Lower sea levels in the Middle Cenomanian

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Abstract: It has been known since the 1970's that the relatively high sea levels during the Cenomanian in southern England and northern France were interrupted by a strong fall in sea level early in the Middle Cenomanian. This was a eustatic trough whose effects can be found not only in north-west Europe, but also from western Kazakhstan in central Asia to Texas, Colorado and South Dakota in the U.S.A.

Key Words: Mid Cenomanian eustatic low; Rouen Fossil Bed; *Primus* Event; Thatcher Limestone [Colorado]; Subzone of *Turrilites costatus*

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Résumé : ***Bas niveaux marins au Cénomanien moyen.-*** Depuis les années 70, il est admis que les hauts niveaux marins d'âge cénomanien identifiés dans le sud de l'Angleterre et le nord de la France ont été interrompus par une chute significative de ce même niveau relatif au début du Cénomanien moyen. Les effets de ce bas niveau eustatique ont été observés non seulement dans le nord-ouest de l'Europe, mais également depuis l'ouest du Kazakhstan (en Asie centrale) jusqu'au Texas, au Colorado et au Dakota du Sud (en Amérique du Nord).

Mots-Clefs : Bas niveau marin ; Cénomanien moyen ; couche fossilifère de Rouen ; événement à *Primus* ; Thatcher Limestone [Colorado] ; Sous-zone à *Turrilites costatus*

Introduction

One of the famous geological features in Normandy is the Rouen Fossil Bed, known as a source of fossils since the early 19th century. It is a glauconitic chalk with a little quartz-sand and with numerous internal moulds, mainly of molluscs, preserved in light brown collophane. This is a typical condensed facies in the Upper Cretaceous of northern Europe, a condensation during a transgression. It is this transgressive aspect which has generally been remarked on until recently, *e.g.* DANGEARD (1951). But it is widely agreed that transgressions associated with condensation are often preceded by regressions which resulted from a fall in sea-level (*e.g.* CURRY, 1989; SARG, 1989). Interestingly, it was not until 1980, with the work of JUIGNET, that there was an analytical emphasis on the sea-level fall and regression beneath the Rouen Fossil Bed, shown up by a widespread hardground named by JUIGNET as Rouen no. 1 Hardground. That there was this marked low in the sea-level around the start of the Middle Cenomanian had already been suggested by COOPER (1977, fig. 1).

There is now a detailed survey of the sequence-stratigraphy in the Cenomanian of the Anglo-Paris basin (ROBASZYNSKI *et alii*, 1999). They recognized: "The presence of an important fall in sea-level (…) represented on the basin margins by a marked break at the Lower-Middle Cenomanian boundary" but they did not provide an analysis of sea-level changes through the Cenomanian. Indeed, if one takes the sequence-boundary to mean the trough in the sea-level, they place this trough within the Zone of *Mantelliceras dixoni* (ROBASZYNSKI *et alii*, 1999, fig. 14). This is appreciably earlier than the actual trough.

Much of the Cenomanian chalk succession in the basinal successions in England, France and Germany is developed as alternations of chalk and clay-marl. These simple rhythms are believed to be MILANKOVITCH cycles of 20,000 - 23,000 years (HART, 1987; GALE, 1990; GALE *et alii*, 1999). GALE has carefully logged these rhythms so that we have a detailed cyclostratigraphy for the Cenomanian stage (GALE, 1995). But these cycles do not show the same proportion of $CaCO_3$ to siliciclastic minerals through the Cenomanian (Table 1). Long ago HATTIN (1966) demonstrated that the overall ratio of chalk to clay in such successions was a measure of sea-level. Deeper water means that the supply of clay detritus will be further from the basin. At such times the chalk unit in the rhythm is almost pure calcite and the marl unit is insignificantly thin. When the sea is more shallow, the source of detritus will be closer to the depositional basin. Each rhythm will then have a thin chalk unit in which even

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the chalk has some admixture of clay; and the marl unit is prominent and more clay than marl (HART, 1987, figs. 1b and 1a). As

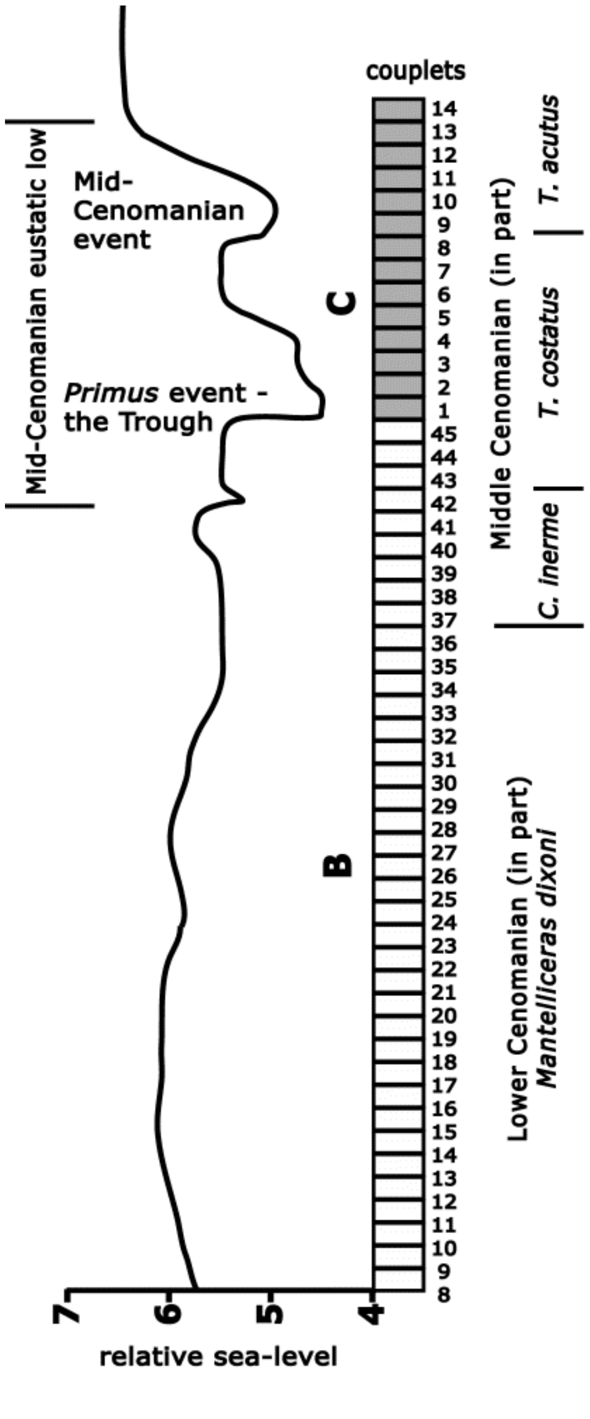

Figure 1: Relative sea-level changes through the latest Early Cenomanian and early Middle Cenomanian in north-west Europe. The graph assumes that the proportions of carbonate and clay in chalk successions are a measure of sea-level. These proportions in the rhythmic couplets in the Cenomanian are described by GALE (1995).

further developed by KAUFFMAN (1969), and summarized by HANCOCK & KAUFFMAN (1979), the sequence of ratios can be used to make a graph of rises and falls in sea-level, and their resultant transgressions and regressions (Fig. 1). The overall pattern is easier to see in the Western interior of the USA where the climate ensured that there is a full development of nearer shore clastic sedimentation.

Figure 1 is based on chalk-marl data from basinal successions in south-east England, north-east France and the Münster basin in Germany. The broad lower sea-level from late in the Zone of *Cunningtoniceras inerme* to the early part of the Subzone of *Turrilites acutus* is widespread and is here called the Mid-Cenomanian Eustatic Low. The most extreme part of this low was early in the Subzone of *Turrilites costatus*; this is the Mid-Cenomanian Regressive Trough.

1. North-west Europe

Even in the basins, but more particularly on the flanks of the basins, the Regressive Trough is marked by a distinctive coarser chalk, called in Germany the *Primus* Event after the occurrence of the belemnite *Actinocamax primus* ARKHANGELSKY.

In chalk successions over stable areas, such as the London-Brabant High in eastern England, there was submarine erosion during the Regressive Trough. The sediment in the erosional channels, which in some places cut down to the Zone of *Mantelliceras mantelli* in the lower Lower Cenomanian, forms a hard bed known as the Totternhoe Stone. Part of this is a debris-flow.

The developments near the margins of the Chalk basins vary from region to region. In Northern Ireland the Mid-Cenomanian Eustatic Low is entirely contained within a condensed glauconite-rich facies, the Glauconite Sands. In much of south Devon and west Dorset in south-west England there are simply hardly any pre-*acutus* Subzone sediments. There are some localities where the *acutus* Subzone rests directly on Upper Greensand of the lowest Cenomanian or high Albian.

Near the original stratotype around Le Mans (Fig. 2), on the south-west flank of the Paris basin, the eustatic Trough is not conspicuous within an arenaceous sequence. However, the rise in sea-level after the Trough, first during the later *costatus* Subzone and then during the main part of the *acutus* Subzone shows up as the earliest chalk development in the district: the "Craie de Théligny" (JUIGNET, 1980).

2. Crimea and Kazakhstan

The Mid-Cenomanian Eustatic Low had strong effects in these regions (GALE, HANCOCK & KENNEDY, 1999). In the chalky succession in the Crimea the submarine erosion went down to the top of the *M. dixoni* Zone and sedimentation did not re-start until near the end of the *T. costatus* Subzone.

In the Mangyshlak Hills in western Kazakhstan (Fig. 2) there was not quite so much erosion during the Eustatic Low, but sedimentation did not resume until the high Middle Cenomanian Zone of *Acanthoceras jukesbrownei* (NAIDIN, BENJAMOVSKY & KOPAEVICH, 1984; GALE, HANCOCK & KENNEDY, 1999, figs. 4 and 6).

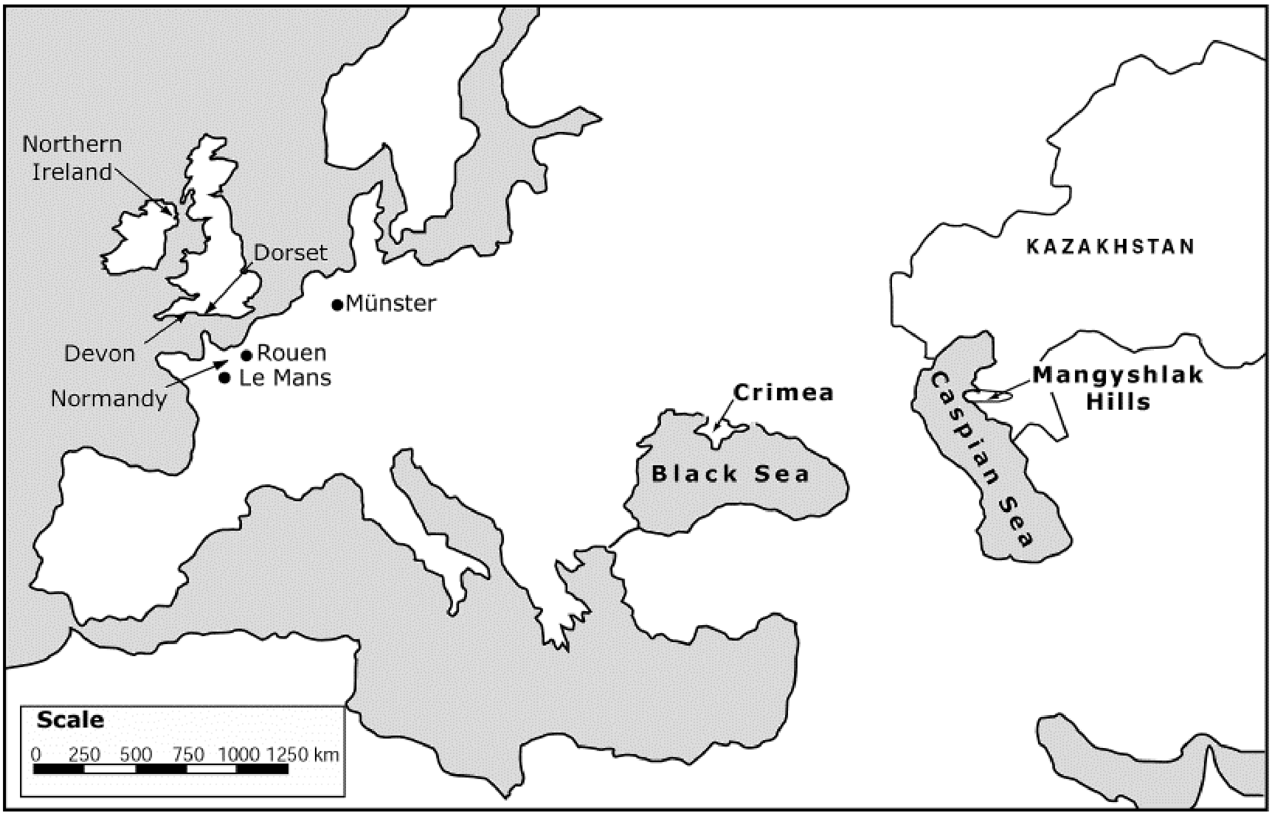

Figure 2: Localities mentioned in Europe and Asia.

3. United States of America

During most of the Late Cretaceous there was a seaway-connection, up to 1,400 km wide, between Arctic Canada and Mexico. As world sea-level rose and fell the boundaries of this linear "Western Interior" basin widened and narrowed (summary in KAUFFMAN & CALDWELL, 1994). The Mid-Cenomanian Eustatic Low and the Trough itself can be detected in rock successions in various places. Three examples are considered here (Fig. 3).

3a. Colorado

The Trough is represented by the Thatcher Limestone in south-east Colorado near Pueblo. Although only 0.2 to 0.4 m thick, this Limestone involves at least six sedimentation events. The principal age is probably the Subzone of *Turrilites costatus* but it is possible that it ranges from the Zone of *C. inerme* to the beginning of the Subzone of *T. acutus*. In local terms it belongs to the Zone of *Conlinoceras tarrantense* (ADKINS).

The Thatcher Limestone is contained within a deeper-water grey fissile clay known as the Graneros Shale (COBBAN & SCOTT, 1972; COBBAN *et alii*, 1994). The base of the Thatcher Limestone rests on a marked erosion surface cut into Graneros Shale as a result of the fall in sea-level. Yet the Thatcher Limestone itself marks a transgression on top of this erosion surface; i.e. it is a transgression but a shallower water facies than the Graneros Shale on which it rests and the higher Graneros Shale which overlies it.

Only a few cm beneath the base of the Thatcher Limestone there is a bentonite which has been dated by OBRADOVICH (1994) on ^{40}Ar:^{39}Ar in sanidines as 95.78±0.61 Ma.

Figure 3: Localities mentioned in the U.S.A.

3b. South Dakota

South Dakota is on the eastern side of the seaway where much of the Cenomanian is represented by the Belle Fourche Shale: black laminated shales possibly even less aerated than the Graneros Shale of Colorado. Within the Shale there is a ¼ m bed, informally known as the Junction Bed: poorly bedded clay containing small pebbles of clay, angular granules and streaks of quartz sand. Whilst not easy to interpret, it is clearly a much shallower facies than the main parts of the Belle Fourche Shale. The Junction Bed has yielded *C. tarrantense* (ADKINS) and represents the Mid-Cenomanian Regressive Trough.

3c. Texas

Near Fort Worth the upper part of the Lower Cenomanian, within the Woodbine Formation, is nearly non-marine with no ammonites (OLIVER, 1971). The Formation is topped by a distinct break in sedimentation shown by a thin limestone topped by an oyster-studded surface. This break represents the Trough. It is succeeded by the Tarrant Formation, a transgressive equivalent of the Thatcher Limestone: an orange-brown clay with carbonate concretions containing a *C. tarrantense* fauna.

As one goes southward from Fort Worth towards Austin the whole of the Woodbine and Tarrant formations wedge out against the San Marcos Platform.

There is sedimentological and fossil evidence that from early in the Middle Cenomanian, late in the Zone of *Cunningtoniceras inerme* to mid-Middle Cenomanian, early in the Subzone of *Turrilites acutus*, sea-levels were lower than before and afterwards. The lowest sea-level of all, the Regressive Trough, was early in the Subzone of *Turrilites costatus*.

Evidence for a sea-level low can be found over 1,400 km from South Dakota southwards to north Texas. Lower sea-levels at this time occurred over thousands of km eastwards from the United States across northern Europe to central Asia. Such simultaneous changes in sea-level argue for a eustatic explanation.

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References

COBBAN W.A. & SCOTT G.R. (1972).- Stratigraphy and ammonite fauna of the Graneros Shale and Greenhorn Limestone near Pueblo, Colorado.- *U.S. Geological Survey*, *Professional Paper*, Washington D.C., 645, p. 1-108, 39 pls.

COBBAN W.A., MEREWETHER E.A., FOUCH T.D. & OBRADOVICH J.D. (1994).- Some Cretaceous shorelines in the Western Interior of the United States.- *In*: CAPUTO M.R., PETERSON J.A. & FRANSZYK K.J. (Eds.), Mesozoic systems of the Rocky Mountain region, USA.- Rocky Mountain Section, SEPM (Society for Sedimentary Geology), Denver, p. 393-414.

COOPER M.R. (1977).- Eustacy during the Cretaceous: its implications and importance.- *Palaeogeography Palaeoclimatology Palaeoecology*, Amsterdam, 22, p. 1-60.

CURRY D. (1989).- The rock floor of the England Channel and its significance for the interpretation of marine unconformities. *Proceedings of the Geologists' Association* (*London*), London, 100, p. 339-352.

DANGEARD L. (1951).- La Normandie.- Hermann, Paris, 241 pp.

GALE A.S. (1990).- A MILANKOVITCH scale for Cenomanian time.- *Terra Nova*, Oxford, 1, p. 420-425.

GALE A.S. (1995).- Cyclostratigraphy and correlation of the Cenomanian Stage in western Europe. *In*: HOUSE M.R. & GALE A.S. (Eds.), Orbital forcing timescale and cyclostratigraphy.- *Geological Society of London*, *Special Publication*, London, 85, p. 177-197.

GALE A.S., YOUNG J.R., SHACKLETON N.J., CROWHURST A.J. & WRAY D.A. (1999).- Orbital tuning of Cenomanian marly chalk successions: towards a MILANKOVITCH time-scale for the Late Cretaceous.- *Philosophical Transactions of the Royal Society of London*, London, (A), 357, p. 1815-1829.

GALE A.S., HANCOCK J.M. & KENNEDY W.J. (1999).- Biostratigraphical and sequence correlation of the Cenomanian successions in Mangyshlak (W. Kazakhstan) and Crimea (Ukraine) with those in southern England.- *Institut royal des Sciences naturelles de Belgique*, *Bulletin*, Bruxelles, Sciences de la Terre, Vol. 69 (Suppl. A), p. 67-86.

HANCOCK J.M. & KAUFFMAN E.G. (1979).- The great transgressions of the Late Cretaceous.- *Geological Society of London*, *Journal*, London, 136, p. 175-186.

HART M.B. (1987).- Orbitally induced cycles in the Chalk facies of the United Kingdom.- *Cretaceous Research*, Amsterdam, vol. 8, p. 335-348.

HATTIN D.E. (1966).- Cyclic sedimentation in the Colorado Group of west-central Kansas. *In*: D.G. MERRIAM (Ed.), Symposium on cyclic sedimentation.- *Kansas*, *State Geological Survey*, *Bulletin*, Lawrence, 169, p. 205-217.

JUIGNET P. (1980).- Transgressions-régressions, variations eustatiques et influences tectoniques de l'Aptien au Maastrichtien dans le Bassin de Paris occidental et sur la bordure du Massif Armoricain.- *Cretaceous Research*, Amsterdam, vol. 1, p. 341-357.

KAUFFMAN E.G. (1969).- Cretaceous marine cycles of the Western Interior.- *The Mountain Geologist*, Denver, 6, p. 227-245.

KAUFFMAN E.G. & CALDWELL W.G.E. (1994).- The Western Interior Basin in space and time. *In*: CALDWELL W.G.E. & KAUFFMAN E.G. (Eds.), Evolution of the Western Interior Basin.- *Special Paper - Geological Association of Canada*, Toronto, 39, p. 1-30.

NAIDIN D.P., BENJAMOVSKY V.N., & KOPAEVICH L.F. (1984).- Methods of studying transgressions and regressions (exemplified by the Late Cretaceous basins of western Kazakhstan).- [in Russian], Moscow University, Moscow, p. 1-64.

OBRADOVICH J.D. (1994).- A Cretaceous time scale. *In*: CALDWELL W.G.E. & KAUFFMAN E.G. (Eds.), Evolution of the Western Interior Basin.- *Special Paper - Geological Association of Canada*, Toronto, 39, p. 379-396.

OLIVER W.R. (1971).- Depositional systems in the Woodbine Formation (Upper Cretaceous), northeast Texas.- *Bureau of Economic Geology*, *University of Texas*, *Report of Investigations*, Austin, 73, p. 1-28.

ROBASZYNSKI F., GALE A.S., JUIGNET P., AMÉDRO F. & HARDENBOL J. (1998).- Sequence stratigraphy in the Upper Cretaceous series of the Anglo-Paris Basin: Exemplified by the Cenomanian stage. *In*: GRACIANSKY P.C. de *et alii* (Eds.), Mesozoic and Cenozoic sequence stratigraphy of European Basins.- *Society of Economic Paleontologists and Mineralogists*, *Special Publication*, Tulsa, 60, p. 363-386.

SARG J.F. (1989).- Carbonate sequence stratigraphy. *In*: WILGUS C.K. *et alii* (Eds.), Sea-level changes: an integrated approach.- *Society of Economic Paleontologists and Mineralogists*, *Special Publication*, Tulsa, 42, p. 155-181.

STAGE		ZONES	SUBZONES
TURONIAN		*Watinoceras devonense*	
CENOMANIAN	**Upper**	*Neocardioceras juddii*	
		Metoicoceras geslinianum	
		Calycoceras guerangeri	
	Middle	*Acanthoceras jekesbrownei*	
		Acanthoceras rhotomagense	*Turrilites acutus*
			Turrilites costatus
		Cunningtoniceras inerme	
	Lower	*Mantelliceras dixoni*	
			Mantelliceras saxbii
		Mantelliceras mantelli	*Sharpeiceras schlueteri*
			Neostlingoceras carcitanense
ALBIAN		*Stoliczkaia dispar*	

Table 1: Ammonite zones and subzones in the Cenomanian stage; see GALE, HANCOCK & KENNEDY (1999).