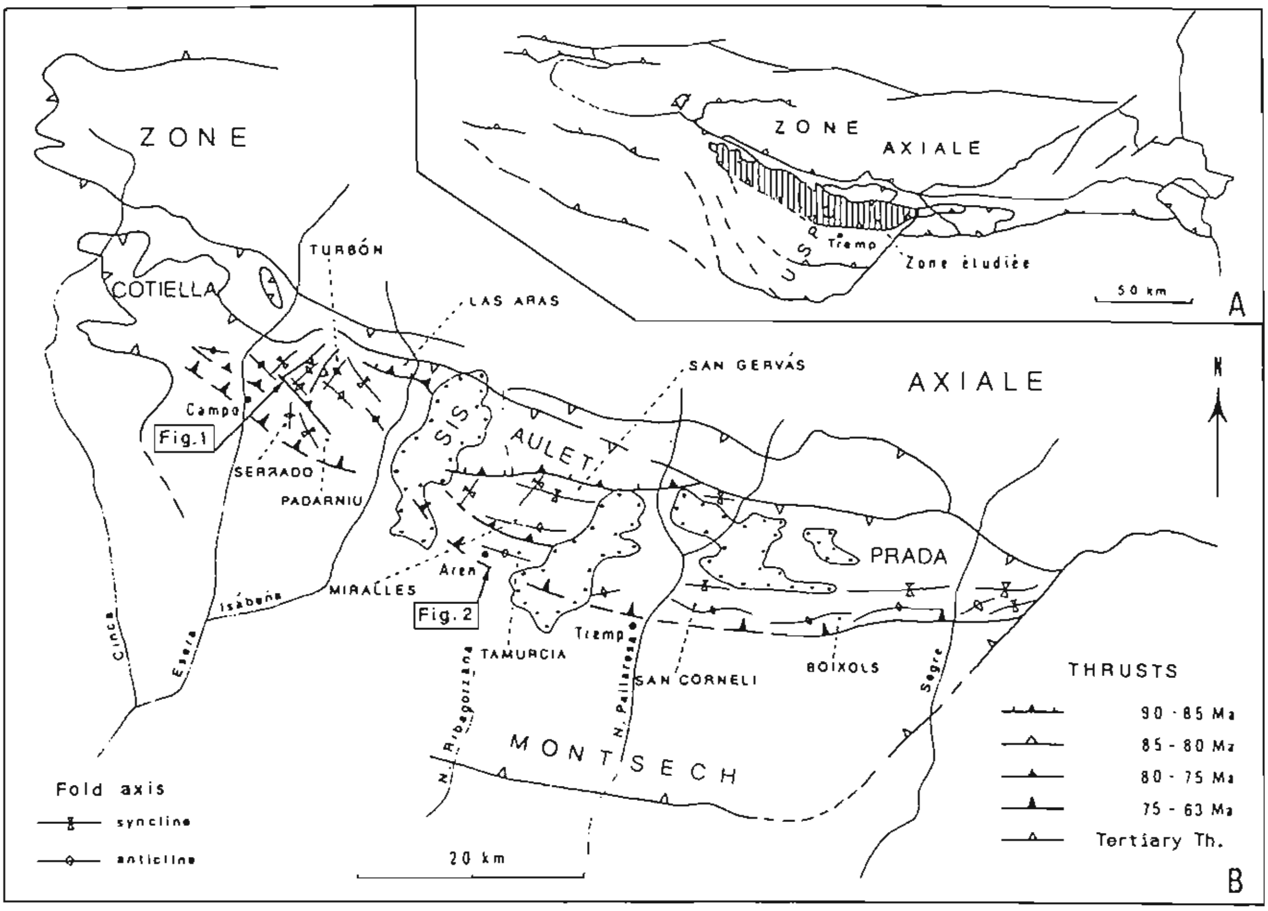

Fig. 3 - South-Pyrenean Cretaceous fold-and-thrust belt.

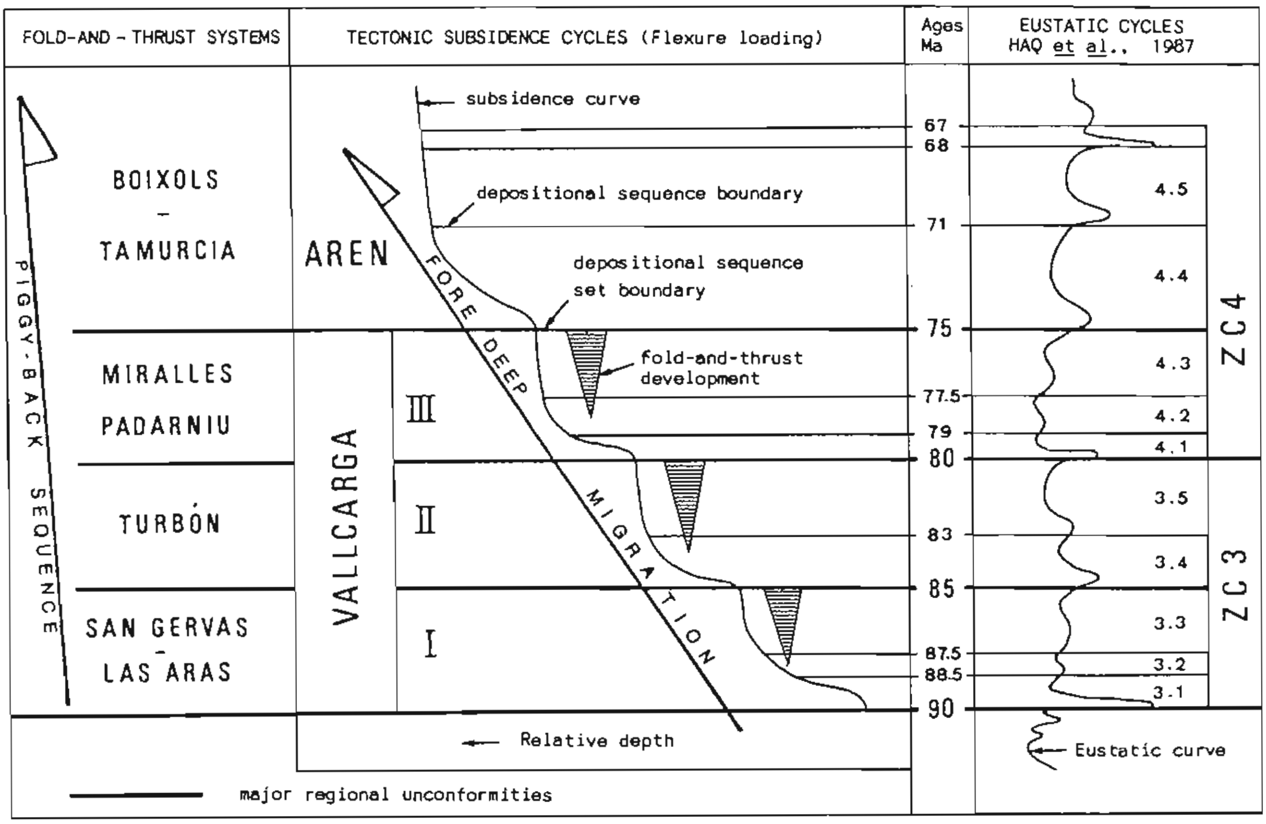

Fig. 4 - Eustacy-Tectonic relationships in the South-Pyrenean Cretaceous foredeep.

migrating away from the axis of the suture are related to four steps of a piggy-back fold-and-thrust sequence (fig. 3) : San Gervas - Las Aras (90-85 Ma) ; Turbon (85-80 Ma) ; Miralles - Padarniu (80-75 Ma) ; Boixols - Tamurcia (75-60 Ma). Such tectono-sedimentary evolution shows that a shortening regime on the southern side of the Pyrénées acted from latest Turonian through Senonian times, i.e. throughout the so-called flysch deposition.

An important conclusion is that the foredeep basin is divided into eustatically-controlled depositional sequences and tectonically-controlled depositional sequence sets (fig. 4).

Cyclic sedimentation in peritidal carbonates (upper Tithonian - lower Berriasian, French Jura Mountains)

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ABSTRACT. - Three complete sections of the Tidalites-de-Vouglans Formation (Portlandian, Upper Tithonian) and the Goldberg Formation (Purbeckian, Lower Berriasian) have been studied in the French Jura. The sedimentary record consists of well stratified carbonates which represent shallow-lagoonal, intertidal and supratidal depositional environments where salinities ranged from normal marine to hypersaline or freshwater.

The beds are hierarchically stacked. One bed represents in most cases an elementary depositional sequence. An average of 5 elementary sequences composes larger sequences, which again form groups of 4. The sequences of all three orders generally display a shallowing-upward trend of facies evolution. Recurring pedogenetic caps and wide-spread erosion surfaces imply repeated drops of sea level, and thus sea level fluctuations.

As the formation of the sequences was, at least partly, controlled by sea level, sequence stratigraphy may be applied in their description and interpretation. Bed surfaces correspond to sequence boundaries, the overlying calcretes, conglomerates and marls to lowstand deposits. Transgressive surfaces are mostly well defined. Transgressive deposits contain reworked pebbles and mixed marine and freshwater fossils. Highstand deposits commonly exhibit subtidal, marine to restricted facies in their lower part, then shallow up into intertidal and supratidal, hypersaline or freshwater facies.

The hierarchical stacking of sequences is probably due to sealevel fluctuations controlled by climatic cycles in the Milankovitch frequency band. The elementary sequences may correspond to the 21,000-year cycle of the precession of the equinoxes, the two larger orders of sequences to the eccentricity cycles with periods of 100,000 and 400,000 years.

Partial time control by ammonites and charophyte-ostracod assemblages allows to integrate these small-scale sequences within the large sequences resulting from globally recognized sea level fluctuations. Large-scale features of sequence stratigraphy are not always easy to recognize : in the peritidal depositional environments, high-frequency sea level fluctuations overprinted many of the signals of a general sea level change. A transgressive surface at about 131 my and a sequence boundary at 131.5 my could be identified at the top of the studied sections. A sequence boundary at 134 my is thought to mark their base. This indicates a duration of 3 my for the studied sedimentary record. However, analysis of the sequential pattern and timing by the supposed Milankovitch cycles rather suggest a duration of about 3.5 my.

More biostratigraphical and palaeomagnetic work, very detailed analyses of facies evolution and sequential patterns, and comparisons with other, widely-spaced sections are needed to resolve this incoherency. If it can be demonstrated that the recognized sequences indeed represent Milankovitch cycles with periodes of 21,000, 100,000 and 400,000 years, and if time-correlations of the sequences are well established, a very precise framework of absolute time will be available.

Stratigraphic signatures separating tectonic, eustatic and sedimentologic effects on sedimentary sections

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ABSTRACT. - The depositional patterns of sedimentary rocks are controlled by the complex interaction of tectonics, eustacy and sediment supply. Tectonic and eustatic effect combine to cause relative changes of sea level which control the space available for sediments (accommodation space). Sediment supply controls how much of the accommodation space, created by the relative changes of sea level, is filled. This paper demonstrates how the signature of each of these variables can be recognized in the stratigraphic record and quantified. The resulting categorization of sedimentary rocks is important for basin analysis, paleogeographic reconstructions, geologic history interpretations, resource evaluation of sedimentary basins and global correlations. The effects of tectonism, eustacy and sediment supply are ranked according to their cumulative effect on the space available (accommodation) (fig. 1).

Tectonism has the greatest effect on accommodation and is divided into three stratigraphic signatures. These three signatures are : sedimentary basins, major transgressive/regressive facies cycles, and structuring and or volcanism. The evolution of sedimentary basins are interpreted as first-order tectonic cycles. This is observable in a generalised regional tectonic subsidence curve. A basin's first-order tectonic subsidence cycle is non-periodic and regional in nature ; it is created by thermal processes or flexural loading. Major transgressive/regressive facies cycles are caused by second-order tectonic cycles. They are formed during the time interval between significant increases in the rate of tectonic subsidence. The second-order tectonic cycles are also non-periodic and regional in nature. They are created by abrupt regional increases in the rate of tectonic subsidence within a basin and are related to plate tectonic events and

Stratigraphic Analysis

	Tectonic Effects			Eustatic Effects		Sedimentologic Effects
Stratigraphic Signature	Basin Formation	Major Transgressive/ Regressive Facies Cycles	Folding, Faulting, and Volcanic events	Major Continental Flooding Cycles	Sequence Cycles	Depositional System Events
Distribution in Space	Regional	Regional	Local to Regional	Global	Global	Local
Distribution in Time	1st Order Tectonic Cycles Non-periodic	2nd Order Tectonic Cycles Non-periodic	Non-periodic	1st Order Eustatic Cycles	2nd-5th Order Eustatic Cycles	Episodic
Cause	Flexure Loading Thermal Cooling	IntraPlate Stress (Changes in Subsidence Rates)	Local stresses Thermal Perturbations	Tectonoeustasy Changes in Ocean Basin Volume	Glacioeustasy ? Changes in Water Volume	Local Sedimentary Processes Storm Events, Tides, Floods

Highest — Cumulative Effects on Space Available for Sediments (Accomodation Space) — Lowest

Figure 1

intraplate stresses. Structuring and volcanic events are non-periodic. They commonly occur during particular phases of the second-order tectonic cycles, depending on the basin type. They can be regional to very local in nature and are caused by the development of local stresses and thermal perturbations. Structuring tends to enhance or obscure eustatically caused sequence and system tracts boundaries, but does not affect the age of the boundaries when dated at their conformable position. Structuring events may trigger stratigraphic marker beds, such as slumps and megaturbidites. Volcanism will produce bentonite stratigraphic marker beds and datable igneous sills and dikes.

The effect of eustacy is relatively minor on the accommodation space, but it is of major importance in regulating the rate of change of shelfal accommodation. The eustatically controlled rate of change of relative sea level is the major controlling factor of the timing of stratigraphic discontinuities. The discontinuities create the boundaries between sequences, systems tracts and periodic parasequences. Eustatic effects are divided into two stratigraphic signatures : major continental flooding cycles and depositional sequence cycles. Major continental flooding cycles are first-order eustatic cycles. They are non-periodic and global in nature, and are expressed by important variations in the sediment encroachment on continental margins. These continental flooding cycles are originated by changes in sea level which, in turn, create accommodation space on the continental margins. High sea level causes increased accommodation, and sediments extend at the time of deposition far onto the continents. Low sea level causes decreased accommodation, and sediments are restricted to continkental margins and tectonically low areas. The cause of continental flooding cycles is believed to be tectonoeustasy (changes in ocean basin volume). During the Phanerozoic there are two continental flooding cycles : one occurs primarily in the Paleozoic and the other in the Mesozoic and Tertiary. Depositional sequence cycles are believed to be caused by third-order eustatic cycles ; their duration averages about 1.6 M.A., ranging between 0.8 and 4.0 M.A. They group into se-

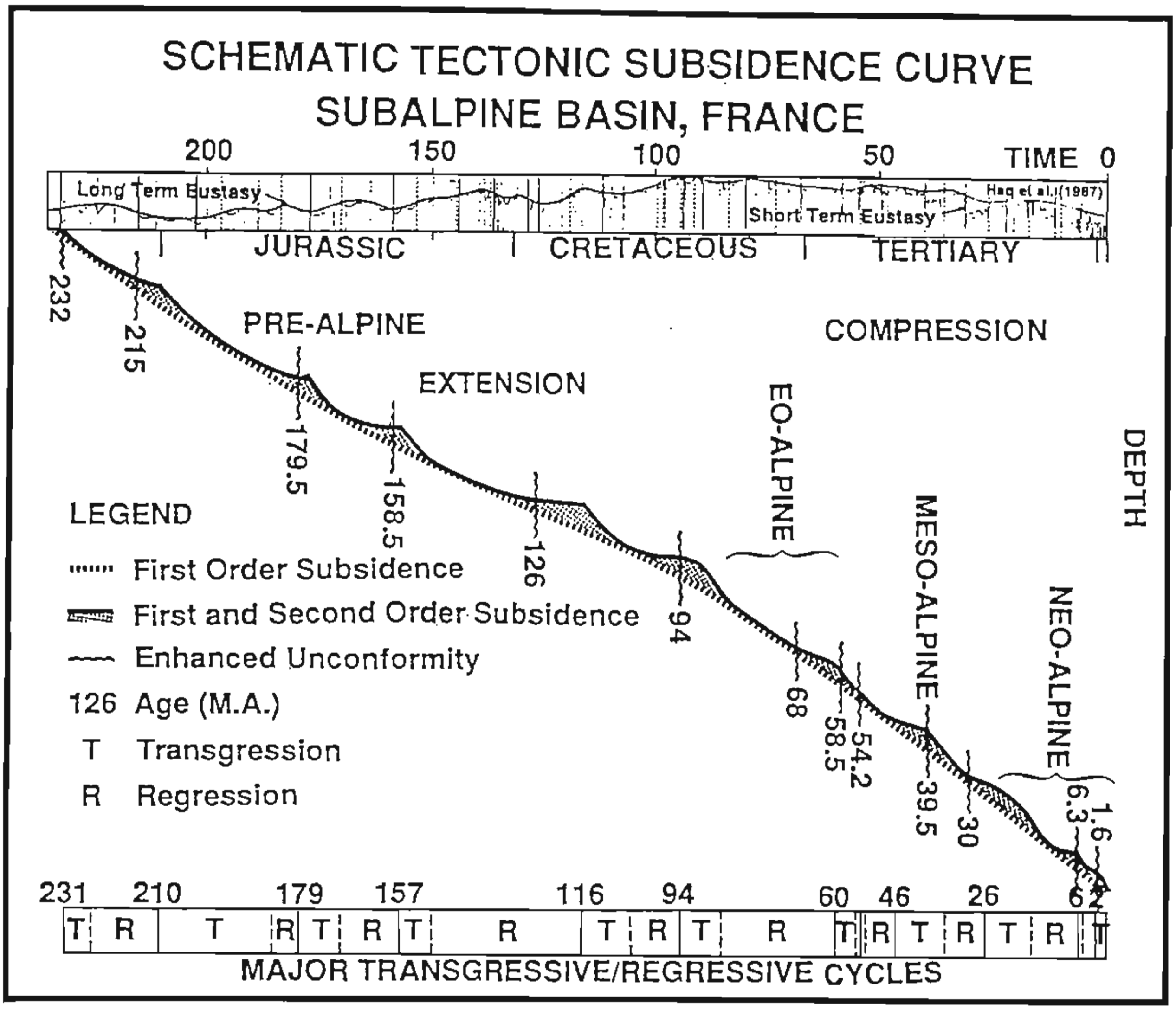

Figure 2

quence sets which are throught to be originated by second-order eustatic cycles whose duration average about 9-10 M.A. The second-order eustatic cycles are commonly grouped in packages of four (approx. 36 M.A.), and are called second-order eustatic cycle sets. Depositional sequences are composed of parasequences. Paresequences are considered to be fourth and fifth-order cycles. Depositional sequence cycles are thought to be caused by glacioeustacy (changes in water volume). Periodic parasequences are probably caused by climatic changes, which provoke minor relative changes of sea level, and are related to the Milankovich cycles.

The sedimentologic effect does not create accommodation space, on the contrary, it fills the space originated by the relative changes of sea level. It is episodic in nature and local in distribution. The sedimentologic effect involves local sedimentary processes such as storm events, tides and floods. Thus laminae, laminae sets, beds and bed sets are built forming lithofacies tracts and depositional systems. Stratigraphic marker beds may be created by certain depositional events. Episodic parasequences may be created by such factors as delta lobe shifts.

Figure 2 shows our first working hypothesis of the application of these concepts to the Subalpine Basin in southeastern France.

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