

A new upper Bedoulian section in the Aptian stratotypic area: Croagnes (5 km NW of Gargas, Vaucluse, SE France)

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Abstract: The discovery and exploitation of a new outcrop of the "A¹ Unit of yellow marls and marly limestones" of LEENHARDT (1883), comprised between the Urgonian limestones and the "Aptian marls" of the authors, leads to question the generalized attribution of this formation to the *Deshayesites grandis* ammonite Subzone. Data from this section at Croagnes rather lead to place A¹, at least locally in the stratotypic area of the surroundings of Apt, at the level of the onset of the anoxic event OAE1a, just below the *Roloboceras hambrovi* Subzone. The assumed isochroneity of this Unit is also questioned.

Key Words: Aptian; Bedoulian; stratotype; microbiostratigraphy; carbon isotope stratigraphy; OAE1a.

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Résumé : *Une coupe inédite du Bédoulien supérieur dans l'aire stratotypique aptienne : Croagnes (5 km au NW de Gargas, Vaucluse, SE de la France).*- La découverte et l'exploitation d'un nouvel affleurement de l' "Unité A¹ des marnes et calcaires marneux jaunes" de LEENHARDT (1883), comprise entre l'Urgonien et les "marnes aptiennes" des auteurs, conduit à mettre en question l'attribution généralisée de cette formation à la Sous-Zone d'ammonites à *Deshayesites grandis*. Les données obtenues à Croagnes permettent plutôt de la situer, au moins localement dans le secteur stratotypique des environs d'Apt, au niveau du début de l'événement anoxique OAE1a, juste avant la Sous-Zone à *Roloboceras hambrovi*, et remettent en question le postulat de son isochronie.

Mots-Clefs : Aptien ; Bédoulien ; stratotype ; microbiostratigraphie ; stratigraphie isotopique du carbone ; OAE1a.

1. Introduction

LEENHARDT (1883) was the first to describe in the vicinity of Apt a thin decametric Unit of yellowish marlstones overlying the Urgonian limestones and underlying the grey-blue Aptian marls. This Unit was named "A¹" and, on the basis of few ammonites, given an Early Aptian age by the author.

Subsequent studies (GOGUEL, 1933; ABOUSOUAN, 1963; ROCH, 1971; MASSE, 1976) of these beds from several outcrops close to localities surrounding the Apt area (Gordes, Murs, Villes, Le Chêne, Jocas) (Fig. 1) confirmed their Bedoulian and even more precisely late Bedoulian age. This age assignment was particularly based on the occurrence of the species *Deshayesites deshaysi* among the ammonites collected in A¹.

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This Unit A¹ has recently been briefly mentioned by MASSE & FENERCI-MASSE (2011) in a paper more extensively devoted to stratigraphic correlations in the upper Barremian-lower Aptian platform carbonates of southeast France. In this work these supra-Urgonian beds are given a still more precise latest Bedoulian age, since they are assigned to the *Deshayesites grandis* ammonite Subzone (Fig. 2).

Micropaleontological and geochemical results that we have obtained by studying a deeply hidden outcrop discovered by one of us (P.M.) close to Croagnes shed a new light on this Unit and in particular led us to question its recent assignment to the *D. grandis* Subzone. The purpose of this paper is thus to provide a short description of this new outcrop and to present an overview of the first results from its study.

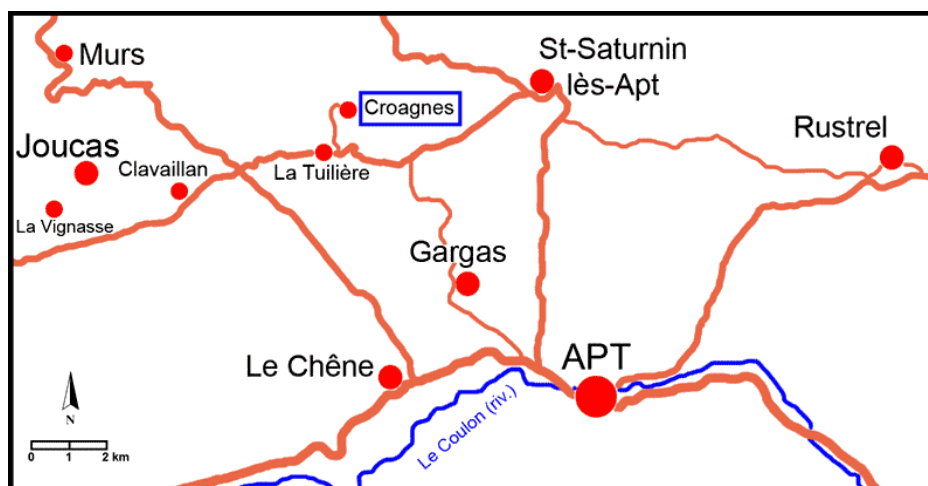


Figure 1: Geographic location of the area of study. Croagnes is located at 43° 93' N, 5° 33' E.

2. The Croagnes section

The studied section (Fig. 3) is located within the forest of Coste Granière, 500 m NE of the small village of Croagnes (Fig. 1). A 13 m thick sequence of marls, superficially yellowish/brownish or, locally, bluish (Fig. 4) is exposed there, in a kind of sloped clearing. In depth marls of the first part of the section consist of dark grey, moderately indurated, thin platelets, which become progressively softer and darker up in the series, where they include plant debris. Echinids (*Miotxaster collegnoi*) also occur, mostly from the middle part of the section.

This facies and its fossil content are consistent with what is usually described as and ascribed to the A¹ Unit. However, direct contacts with the supposedly enclosing beds, respectively the Urgonian limestones, which locally crop out nearby, and the Aptian marls, seen W of Croagnes, cannot be found there. Thus we analyzed samples from this series for micropaleontology and geochemistry, in order to clarify its stratigraphic status.

STAGES	ZONES	SUBZONES
APTIAN (<i>pro parte</i>)	<i>Parahoplites melchioris</i>	
	<i>Epicheloniceras martini</i>	<i>Epicheloniceras buxtorfi</i>
		<i>Epicheloniceras gracile</i>
	<i>Dufrenoyia furcata</i>	<i>Epicheloniceras debile</i>
BEDOULIAN		<i>Dufrenoyia dufrenoyi</i>
		<i>Dufrenoyia furcata</i>
	<i>Deshayesites deshayesi</i>	<i>Deshayesites grandis</i>
	<i>Deshayesites weissiforbesi</i>	<i>Roloboceras hambrovi</i>
	<i>Deshayesites oylanensis</i>	

Figure 2: Ammonite zonation of the Bedoulian and Aptian (lower part) stages (modified from DUTOUR, 2005; ROPOLLO *et al.*, 2006, 2008; REBOULET *et al.*, 2011; MOULLADE *et al.*, 2011).

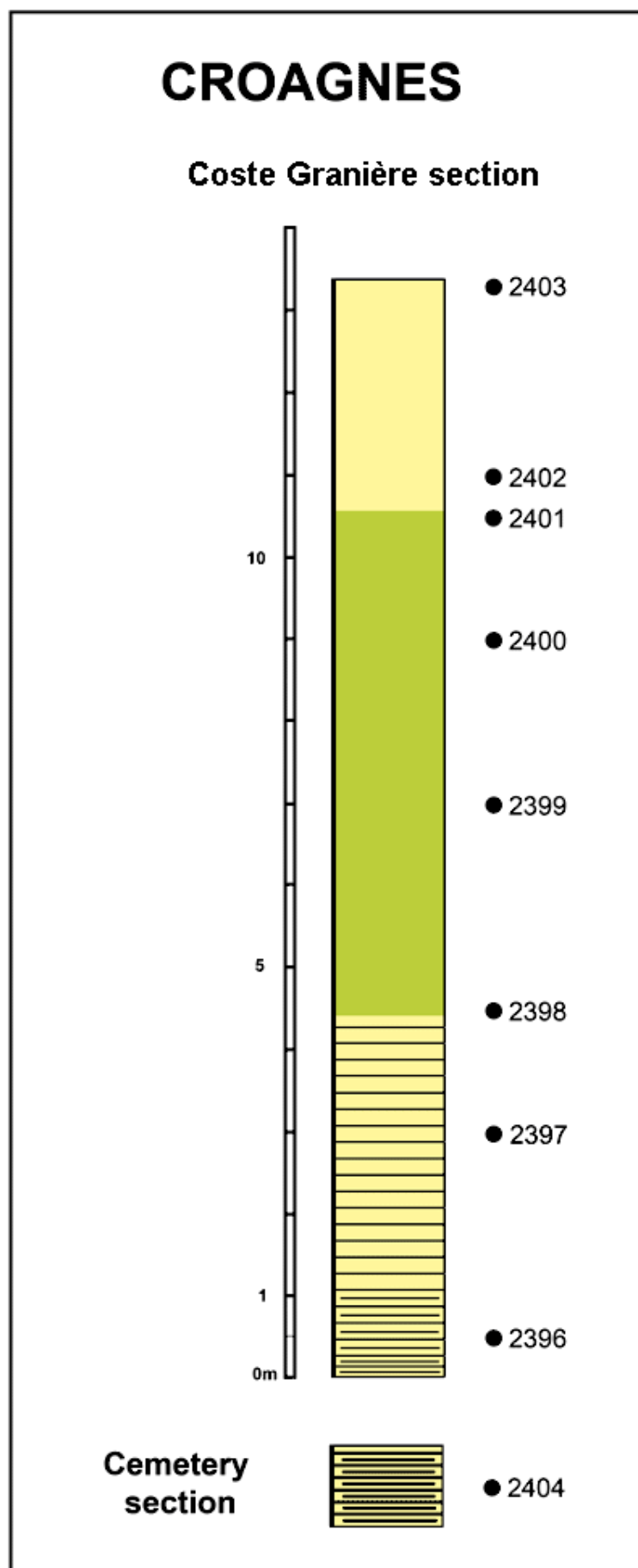


Figure 3: Schematic log of the Croagnes sections.

3. Micropaleontology

The foraminiferal content of the samples taken from the Croagnes section differs significantly from that (MOULLADE *et al.*, 2008) of the typical Aptian marls from the same area. Planktonic forms are very rare and low diversified, benthic foraminifers and ostracods are much more predominant. Fragments of echinids, bivalves and other invertebrates are abundant among the >250 µm washed residues. On the other hand, benthic foraminifers include there a significant proportion of very shallow water forms, such as small orbitolinids, miliolids, *Arenobulimina*, *Nezzazzata*, *Trocholina*, *Conorboidea*, *Patellina*. These taxa are most often absent or, for some of them (*Patellina*), extremely rare in the typical Aptian marls. Such assemblages lead us to suggest that the deposition of the marls of Croagnes either occurred soon after the demise of the Urgonian platform or, preferably, as indicated by obvious signs of transportation, that these shallow-dwellers came from the close Urgonian platform and were redeposited in slightly deeper periplatform environments.

Among the remaining part of the microfauna from Croagnes, it is of interest to note that three species (Fig. 5), which are known as well-calibrated biostratigraphic markers in the stratotypic area of Cassis-La Bédoule (MOULLADE *et al.*, 1998, 2005), follow a similar global pattern of near simultaneous first appearances in both localities:

- the benthic species *Lenticulina* cf. *nodosa* first occurs in sample 2396 at Croagnes and in bed 137 at Cassis,
- the planktonic species *Schackoina* (*Leupoldina*) *cabri* first occurs in sample 2399 (Croagnes) vs bed 146 (Cassis),
- the ostracod species *Procythere bedoulensis* has its FO in sample 2402 (Croagnes) vs bed 147 in Cassis and La Bédoule sections.



Figure 4: Outcrop of the Croagnes (Coste Granière) section.

In Cassis-La Bédoule the sequence from bed 137 to bed 147 is located just below the lower boundary (bed 148) of the ammonite *Roloboceras hambrovi* Subzone (Figs. 2 & 5) of the *D. deshayesi* Zone (ROPOLO *et al.*, 2006). On the other hand, in a well at La Bédoule (LORENZEN *et al.*, 2012) bed 146 has been correlated with the C3/C4 MENEGATTI *et al.* (1998) isotopic stages boundary (Fig. 5). Thus, on the basis of these three microfaunal markers, the Croagnes section appears to straddle both the lower boundary of the *Roloboceras hambrovi* ammonite Subzone and that of the *Schackoina* (*Leupoldina*) *cabri* foraminiferal Zone, as well as the C3/C4 transition.

4. Carbon isotope stratigraphy

In view to better constrain these stratigraphic hypotheses based on correlations with the stratotypic area of Cassis-La Bédoule, isotopic measurements for $\delta^{13}\text{C}$ were performed on 9 samples from Croagnes at the Leibniz-Laboratory for radiometric Dating and Isotope Research in Kiel (Germany). This set of samples included 8 samples from the Coste Granière section, and one taken from a small isolated outcrop located

across the Cemetery of Croagnes; the geometric position, the facies (grey-blue yellowish platy marly limestone) and the composition of the microfaunal content of this outcrop led us to place it slightly below the base of the Coste Granière section, *i.e.*, still closer to the top of the Urgonian.

The measured values and the signature of the plotted curve at Croagnes (Fig. 5) appear to be consistent with the middle/upper part of the C3 isotopic stage and its transition towards C4.

As a kind of counterproof, $\delta^{13}\text{C}$ measurements were also performed on three samples of upper Bedoulian marlstones from the base of the section of Clavaillan (Figs. 1 & 6), 2 km WSW of Croagnes, where numerous ammonites of the *Deshayesites grandis* Subzone have been found (DUTOIR, 2005; plus our own record). The $\delta^{13}\text{C}$ values obtained there (Fig. 5) are significantly higher than those from Croagnes and very close to those of the C6/C7 transition measured in Cassis (KUHN *et al.*, 1998) and La Bédoule (KUHN *et al.*, 2011; LORENZEN *et al.*, 2012) at the level of the base of the *Deshayesites grandis* Subzone.

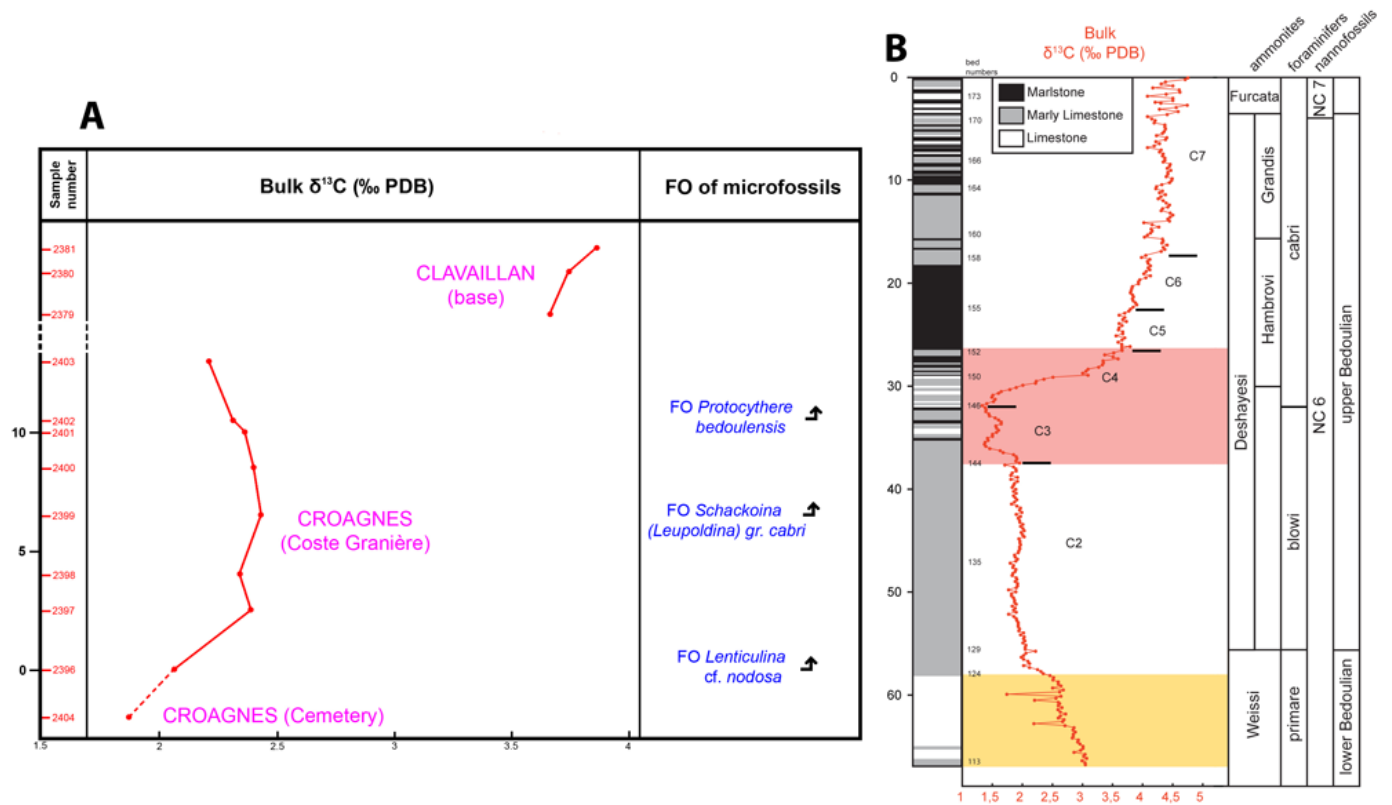


Figure 5: A.- $\delta^{13}\text{C}$ measurements and first occurrences of microfossil markers in the Croagnes and Clavaillan (base) sections. B.- Isotopic ($\delta^{13}\text{C}$) and biostratigraphic records at La Bédoule (LB1 borehole) (modified from LORENZEN *et al.*, 2012).



Figure 6: Outcrop of the base of the Clavaillan section, where ammonites of the *D. grandis* Subzone have been found.

5. Conclusion

Preliminary micropaleontological and isotopic data obtained from a newly discovered "A¹ like" section at Croagnes point to ascribe this outcrop to the middle part of the late Bedoulian, around the onset of the OAE1a event. These beds cannot be attributed there to the *Deshayesites grandis* Subzone, an age recently assigned by MASSE & FENERCI-MASSE (2011) to all the other known outcrops of the A¹ Unit. Our results led also to assume that in the area of Croagnes there is a gap of observation between A¹ and younger beds indisputably dated of the *D. grandis* Subzone, which show the lithological facies and microfaunal content of the typical "Aptian marls". This gap must cover at least the most part of the isotopic stage C4, the entire C5 and most of C6.

However, before reconsidering the global age assignment of MASSE & FENERCI-MASSE (2011) quoted above, further micropaleontological and isotopic researches ought to be carried out on all the other known outcrops of this Unit, the isochroneity of which is not fully demonstrated yet.

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Bibliographic references

- ABOUSSOUAN M.T. (1963).- Contribution à l'étude sédimentologique et paléocéanographique des terrains aptiens et albiens de la Provence aux Baronnières.- *Recueil des Travaux de la Station marine d'Endoume*, Marseille, vol. 30, n° 45, p. 95-164.
- DUTOIR Y. (2005).- Biostratigraphie, évolution et renouvellements des ammonites de l'Aptien supérieur (Gargasien) du bassin vocontien (Sud-Est de la France).- Thèse Université Claude Bernard, Lyon 1, 302 p. (31 pls.).
- GOGUEL J. (1933).- Sur l'extension des faciès urgoniens dans les monts de Vaucluse.- *Bulletin de la Société géologique de France*, Paris, (série 5), vol. 2, p. 445-464.
- KUHNT W., MOULLADE M., MASSE J.-P. & ERLKENKUSER H. (1998).- Carbon isotope stratigraphy of the lower Aptian historical stratotype at Cassis-La Bédoule (S.E. France).- *Géologie méditerranéenne*, Marseille, vol. 25, n° 3-4, p. 63-79.
- KUHNT W., HOLBOURN A. & MOULLADE M. (2011).- Transient global cooling at onset of early Aptian Anoxic Event (OAE 1a).- *Geology*, Boulder, vol. 39, n° 4, p. 323-326.
- LEENHARDT F. (1883).- Étude géologique de la région du Mont-Ventoux.- Thèse Doctorat ès Sciences, Universités de Montpellier et de Paris, 273 p.
- LORENZEN J., KUHNT W., HOLBOURN A., FLÖGEL S., MOULLADE M. & TRONCHETTI G. (2012, in press).- A new sediment core from the Bedoulian (Lower Aptian) stratotype at Roquefort-La Bédoule, SE France.- *Cretaceous Research*, London, 11 p.
doi:10.1016/j.cretres.2012.03.019
- MASSE J.-P. (1976).- Les calcaires urgoniens de Provence (Valanginien-Aptien inférieur). Stratigraphie, paléontologie, les paléoenvironnements et leur évolution.- Thèse Doctorat ès Sciences, Université d'Aix-Marseille II, 445 p.
- MASSE J.-P. & FENERCI-MASSE M. (2011).- Drowning discontinuities and stratigraphic correlation in platform carbonates. The late Barremian-Early Aptian record of southeast France.- *Cretaceous Research*, London, vol. 32, n° 6, p. 659-684.
- MENEGATTI A.P., WEISSERT H., BROWN R., TYSON R.V., FARRIMOND P., STRASSER A. & CARON M. (1998).- High-resolution $\delta^{13}\text{C}$ stratigraphy through the early Aptian "Livello Selli" of the Alpine Tethys.- *Paleoceanography*, Washington D.C., vol. 13, n° 5, p. 530-545.
- MOULLADE M., TRONCHETTI G., KUHNT W. & MASSE J.-P. (1998).- Les Foraminifères benthiques et planctoniques de la série du stratotype historique de l'Aptien inférieur dans la région de Cassis-La Bédoule (SE France).- *Géologie Méditerranéenne*, Marseille, vol. 25, n° 3-4, p. 187-225.
- MOULLADE M., BELLIER J.-P. & TRONCHETTI G. (2005).- Le Gargasien (Aptien moyen) de Cassis-La Bédoule (stratotype historique de l'Aptien inférieur, SE France) : associations et biostratigraphie des Foraminifères benthiques et planctoniques.- *Carnets de Géologie - Notebooks on Geology*, Brest, Article 2005/02 (CG2005_A02), 20 p. (5 Pls.).
- MOULLADE M., TRONCHETTI G. & BELLIER J.-P. (2008).- Associations et biostratigraphie des Foraminifères benthiques et planctoniques du Bédoulien sommital et du Gargasien inférieur de La Tuilière - St-Saturnin-lès-Apt (aire stratotypique de l'Aptien, Vaucluse, SE France).- *Carnets de Géologie - Notebooks on Geology*, Brest, Article 2008/01 (CG2008_A01), 50 p. (10 Pls.).
- MOULLADE M., GRANIER B. & TRONCHETTI G. (2011).- The Aptian stage: back to fundamentals.- *Episodes*, Bangalore, vol. 34, n° 3, p. 148-156.
- REBOULET S., RAWSON P.F., MORENO-BEDMAR J. A., AGUIRRE-URRETA M.B., BARRAGÁN R., BOGOMO-

- LOV Y., COMPANY M., GONZALEZ-ARREOLA C., STOYANOVA V.I., LUKENEDER A., MATRION B., MITTA V., RANDRIANALY H., VAŠÍČEK Z., BARABOSHKIN E.J., BERT D., BERSAC S., BOGDANOVA T.N., BULOT L. G., LATIL J.L., MIKHAILOVA I.A., ROPOLO P. & SZIVES O. (2011).- Report on the 4th International Meeting of the IUGS Lower Cretaceous Ammonite Working Group, the "KILIAN Group" (Dijon, France, 2010).- *Cretaceous Research*, London, vol. 32, n° 6, p. 786-793.
- ROCH E. (1971).- Géologie du pays d'Apt (première partie).- *Bulletin du Bureau de Recherches géologiques et minières*, Orléans, sect. 4, n° 3, p. 29-57.
- ROPOLO P., MOULLADE M., GONNET R., CONTE G. & TRONCHETTI G. (2006).- The Deshayesitidae STOYANOV, 1949 (Ammonoidea) of the Aptian stratotype region at Cassis-la Bédoule (SE France).- *Carnets de Géologie - Notebooks on Geology*, Brest, Memoir 2006/01 (CG2006_M01), 46 p. (14 Pls.).
- ROPOLO P., CONTE G., MOULLADE M., TRONCHETTI G. & GONNET R. (2008).- The Douvilleiceratidae (Ammonoidea) of the Lower Aptian historical stratotype area at Cassis-La Bédoule (SE France).- *Carnets de Géologie - Notebooks on Geology*, Brest, Memoir 2008/03 (CG2008_M03), 60 p. (24 Pls.).