BULLETIN DE L'INSTITUT ROYAL DES SCIENCES NATURELLES DE BELGIQUE SCIENCES DE LA TERRE, 66-SUPP.: 31-43, 1996
BULLETIN VAN HET KONINKLIJK BELGISCH INSTITUUT VOOR NATUURWETENSCHAPPEN AARDWETENSCHAPPEN, 66-SUPP.: 31-43, 1996

The Aptian Stage

by Elisabetta ERBA,

with contributions by Roque Aguado, Emil Avram, Evgenii J. Baraboschkin, James A. Bergen, Timothy J. Bralower, Fabrizio Cecca, James E. T. Channell, Rodolfo Coccioni, Miguel Company, Gérard Delanoy, Jochen Erbacher, Timothy D. Herbert, Philip Hoedemaeker, Mikhail Kakabadze, Han Leereveld, Andrea Lini, Irina A. Mikhailova, Jörg Mutterlose, James G. Ogg, Isabella Premoli Silva, Peter F. Rawson, Katharina von Salis, Helmut Weissert.

Abstract

Detailed multidisciplinary analyses of several sections through the Barremian-Aptian interval resulted in the revision of the Aptian stage, including the Barremian-Aptian boundary. The Aptian Working Group (= AWG) established an integrated stratigraphy based on biostratigraphy (ammonites, belemnites, calcareous nannofossils, planktonic and benthic foraminifera, dinoflagellates, radiolarians), magnetostratigraphy, isotope stratigraphy ($\delta^{13}C$ and $^{86}Sr/^{87}Sr$), event stratigraphy, sequence stratigraphy, and cyclostratigraphy.

Historical precedence was considered and the preliminary proposals made at the Copenhagen Symposium in 1983 were considered as starting point. The new information highlighted the difficulty of using the first appearance of *Prodeshayesites* for the definition of the base of the Aptian, and revealed the importance of biostratigraphy based on other fossil groups, especially micro- and nannofossils, as well as physical and chemical tools such as magnetostratigraphy, chemostratigraphy, sequence stratigraphy and cyclostratigraphy in global correlations.

Following the discussions at and after the Second International Symposium on Cretaceous Stage Boundaries (Brussels, 8-16 September 1995), the majority of the AWG selected the base of magnetic chron MO as the event for the definition of the base of the Aptian stage. It must be emphasised that magnetostratigraphy must always be integrated with biostratigraphy and magnetic chron MO must be identified in relation to palaeontological events.

After accepting the base of magnetic chron MO as the base of the Aptian stage, the AWG identified the Gorgo a Cerbara section (Umbria-Marche Basin, Central Italy) as possible GSSP for the base of the Aptian Stage. This section represents an excellent exposure of Barremian to Aptian pelagic carbonates, and offers a wide range of available stratigraphies including magnetostratigraphy, calcareous nannofossil and planktonic foraminiferal biostratigraphy, radiolarian biostratigraphy, dinoflagellate biostratigraphy, chemostratigraphy ($\delta^{13}C$) and cyclostratigraphy. Moreover, the Oceanic Anoxic Event 1a is represented by the black shales of the Selli level. The record of ammonites is not continuous; however, a few diagnostic layers have been detected.

The Aptian substage subdivision was also discussed, but the AWG has not yet provided recommendations. While a two-fold subdivision is adopted for the Boreal Aptian, a three-fold subdivision is often applied to low-latitude sequences. The integrated stratigraphy elaborated by the AWG for the stage is still under revision and Aptian subdivisions will be the subject of further work.

Key-words:
Aptian, Lower Cretaceous, biostratigraphy, magnetostratigraphy, chemostratigraphy, cyclostratigraphy, anoxic events, GSSP, stratotypes.

Résumé

Des analyses détaillées et multidisciplinaires de plusieurs sections de l'intervalle Barrémien-Aptien ont permis la révision de l'étage Aptien et de la limite Barrémien-Aptien. Le Groupe de Travail Aptien (= AWG) a établi une stratigraphie intégrée, basée sur la biostratigraphie (ammonites, bélemnites, nannofossiles calcaires, foraminifères planctoniques et benthiques, dinoflagellés, radiolaires), la magnétostratigraphie, la stratigraphie isotopique ($\delta^{13}C$ et $^{86}Sr/^{87}Sr$), la stratigraphie événementielle, la stratigraphie séquentielle, et la cyclostratigraphie.

L'historique de la question a été pris en considération et les propositions préliminaires faites au Symposium de Copenhague en 1983 ont servi de point de départ. Des nouvelles données ont mis en lumière la difficulté que présente la première apparition de *Prodeshayesites* pour la définition de la base de l'Aptien, et démontrés l'importance de la biostratigraphie fondée sur d'autres groupes fossiles, particulièrement les micro- et nanno-fossiles, ainsi que des outils physiques et chimiques tels que la magnétostratigraphie, la chimiostratigraphie, la stratigraphie séquentielle et la cyclostratigraphie pour des corrélations globales.

Pendant et après les discussions du Second Symposium sur les Limites d'Etages du Crétacé (Bruxelles, 8 - 16 Septembre 1995), la majorité de l' AWG a sélecté la base du chron magnétique MO comme l'événement pour la définition de la base de l'Aptien. L'attention a été attirée sur le fait que la magnétostratigraphie devait être intégrée à la biostratigraphie et que le chron magnétique devait être défini en relation avec des événements paléontologiques.

Après avoir accepté le chron magnétique MO comme la base de l'étage Aptien, l'AWG a indiqué la coupe de Gorgo a Cerbara (le Bassin d'Ombrie-Marche, Italie centrale) comme GSSP possible pour la base de l'Aptien. Cette coupe représente un excellent affleurement de carbonates pélagiques d'âge Barrémien à Aptien, et permet de nombreuses aplications stratigraphiques, entre autres la magnétostratigraphie, la biostratigraphie des nannofossiles calcaires et des foraminifères planctoniques, des radiolaires, des dinoflagellés, la chimiostratigraphie ($\delta^{13}C$) et la cyclostratigraphie. En plus l'"Oceanic Anoxic Event 1a" est représenté par les "black shales" du niveau Selli. Les ammonites ne s'y retrouvent pas de façon continue, mais certains niveaux diagnostiques ont été découverts.

La division de l'Aptien en sous-étages a aussi été discutée, mais l'AWG n'a pas encore fait de recommandations. L'Aptien boréal est en général divisé en deux, mais l'Aptien des basses latitudes est souvent divisé en trois. La stratigraphie intégrée élaborée par l'AWG est encore en révision et les subdivisions aptiennes feront l'objet de travaux ultérieurs.

Mots-clefs:
Aptien, Crétacé inférieur, biostratigraphie, magnétostratigraphie, chimiostratigraphie, cyclostratigraphie, événements anoxiques, GSSP, stratotypes.

Аптский ярус.

Резюме.
Благодаря подробному и многопредметному изучению ряда разрезов Барремско-Аптского интервала ученым удалось пересмотреть понятия Аптского яруса и Барремско-Аптской границы. Рабочая группа Аптского яруса установила, что интегрированная стратиграфия базируется на биостратиграфии, включающей аммониты, белемниты,

известковые нанофоссилии, планктонические и бентические фораминиферы, динофлагеллаты и радиолярии, а также на магнитостратиграфии, циклостратиграфии, изотопической ($\delta^{13}C$ и $^{86}Sr/^{87}Sr$) событийной и секвентной стратиграфиях.

Предыстория данного вопроса была принята во внимание, а предварительные предложения, прозвучавшие на копенгагском Симпозиуме 1983 года, послужили точкой отсчёта. Новые данные подробно осветили то препятствие, которое представляет собой первое появление *Prodeshayesites* для определения основания Аптского яруса и продемонстрировали важную роль биостратиграфии, основанной на изучении других групп ископаемых, в частности, микро- и нанофоссилий, а также физических и химических технологий, таких как магнитостратиграфия, хемостратиграфия, циклостратиграфия и секвентная стратиграфия, в глобальных корреляциях.

Обсуждения, проведённые в течение и после Второго Симпозиума, посвящённого Границам Меловых Ярусов (Брюссель, 8-16 сентября 1995), позволили большинству участников Рабочей Группы Аптского Яруса определить основание магнитного хрона (МО) как главного элемента для определения основания Аптского яруса. Учёные обратили особое внимание на тот факт, что магнитостратиграфия должна всегда составлять единое целое с биостратиграфией, и что магнитный хрон должен быть определён неразрывно от палеонтологических событий.

Приняв магнитный хрон МО за основание Аптского яруса, Рабочая Группа Аптского Яруса указала разрез Gorgo a Cerbara (бассейн Umbria-Marche, Центральная Италия) как вероятный GSSP для основания Аптского яруса. Этот разрез является идеальным примером отложений пелагических карбонатов от барремского до аптского возрастов и отличным объектом для применения многочисленных существующих стратиграфий, включающих магнитостратиграфию, биостратиграфию известковых нанофоссилий и планктонических фораминифер, биостратиграфию радиолярий и динофлягеллатов, хемостратиграфию (δ^{13} C) и циклостратиграфию. Кроме того, «Oceanic Anoxic Event 1a» представлен «black shales» уровня Selli, где аммониты присутствуют неравномерно. Тем не менее, было раскрыто несколько диагностиеских слоёв.

Разделение Аптского яруса на подъярусы также стало объектом дискуссий, но Рабочая Группа Аптского Яруса не вынесла каких-либо рекомендаций. Бореальный Апт обычно делится на 2 части, в то время как Апт «lower latitudes» часто делится на 3 части. Интегрированная стратиграфия, разработанная Рабочей Группой Аптского Яруса, находится в процессе ревизии, а подъярусы Апта будут подробнее рассмотрены в последующих работах.

Ключевые слова: Аптский ярус, нижний мел, биостратиграфия, магнитостратиграфия, хемостратиграфия, циклостратиграфия, безкислородные события, GSSP, стратотипы.

Introduction

Revision of the Aptian stage, including the Barremian/ Aptian (B/A) boundary interval, has been carried out by the Aptian Working Group in the past three years. The aims of the Aptian Working Group are to nominate an internationally acceptable boundary for the base of the stage and substage boundaries where appropriate, and propose candidate stratotype sections.

The recommended boundary must be recognisable over as wide an area as possible and ideally in both Tethyan and Boreal Realms. The selection of the boundary is determined by good correlation based on all available tools including (quantitative) biostratigraphy, magnetostratigraphy, isotope stratigraphy, event stratigraphy, sequence stratigraphy, and cyclostratigraphy. The strati-

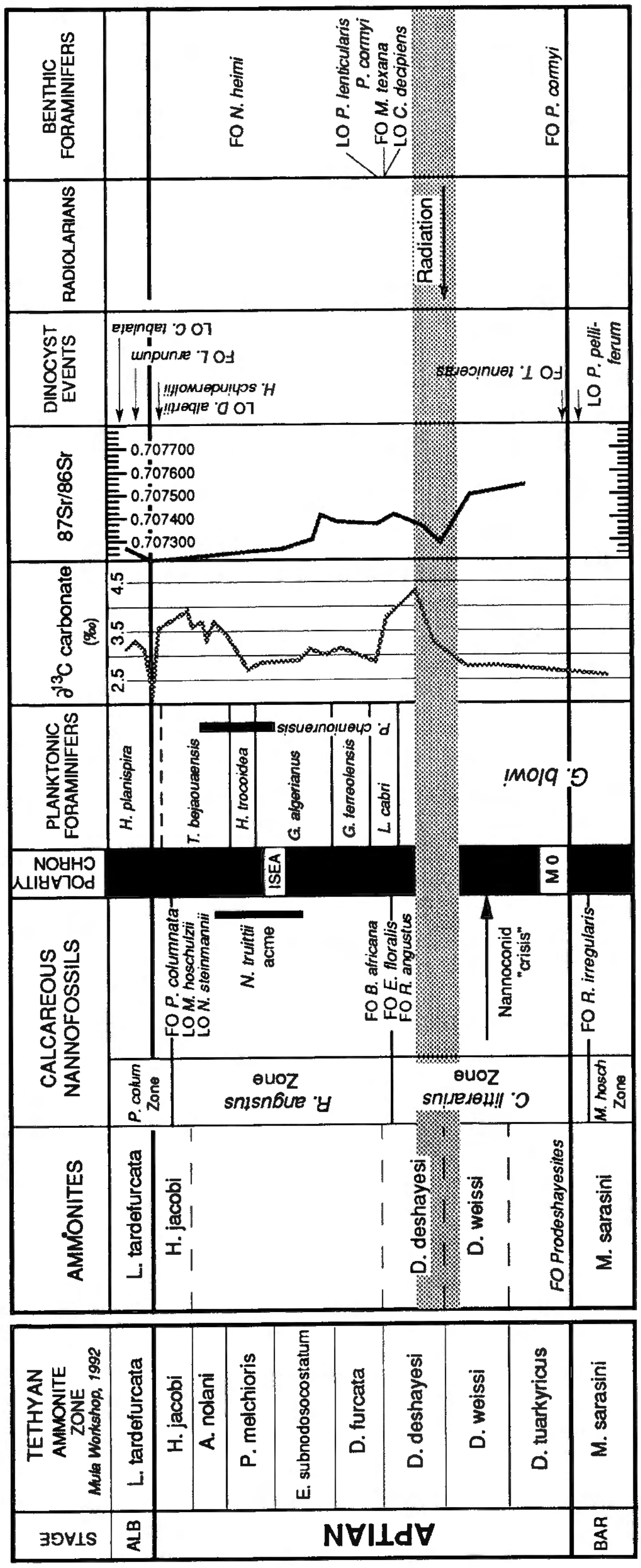

Fig. 1 — Integrated stratigraphy of the Aptian for the Tethyan area and low latitudes.

Table 1 – Sections studied and/or revised for the discussion of the Barremian/Aptian boundary

Area	Section	Studied Interval	Type of Investigation	Reference
SE France	Angles (Route d'Angles)	Barremian/Aptian boundary	Ammonites, Calcareous nannofossils, Dinoflagellates	Delanoy, 1991, 1995 Erba, in prep. Thierstein, 1973 Leereveld, 1995
SE France	Le Combe Lambert	Lower Aptian	Ammonites	Delanoy, 1995
SE France	Méouilles	Lower Aptian	Ammonites	Delanoy, 1995
SE France	La Colle gully	Lower Aptian	Ammonites	Delanoy, 1995
SE France	Vignon's gully	Lower Aptian	Ammonites	Delanoy, 1995
England	Speeton	Barremian-Aptian	Ammonites	Rawson, pers. com. 95
S Spain	Campillo de Arenas	Barremian-Aptian	Ammonites, Calcareous nannofossils, Planktonic foraminifers, Radiolarians	Aguado et al., 1992 Aguado et al., 1995
S Spain	Huéscar	Barremian-Aptian	Ammonites, Calcareous nannofossils	Aguado et al., 1995
S Spain	Barranco de Cabila	Barremian-Aptian	Ammonites, Calcareous nannofossils	Aguado et al., 1995
S Spain	Caprés	Barremian-Aptian	Ammonites, Calcareous nannofossils	Aguado et al., 1995
S Spain	Foncalet	Barremian-Aptian	Ammonites, Calcareous nannofossils	Aguado et al., 1995
S Spain	Busot	Barremian-Aptian	Ammonites, Calcareous nannofossils	Aguado et al., 1995
S Spain	Sierra del Corque	Barremian-Aptian	Ammonites, Sequence stratigraphy	Company et al., 1992
S Spain	Rio Argos	Barremian-Aptian	Ammonites, Dinoflagellates, Calcareous nannofossils, Planktonic foraminifers, Sequence stratigraphy	Hoedemaeker & Leereveld, 1995 Coccioni & Premoli Silva, 1994
Central Italy	Gorgo a Cerbara	Upper Hauterivian-Aptian	Ammonites, Planktonic foraminifers, Calcareous nannofossils, Magnetostratigraphy, Cyclostratigraphy, Radiolarians, $\delta^{13}C$, $\delta^{18}O$	Lowrie & Alvarez, 1984 Coccioni et al., 1992 Bralower, 1987 Herbert, 1992 Cecca et al., 1994 Erba, 1994 Erbacher, 1995
Central Italy	S.S. Apecchiese	Upper Barremian-Aptian	Calcareous nannofossils, Planktonic foraminifers	Erba et al., 1989
Central Italy	Piobbico core	Aptian-Albian	Calcareous nannofossils, Planktonic foraminifers, Trace fossils, Cyclostratigraphy	Erba, 1988, 1992, 1994 Tornaghi et al., 1989 Herbert & Fischer, 1986 Fischer et al., 1991 Erba & Premoli Silva, 1994 Herbert et al., 1995
N Italy	Polaveno	Berriasian-Barremian	Calcareous nannofossils, Planktonic foraminifers, Magnetostratigraphy, Radiolarians	Erba & Quadrio, 1987 Channell & Erba, 1992 Jud, 1995 Channell et al., 1995
N Italy	Pié del Dosso	Upper Barremian-Aptian	Calcareous nannofossils, Planktonic foraminifers, Magnetostratigraphy	Erba & Quadrio, 1987 Channell & Erba, 1992 Erba, 1994
N Italy	Capriolo	Berrasian-Aptian	Calcareous nannofossils, Planktonic foraminifers, Magnetostratigraphy, Carbon isotope stratigr., Radiolarians	Channell et al., 1987, 1993 Channell & Erba, 1992 Weissert & Lini, 1991 Lini et al., 1992 Jud, 1995

Continuation of Table 1

N Italy	Cismon	Hauterivian-Aptian	Calcareous nannofossils, Planktonic foraminifers, Magnetostratigraphy, Carbon isotope stratigr., Cyclostratigraphy	Channell et al., 1979 Weissert et al., 1985 Bralower, 1987 Weissert, 1989 Erba, 1994 Herbert, 1992
N Italy	Alpetto-Laghetto	Upper Barremian-Aptian	Ammonites, Calcareous nannofossils, Magnetostratigraphy, Sequence stratigraphy	Cecca & Landra, 1994 Channell et al., 1995 Bersezio, 1994
Georgia	Tvishi	Upper Barremian	Ammonites	Kakabadze & Kotetishvili, 1995
Carpathians	Medziholie	Lower Aptian	Ammonites	Vasicek & Rakùs, 1995
Transcapian	Tuarkyr Anticline	Barremian/Aptian boundary	Ammonites	Bogdanova & Lobacheva, 1995
Pacific Ocean	DSDP 463	Barremian-Aptian	Calcareous nannofossils, Planktonic foraminifers, Magnetostratigraphy, T.O.C.	Tarduno et al., 1989 Sliter, 1992 Erba, 1994 Bralower et al., 1993
Pacific Ocean	DSDP 167	U. Barremian-Aptian	Calcareous nannofossils, Planktonic foraminifers, Magnetostratigraphy, T.O.C.	Tarduno et al., 1989 Sliter, 1992 Bralower et al., 1993
Pacific Ocean	DSDP 317	Aptian-Albian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993
Pacific Ocean	DSDP 305	Aptian-Albian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993 Sliter, 1992
Pacific Ocean	DSDP 306	Aptian-Albian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993 Sliter, 1992
Atlantic Ocean	DSDP 364	Lower Aptian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993
Atlantic Ocean	DSDP 370	Aptian-Albian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993
Atlantic Ocean	DSDP 398	U. Barremian-Aptian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993
Atlantic Ocean	DSDP 402	Aptian-Albian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993
Atlantic Ocean	DSDP 417	Aptian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993
Atlantic Ocean	DSDP 511	U. Barremian-Aptian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993
Atlantic Ocean	DSDP 534	Barremian-Aptian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993 Ogg, 1987 Roth, 1978
Atlantic Ocean	ODP 641	U. Barremian-Aptian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993 Applegate & Bergen, 1988 Ogg, 1988
Indian Ocean	ODP 763	U. Barremian-Aptian	Calcareous nannofossils, Planktonic foraminifers, T.O.C.	Bralower et al., 1993

graphic level of the recommended boundary should conform as closely as feasible with current practice and the proposed boundary stratotype section depends primarily on the chosen boundary.

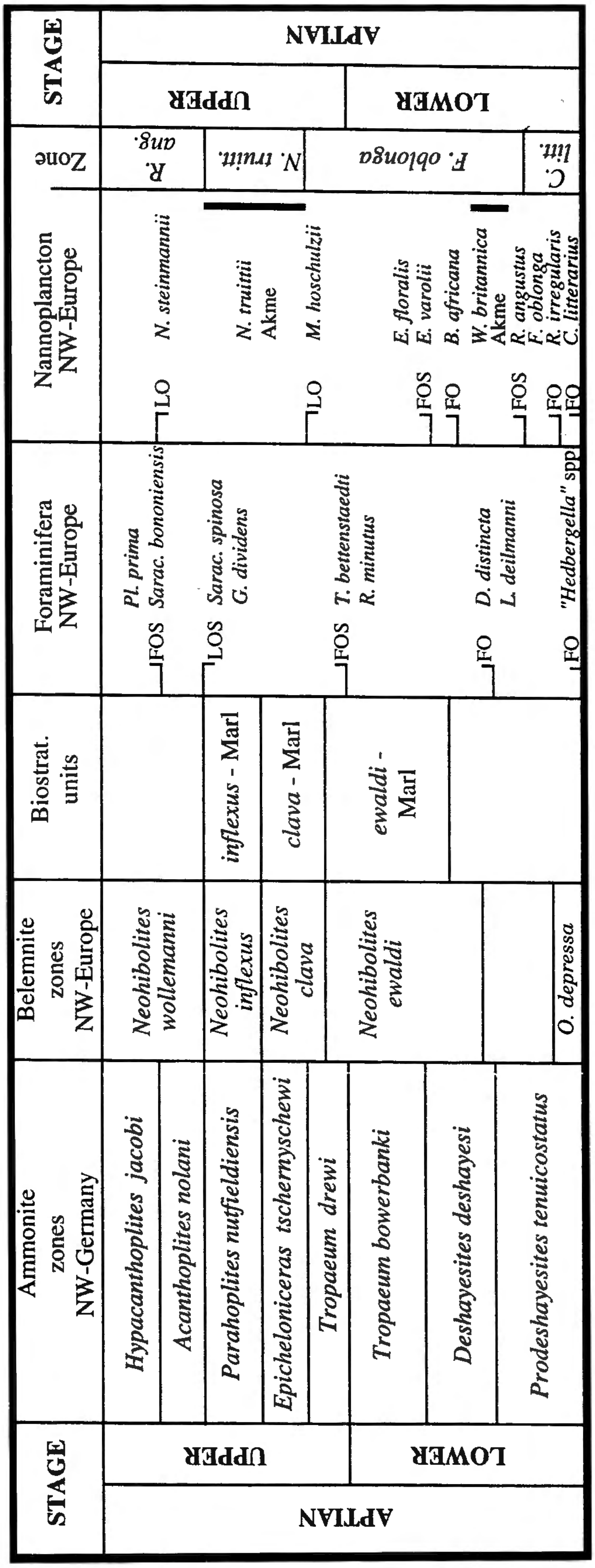

Fig. 2 — Integrated stratigraphy of the Aptian for Boreal realm and high latitudes (Mutterlose, pers. comm., 1995).

Although historical precedence was considered it has not over-ridden the importance of choosing a widely correlatable boundary. As recommended by the Subcommission on Cretaceous Stratigraphy, the preliminary proposals made at the Subcommission's 1983 Copenhagen conference (Birkelund *et al.*, 1984) were considered as starting point. At the Copenhagen conference, the discussion of the Aptian stage was focussed on the ammonite sequence, whereas other (micro)fossil groups as well as other stratigraphic tools were disregarded. In the past decade, detailed multidisciplinary analyses have been carried out on several sections through the Barremian-Aptian interval (Table 1). Studies were conducted also within the framework of the IGCP 262 - Tethyan Cretaceous Correlations, Pelagic Working Group and IGCP 362-Tethyan Boreal Cretaceous. The new information highlighted the difficulty of using ammonite sequences, and revealed the importance of biostratigraphy based on various fossil groups, especially micro- and nannofossils, magnetostratigraphy, chemostratigraphy, sequence stratigraphy and cyclostratigraphy in global correlations.

The Aptian Working group elaborated an integrated stratigraphy for the stage (Figures 1 and 2) that is the base for recommendations on the boundary level.

Definition of the Aptian stage

The Aptian stage was originally defined by d'Orbigny (1840) and Apt (Vaucluse) in southeast France was indicated as type area. La Bedoule, Gargas (near Apt) and Clansayes are all reference sections for subdivisions of the Aptian though not all satisfactory for correlation purposes (see Rawson, 1983).

At the Copenhagen conference, it was recommended (1) to place the base of the Aptian at the first appearance of *Prodeshayesites* and (2) to consider sections in southeast France, Turkmenia, England and north Germany for selection of the boundary stratotype. The discussion of regional correlation pointed out that there was less faunal differentiation across Europe during the Aptian than during earlier periods, though the proportion of Tethyan genera increases southwards. The French ammonite sequence was inadequately documented (see Moullade *et al.*, 1980), but "*Prodeshayesites*" / *Deshayesites* occurs there with more typically Tethyan genera and thus provides a link between Boreal and Tethyan faunas. *Deshayesites* may be widespread geographically, but there has been dispute as to whether the Venezuelan faunas, for example, really belong to this genus.

The base of the Aptian

The IUGS Subcommission on Cretaceous Stratigraphy

(BIRKELUND *et al.*, 1984) recommended to place the Barremian/Aptian boundary at the chronostratigraphic level coinciding with the appearance of the subgenus *Deshayesites (Prodeshayesites).* No alternative boundaries have been proposed since then. Most ammonite palaeontologists of the Aptian working group prefer to maintain the Barremian/Aptian boundary at the first occurrence of *Prodeshayesites*, and potential stratotype sections have been studied in various areas. In addition, DSDP (Deep Sea Drilling Project) and ODP (Ocean Drilling Program) sites drilled in the Pacific, Atlantic and Indian oceans have been investigated (Table 1). These studies revealed that virtually no ammonite-dated sections represent a continuous and complete Barremian/Aptian boundary. Thus the working group considered the possibility of placing the base of the Aptian (= the Barremian/Aptian boundary) at other events.

Due to absence or uneven distribution of ammonite faunas in several Aptian sequences from continents or ocean drilling sites, chronostratigraphy is routinely derived from calcareous nannofossil and planktonic foraminiferal biostratigraphy. Calcareous plankton (nannofossils and planktonic foraminifers) were exhaustively studied in several sections, but no events were detected at the Barremian/Aptian boundary as defined by ammonites. A few dinoflagellate cyst events occur close to this boundary, but they are restricted to the Tethyan area.

Stable isotopes are now currently used in stratigraphy and constitute a powerful tool for correlations across different basins. In particular, the $\delta^{13}C$ curve established for the Barremian-Aptian interval is reproducible in pelagic and shallow-water sequences across various basins and can be used for global correlations. The strontium isotopic curve also shows significant fluctuations and constitutes a reliable correlation tool.

For several sections, magnetostratigraphy combined with biostratigraphy provides a high resolution stratigraphy. The youngest reversal of the Lower Cretaceous to Upper Jurassic M-sequence, namely magnetic chron M0, represents a potential chronozone which is detectable at all latitudes and in various settings, both in marine and terrestrial sequences.
We report below a synthesis of the discussion of the various events.

CECCA, 1993 pers.comm.

Rawson, 1983

STAGE	TETHYAN *Mula Workshop, 1992*	South-East France *Lyon Colloquium, 1963*	STAGE	Southern England *Rawson, 1983* *Hancock, 1991*	Northern Germany *Rawson, 1983*	STAGE
APTIAN: upper = *Clansayesian*	H. jacobi	D. nodoso-costatum	APTIAN: upper	H. jacobi	H. jacobi	APTIAN: upper
	A. nolani				A. nolani	
middle = *Gargasian*	P. melchioris	C. subnodoso-costatum		P. nutfieldiensis	P. nutfieldiensis	
	E. subnodosocostatum	A. nisus		C. martinoides	E. tschernyschewi	
					T. drewi	
lower = *Bedoulian*	D. furcata	D. deshayesi	lower	T. bowerbanki	T. bowerbanki	lower
	D. deshayesi			D. deshayesi	D. deshayesi	
	D. weissi			D. forbesi		
	D. tuarkyricus			P. fissicostatus	P. tenuicostatus	
BAR	M. sarasini	S. seranonis	BAR	P. bidentatum	P. bidentatum	BAR

CORRELATION OF TETHYAN AND BOREAL AMMONITE ZONATIONS
(Ammonite zones not in scale)

Fig. 3 — Correlations of Aptian ammonite zonations.

Ammonites

If the first appearance of *Prodeshayesites* is taken to mark the base of the Aptian, as recommended at Copenhagen, problems arise. The type species of *Prodeshayesites*, *P. fissicostatum*, is from Speeton in England. The genus is common in the basal Aptian of eastern England and North Germany, and appears to have spread southward from this region to southern England as transgression spread into the Anglo-Paris Basin, where it gave rise to *Deshayesites*. Thus, using this criterion, a type section should be defined in the North Sea- North German area (Rawson, pers. comm., 1995).

The type section of the Speeton Clay at Speeton (England) shows an ammonite sequence across the Barremian/Aptian boundary which is under study (Rawson, pers. comm. 1995). Heteroceratid ammonites occur with *Aconeceras* just below the lowest record of *Prodeshayesites*. The exposure at Speeton is in the foreshore and often covered. However, if an artificial excavation were to be dug inland, where *Prodeshayesites* is documented from a borehole, a more permanent exposure could be made.

The rare ''*Prodeshayesites*'' so far recorded from SE France and other Tethyan areas belong to late *Deshayesites* and true *Prodeshayesites* have yet to be documented in those regions. Thus, if the first Tethyan ''*Prodeshayesites*'' is taken to mark the base of the Aptian, this boundary will be at a higher level than understood in the Anglo-Paris, North Sea and German basins.

In SE France, the base of the Aptian has been taken at the base of the *deshayesi* Zone. The Barremian/Aptian boundary interval of the Angles-Barrême area has been thoroughly investigated for ammonite distribution (Delanoy, 1995). Several specimens have been collected, but significant ammonites have not been found in the lowermost Aptian. Busnardo (1965) placed the base of the Aptian at the base of bed 197 of the Route d'Angles section because he found the first *Pseudohaploceras matheroni* in that bed. This species is now known to appear in the latest Barremian. Its level at Angles is marked by a ''non-characterised zone'' with few ammonites. Nevertheless, this boundary, which is a transgressive surface, is not in conflict with later discoveries. The first deshayesitids appear only 2 metres above, where ''*Prodeshayesites*'' is recorded in bed 200 (Delanoy, 1991).

Several sections spanning the Barremian/Aptian boundary have been investigated in Southern Spain, but significant ammonites are extremely rare, especially *Deshayesites* (Aguado *et al.*, 1995). The scanty ammonite record does not allow the recognition of the base of the Aptian.

In the Rio Argos sections (Caravaca, Murcia, Spain) the first Aptian ammonites (*Procheloniceras* and *Deshayesites*) occur just above a global transgressive surface, whereas *Colchidites* disappears just below it. It is possible that a hiatus marks the Barremian/Aptian boundary at Rio Argos (Hoedemaeker & Leereveld, 1995).

The Cephalopod Working Group of IGCP Project 262 adopted the Georgian Aptian ammonite sequence as a ''standard'' for the Mediterranean Region because a detailed zonation of the French succession was still not available (Hoedemaeker & Bulot, 1990). Pelagic sections in Georgia (Kakabadze & Kotetishvili, 1995) provide a virtually complete sequence of ammonites across the Barremian/Aptian boundary. Here the base of the Aptian is taken to be the base of the *D. tuarkyricus* Zone; *Prodeshayesites* is not recorded. However, palaeontological data are still insufficient to resolve the Barremian/Aptian boundary in Georgia or correlate with other regions.

Bogdanova & Lobacheva (1995) studied Barremian-Aptian sections in the Transcaspian area, where the base of the Aptian is characterized by rare and non-significant ammonites.

Calcareous Nannofossils

None of the nannofossil events proposed by Thierstein (1973) to place the Barremian/Aptian boundary at low latitudes was proved reliable. In fact, the FO of *Chiastozygus litterarius* is a Barremian event, the FO of *Rucinolithus irregularis* is dated as latest Barremian and *Nannoconus colomii* disappears in the late Aptian. At low latitudes, the FO of *Rucinolithus irregularis* is the most reliable nannofossil event, and the closest to the Barremian/Aptian boundary (Channell & Erba, 1992; Coccioni *et al.*, 1992; Erba, 1994; Channell *et al.*, 1995; Aguado *et al.*, 1995). It occurs in the upper part of the *M. sarasini* ammonite Zone and precedes magnetic polarity zone CM0. The FO of *Flabellites oblongus* is older than the FO of *R. irregularis* and correlates with the lower part of the *M. sarasini* ammonite zone (Aguado *et al.*, 1995).

In the Boreal Realm, the FO of *C. litterarius* is used to place the base of the Aptian (Mutterlose, 1991), but direct correlations with ammonites are not available. The FOs of *R. irregularis* and *F. oblongus* are younger than the FO of *C. litterarius* (Figure 2).

Recently, a distinctive nannofossil event has been documented on a global scale in the Early Aptian (Erba, 1994). Nannofossil assemblages are marked by a ''nannoconid crisis'' that occurred some 0.28 Ma after the end of magnetic Chron CM0. This ''nannoconid crisis'' precedes the black shales of the Oceanic Anoxic subEvent 1a of late early Aptian age (Figure 1).

Planktonic Foraminifers

The FO of *Globigerinelloides blowi* was detected in the Upper Barremian, within the Giraudi Zone and magnetic Chron CM1n and, therefore, predates the Barremian/Aptian boundary (Cecca *et al.*, 1994; Coccioni & Premoli Silva, 1994).

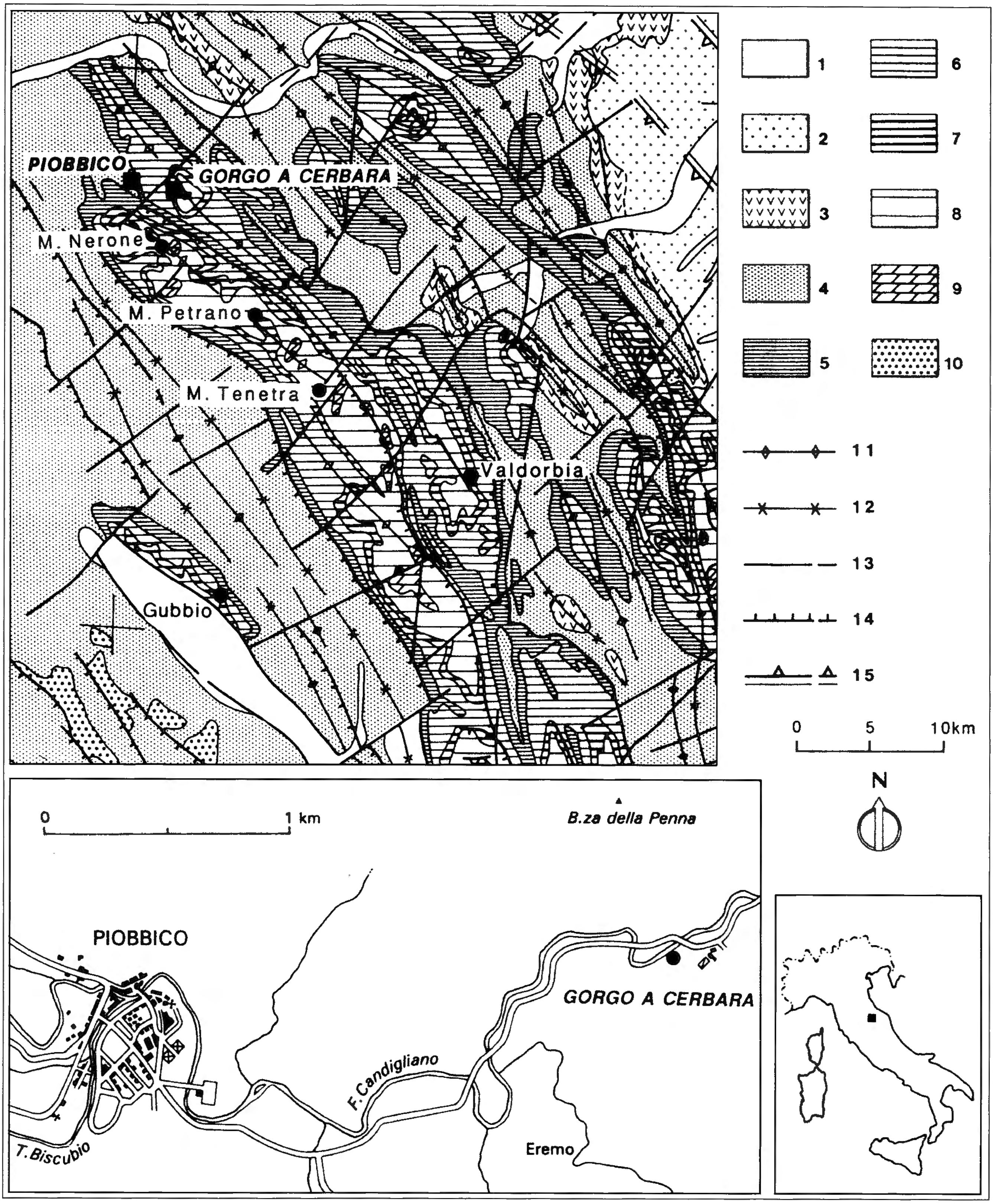

Fig. 4 — Geological map and location of the Gorgo a Cerbara section in the central Apennines (central Italy) (after ERBA, 1988). 1) Quaternary-Pliocene continental facies; 2) Quaternary-Pliocene marine terrigenous facies; 3) Messinian evaporitic facies; 4) Miocene marine terrigenous facies; 5) Oligocene-Paleocene pelagic facies; 6) Upper Cretaceous pelagic facies; 7) mid-Cretaceous pelagic facies (= Scisti a Fucoidi Formation); 8) Lower Cretaceous-Lower Jurassic pp. pelagic facies; 9) Lower Jurassic pp. -Upper Triassic carbonate platform facies; 10) alloctonous units; 11) anticline; 12) syncline; 13) fault; 14) thrust; 15) buried inverse fault.

DINOFLAGELLATE CYSTS

Dinoflagellate cyst events have been derived from ammonite calibrated sections from both Tethyan and Boreal areas (LEEREVELD, 1995). In general, there is a tendency to more extended ranges in the Boreal Realm. In the Tethyan area, the LO of *P. pelliferum* is slightly before the Barremian/Aptian boundary and the FO of *T. tenuiceras* shortly postdates the boundary. In the Boreal Realm, no dinoflagellate cyst events were observed at or close to the base of the Aptian.

MAGNETOSTRATIGRAPHY

Direct calibration of magnetic polarity zones with ammonite biozones in the Barremian/Aptian boundary interval are not available yet. A single specimen of ''*Prodeshayesites*'' was found in the upper part of magnetic chron M0 at the Gorgo a Cerbara section (CHANNELL *et al.*, 1995) (Figure 4).

The FO of the nannofossil species *Rucinolithus irregularis* correlates with the upper part of the uppermost Barremian *M. sarasini* ammonite Zone and precedes magnetic polarity zone CM0. Magnetic chron M0 has been identified in several low-latitude sections from the Tethys, Atlantic, Pacific and Indian oceans as well as in the Boreal Realm in the Isle of Wight (KEITH & HAILWOOD, 1988). Moreover, it is recognisable in pelagic/hemipelagic and neritic facies and in terrestrial sequences as well.

CHEMOSTRATIGRAPHY

Stable carbon isotope stratigraphy of the Barremian-Aptian has been established in several sections with calcareous plankton biostratigraphy and magnetostratigraphy. A major positive excursion correlates with the Oceanic Anoxic Event 1a (Lower Aptian) and a second excursion marks the upper Aptian (WEISSERT & LINI, 1991; WEISSERT & LINI, pers. com. 1994) (Figure 1).

The Strontium isotope curve ($^{86}Sr/^{87}Sr$) is still to be improved for the Barremian-Aptian. However, distinctive variations have been detected in the Aptian (JONES *et al.*, 1994) (Figure 1).

Correlations

For Early Cretaceous chronostratigraphy, time scales of the past decade (HARLAND *et al.*, 1982; KENT & GRADSTEIN, 1985; HARLAND *et al.*, 1990; GRADSTEIN *et al.*, 1994; CHANNELL *et al.*, 1995 b) used magnetostratigraphy integrated with calcareous plankton biostratigraphy. Ammonite control of magnetic chron is available only for a few polarity chrons. In recent time scales, the base of the Aptian is placed at the base of magnetic chron M0.

Recommendations

At the Brussels Symposium (September, 1995), the majority of the Aptian Working Group recommended to equate the Barremian/Aptian boundary, and therefore the base of the Aptian, with the base of magnetic chron M0. It must be emphasised that magnetostratigraphy must be always integrated with biostratigraphy (Figure 1) and magnetic chron M0 must be identified in relation to the FO of *Prodeshayesites*, and/or FO of *Rucinolithus irregularis* and or FO of *Flabellites oblongus* and/or the ''nannoconid crisis'', and/or the FO of *Globigerinelloides blowi*. Black shales of the OAE 1a, the $\delta^{13}C$ and the strontium curves can also provide litho- and chemostratigraphic calibrations of magnetic chron M0.

We report here that most ammonite palaeontologists of the Aptian Working Group prefer to maintain the Barremian/Aptian boundary at the first occurrence of *Prodeshayesites* or ''*Prodeshayesites*'', but virtually no ammonite-dated sections represent a continuous and complete Barremian/Aptian boundary.

Proposed boundary stratotype section

Accepting the base of magnetic chron M0 as base of the Aptian stage, then the Gorgo a Cerbara section (Umbria-Marche Basin, central Italy) (Figures 4 and 5), with an excellent exposure of Barremian to Aptian pelagic carbonates, is proposed as the boundary stratotype section. The section has magnetostratigraphy (LOWRIE & ALVAREZ, 1984; CHANNELL, in prep.), calcareous nannofossil (BRALOWER, 1987; COCCIONI *et al.*, 1992; ERBA, 1994) and planktonic foraminiferal biostratigraphy (COCCIONI *et al.*, 1992), radiolarian biostratigraphy (ERBACHER, 1994), dinoflagellate biostratigraphy (COCCIONI *et al.*, 1993), and chemostratigraphy ($\delta^{13}C$) (HADJI, 1991; ERBACHER, 1994). The Upper Barremian-Lower Aptian portion of the Gorgo a Cerbara section is shown in Figure 5.

The record of ammonites is not continuous; however, a few diagnostic layers have been detected. In particular, a specimen of ''*Prodeshayesites*'' was found at 894.70 m and indicates that magnetic chron M0 correlates with the *D. tuarkyricus* Zone (CHANNELL *et al.*, 1995).

Magnetostratigraphy was originally provided by LOWRIE & ALVAREZ (1984), but the section was sampled in great detail across magnetic chron M0 to increase the stratigraphic resolution of the boundaries (CHANNELL, pers. comm., 1994). Samples up to 893.00 m show normal polarity and indicate magnetic chron M1n. Magnetisation of samples 893.10 and 893.20 is very weak and therefore this short interval is indeterminate. The first reversed sample is at 893.32 m, where we place the base of magnetic chron M0 and, consequently the base of the Aptian.

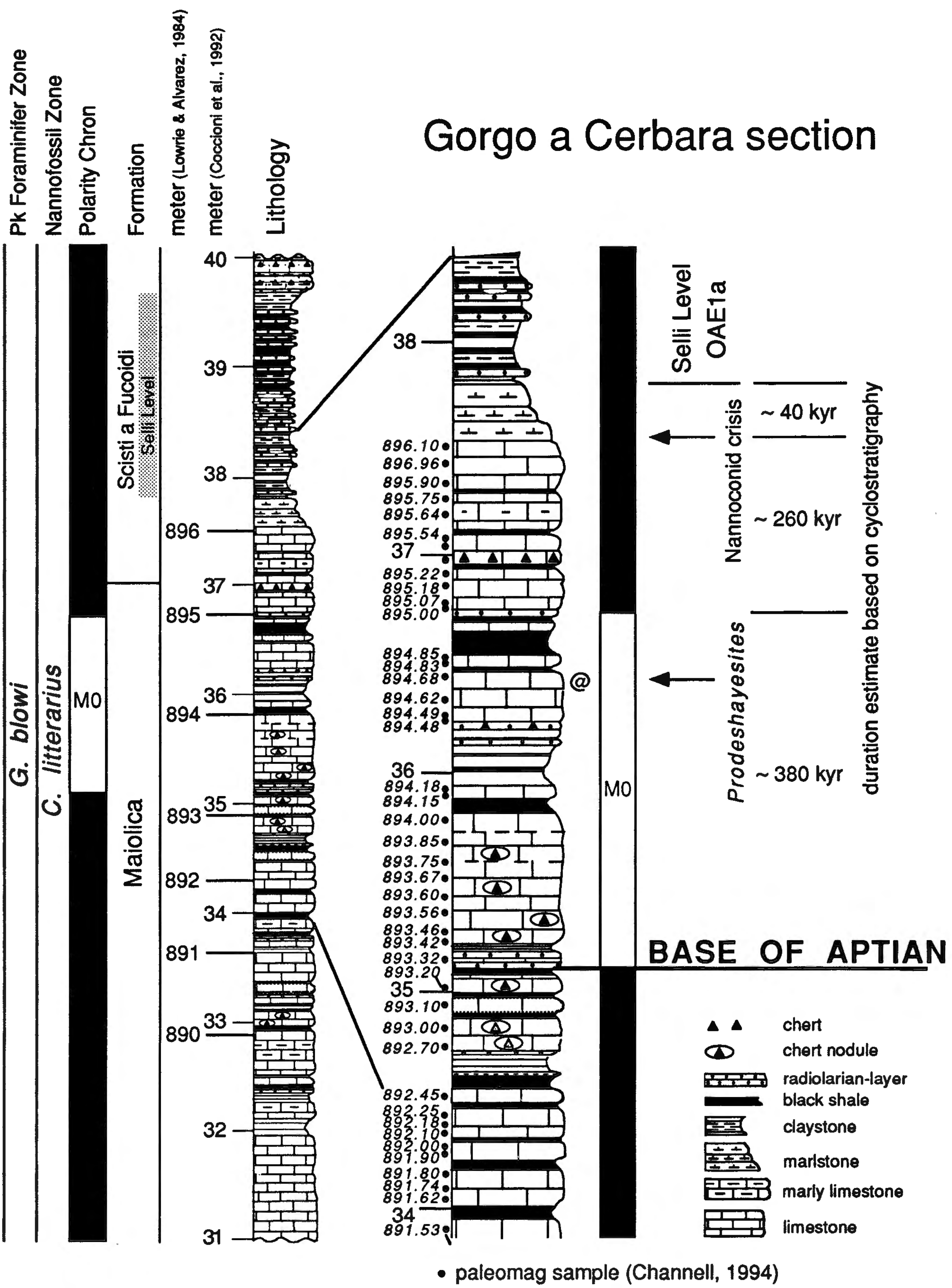

Fig. 5 — Stratigraphy of the Upper Barremian-Lower Aptian interval of the Gorgo a Cerbara section. Calcareous plankton biostratigraphy after COCCIONI *et al.* (1992) and ERBA (1994); magnetostratigraphy after CHANNELL (in prep.); cyclostratigraphy after HERBERT (1992).

Cyclostratigraphy was completed across the Barremian/ Aptian boundary and provides a resolution of 10k years (HERBERT, 1992). Based on Milankovitch-type cycles, the duration of magnetic chron M0 is 380 kyrs (Figure 5).

Aptian substage boundaries

Recent revisions of Cretaceous ammonite zonations (HANCOCK, 1991; HOEDEMAEKER, *et al.*, 1993; RAWSON, 1993) point out that two different ammonite zonations are used for the Boreal and the Tethyan Realms (Figure 3). While a two-fold subdivision (Lower and Upper) is adopted for the Boreal Aptian, a three-fold subdivision (Lower, Middle, Upper) is often proposed for the Tethyan Aptian following the French division into Bedoulian, Gargasian and Clansayesian. RAWSON (1983) discussed at length the Aptian substage subdivisions. The matter was also discussed during the Lower Cretaceous Cephalopod Meeting held in Piobbico (Italy) in 1994, but no final decision was taken.

Stratigraphers using calcareous plankton biostratigraphy, usually subdivide the Aptian into Lower and Upper. This substage boundary is equated to the base of the *L. cabri* foraminiferal Zone and the base of the *R. angustus* (=FO *E. floralis*) nannofossil Zone.

The Aptian Working Group established direct correlations between calcareous plankton stratigraphy, benthic foraminifers, dinocysts, radiolarians, magnetostratigraphy, chemostratigraphy ($\delta^{13}C$ and Strontium) (Figures 1 and 2), but no substage subdivision(s) were proposed. This will be the subject of further work.

References

AGUADO, R., COMPANY, M., O'DOGHERTY, L., SANDOVAL, J. & TAVERA, J. M., 1992. Biostratigraphic analysis of the pelagic Barremian/Aptian in the Betic Cordillera (southern Spain): preliminary data. *Cretaceous Research* **13**, 445-452.

AGUADO, R., COMPANY, M., SANDOVAL, J. & TAVERA, J. M., 1995. Biostratigraphic events around the Barremian-Aptian boundary in the Betic Cordillera (Southern Spain). *Second International Symposium on Cretaceous Stage Boundaries, Abstract Volume*, p. 6.

APPLEGATE, J. L. & BERGEN, J. A., 1988. Cretaceous calcareous nannofossil biostratigraphy of sediments recovered from the Galicia Margin, ODP Leg 103. In *Proceedings of Ocean Drilling Program, Scientific Results* (eds. BOILLOT, G., WINTERER, E. L., *et al.*) **103**, 293-348 (College Station, TX Ocean Drilling Program).

BERSEZIO, R., 1994. Stratigraphic framework and sedimentary features of the Lower Aptian "Livello Selli" in the Lombardian basin (Southern Alps, Northern Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, **99**, 569-589.

BIRKELUND, T., HANCOCK, J. M., HART, M. B., RAWSON, P. F., REMANE, J., ROBASZYNSKI, F., SCHMID, F. & SURLYK, F., 1984. Cretaceous stage boundaries-proposals. *Bulletin of the Geological Society of Denmark* **33**, 3-20.

BOGDANOVA, T. N. & LOBACHEVA, S. V., 1995. The Barremian/ Aptian boundary in the Transcaspian area (ammonites, bivalves, brachiopods, echinoids). *Second International Symposium on Cretaceous Stage Boundaries, Abstract Volume*, p. 24.

BRALOWER, T. J., 1987. Valanginian to Aptian Calcareous Nannofossil Stratigraphy and correlation with the upper M-Sequence magnetic anomalies. *Marine Micropaleontology* **11**, 293-310.

BRALOWER, T. J., SLITER, W. V., ARTHUR, M. A., LECKIE, R. M., ALLARD D. & SCHLANGER, S. O., 1993. Dysoxic/anoxic episodes in the Aptian-Albian (Early Cretaceous). In *The Mesozoic Pacific: Geology, Tectonics, and Volcanism, Geophys. Monogr. Ser.,*vol. 77, edited by M. Pringle, W. W. Sager, W. V. Sliter, and S. Stein, pp. 5-37, AGU, Washington, D. C., 1993.

BUSNARDO, R. 1965. Le stratotype du Barrémien. Lithologie et macrofaune. *Mémoires du Bureau de Recherches Géologiques et Minières*, **34**, 101-116.

CECCA, F.,& LANDRA, G., 1994. Late Barremian-Early Aptian ammonites from the Maiolica Formation near Cesana Brianza (Lombardy Basin, Northern Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, **99**, 395-422.

CECCA, F., PALLINI, G., ERBA, E., PREMOLI SILVA, I. & COCCIONI, R., 1994. Hauterivian-Barremian chronostratigraphy based on ammonites, nannofossils, planktonic foraminifera, and magnetic chrons from Mediterranean Domain. *Cretaceous Research*, **15**, 457-467.

CHANNELL, J. E. T. & ERBA, E. 1992. Early Cretaceous polarity chrons CM0 to CM11 recorded in Northern Italian land sections near Brescia (Northern Italy). *Earth and Planetary Science Letters* **108**, 161-179.

CHANNELL, J. E. T., BRALOWER, T. J.. & GRANDESSO, P., 1987. Biostratigraphic correlation of Mesozoic polarity chrons CM1 to CM23 at Capriolo and Xausa (Southern Alps, Italy). *Earth and Planetary Science Letters* **85**, 203-221.

CHANNELL, J. E. T, CECCA, F. & ERBA, E., 1995. Correlations of Hauterivian and Barremian (Early Cretaceous) stage boundaries to polarity chrons. *Earth and Planetary Science Letters* **134**, 125-140.

CHANNELL, J. E. T., LOWRIE, W. & MEDIZZA, F. 1979. Middle and Early Cretaceous magnetic stratigraphy from the Cismon section, Northern Italy. *Earth and Planetary Science Letters* **42**, 153-166.

CHANNELL, J. E. T., ERBA, E., NAKANISHI, M. & TAMAKI, K., 1995 b. Late Jurassic -Early Cretaceous timescales and oceanic magnetic anomaly block models. *SEPM Special Publications*, **54**, 51-63.

COCCIONI, R., ERBA, E., & PREMOLI SILVA, I. 1992. Barremian-Aptian calcareous plankton biostratigraphy from the Gorgo Cerbara section (Marche, central Italy) and implications for plankton evolution. *Cretaceous Research*, **13**, 517-537.

COCCIONI, R., GALEOTTI, S. & SANTARELLI, A., 1993. Preliminary palynological analysis of the Maiolica-Scisti a Fucoidi transition (Barremian-Aptian) in the Gorgo a Cerbara section (central Italy). *Paleopelagos*, **3**, 199-205.

COCCIONI, R. & PREMOLI SILVA, I., 1994. Planktonic foraminifera from the Lower Cretaceous of the Rio Argos section (southern Spain) and biostratigraphic implications. *Cretaceous Research*, **15**, 645-687.

DELANOY, G. 1991. Sur la présence du genre *Prodeshayesites* Casey, 1961 (Ammonoidea) dans l'Aptien inférieur du bassin Vocontien. *Cretaceous Research* **12**, 437-441.

DELANOY, G. 1995. About some significant ammonites from the Lower Aptian (Bedoulian) of the Angles- Barreme area (South-East France). *Memorie Descrittive della Carta Geologica d'Italia*, **51**, 65-101.

ERBA, E., 1988. Aptian-Albian calcareous nannofossil biostratigraphy of the Scisti a Fucoidi cored at Piobbico (central Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, **94**, 249-284.

ERBA, E., 1992. Calcareous nannofossil distribution in pelagic rhythmic sediments (Aptian-Albian Piobbico core, Central Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, **97**, 455-484.

ERBA, E., 1994. Nannofossils and superplumes: the Early Aptian nannoconid crisis. *Paleoceanography*, **9**, 483-501.

ERBA, E., COCCIONI, R. & PREMOLI SILVA, I., 1989. The "Scisti a Fucoidi" in the Umbria-Marche area: The Apecchiese road sections. *Memorie Descrittive Carta Geologica d'Italia*, **39**, 146-164.

ERBA, E. & PREMOLI SILVA, I., 1993. Orbitally driven cycles in trace fossil distribution from the Piobbico core (Late Albian, Central Italy). *IAS Special Publication*, **19**, 211-225.

ERBA, E. & QUADRIO, B., 1987. Biostratigrafia a Nannofossili calcarei, Calpionellidi e Foraminiferi planctonici della Maiolica (Titoniano superiore-Aptiano) nelle Prealpi Bresciane (Italia Settentrionale), *Rivista Italiana di Paleontologia e Stratigrafia*, **93**, 3-108.

ERBACHER, J., 1994. Entwicklung und Paläozeanographie mittelkretazischer Radiolarien der westlichen Tethys (Italien) und des Nordatlantiks. Ph. D. Thesis, Univ. Tübingen, 119 pp.

FISCHER, A. G., HERBERT, T. D., NAPOLEONE, G., PREMOLI SILVA, I. & RIPEPE, M., 1991. Albian pelagic rhythms (Piobbico core). *Journal of Sedimentary Petrology*, **61**, 1164-1172.

GRADSTEIN, F. M., AGTERBERG, F. P., OGG, J. G., HARDENBOL, J., VAN VEEN, P., THIERRY, J. & HUANG, Z., 1994. A Mesozoic time scale. *Journal Geophysical Research*, **99**, 24051-24074.

HADJI, S. 1991. Stratigraphie isotopique des carbonates pelagiques (Jurassique supérieur-Crétacé inférieur) du Bassin d'Ombrie-Marches (Italie). Ph. D. Thesis, Univ. Pierre et Marie Curie, Paris, 118 pp.

HANCOCK, J.M. 1991. Ammonite scales for the Cretaceous System. *Cretaceous Research*, **12**, 259-291.

HARLAND, W. B., ARMSTRONG, R. L., COX, A. V., CRAIG, L. E., SMITH, A. G. & SMITH, D. G. 1990. *A geologic time scale 1989*, 263 pp. (Cambridge University Press, Cambridge).

HARLAND, W.B., COX, A.V., LLEWELLYN, P.G., PICKTON, C.A.G., SMITH, A.G. & WALTERS, R. 1982. *A geologic time scale*, 131 pp. (Cambridge University Press, Cambridge).

HERBERT, T. D. 1992. Paleomagnetic calibration of Milankovitch cyclicity in Lower Cretaceous sediments. *Earth and Planetary Science Letters*, **112**, 15-28.

HERBERT, T. & FISCHER, A. G., 1986. Milankovitch climatic origin of mid-Cretaceous black shale rhythms in central Italy. *Nature*, **321**, 739-743.

HERBERT, T., PREMOLI SILVA, I., ERBA, E., & FISCHER, A. G., 1995. Orbital chronology of Cretaceous-Paleocene marine sediments. *SEPM Special Publication.*, **54**, 81-93

HOEDEMAEKER, P.J., & BULOT, J.L., 1990. Preliminary ammonite zonation for the Lower Cretaceous of the Mediterranean region. *Géologie Alpine*, **66**, 123-127.

HOEDEMAEKER, P. & COMPANY, M. (Reporters) *et al.* 1993. Ammonite zonation for the Lower Cretaceous of the Mediterranean region: basis for the stratigraphic correlations within IGCP-Project 262. *Revista Española de Paleontologia*, **8**, 117-120.

HOEDEMAEKER, P.J., & LEEREVELD, H., 1995. Biostratigraphy and sequence stratigraphy of the Berriasian-lowest Aptian (Lower Cretaceous) of the Rio Argos succession, Caravaca, SE Spain. *Cretaceous Research*, **16**, 195-230.

JONES, C. E., JENKYNS, H. C., COE, A. L., & HESSELBO, S. P., 1994. Strontium isotopic variations in Jurassic and Cretaceous seawater. *Geochimica et Cosmochimica Acta*, **14**: 3061-3074.

JUD, R. D., 1995. Early Cretaceous radiolarian biostratigraphy of Umbria-Marche Apennines (Italy), Southern Alps (Italy and Switzerland) and Hawasina Nappes (Oman). *In* BAUMGARTNER *et al.* (Eds.) Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: occurrences, systematics, biochronology. Mémoire Géologie Lausanne, 751-797.

KAKABADZE, M., & KOTETISHVILI, E., 1995. New data on the Upper Barremian biostratigraphy of the Georgian region (Caucasus). *Memorie Descrittive della Carta Geologica d' Italia*, **51**, 103-108.

KEITH, M., & HAILWOOD, E.A., 1988. Magnetostratigraphy of the Lower Cretaceous Vectis Formation (Wealden Group) on the Isle of Wight, Southern England. *Journal of the Geological Society, London*, **145**, 351-360.

KENT, D.V. & GRADSTEIN, F.M. 1985. A Cretaceous and Jurassic geochronology. *Geological Society of America Bulletin*, **96**, 1419-1427.

LEEREVELD, H., 1995. Dinoflagellate cysts from the Lower Cretaceous Rio Argos succession (SE Spain). *LLP Contribution Series*, **2**, 173 pp.

LOWRIE, W. & ALVAREZ, W. 1984. Lower Cretaceous magnetic stratigraphy in Umbrian pelagic limestone sections. *Earth and Planetary Science Letters* **71**, 315-328.

MOULLADE, M., TAXY, S. & TRONCHETTI, G., 1980. Aptien. *Mémoires Bureau Recherches Géologiques et Minières*, **109**, 112-115.

MUTTERLOSE, J. 1991. Das Verteilungs- und Migrations-Muster des kalkigen Nannoplanktons in der Unterkreide (Valangin-Apt) NW-Deutschland. *Palaeontographica Abt. B*, **221**, 27-152.

OGG, J. G., 1987. Early Cretaceous magnetic polarity time scale and the magnetostratigraphy of Deep Sea Drilling project Sites 603 and 534, western central Atlantic. *In*: *Initial Reports of DSDP* (eds. van HINTE, J. E., WISE, S. W. Jr., *et al.*), **93**, 849-879.

OGG, J.G., 1988. Early Cretaceous and Tithonian magnetostratigraphy of the Galicia Margin (Ocean Drilling program Leg 103). *In*: *Initial Reports of ODP* (eds. BOILLOT, G., WINTERER, E.L., *et al.*), **103**, 650-682.

ORBIGNY, A. de, 1840. Paléontologie francaise. Terrains crétacés. I. Céphalopodes. 662 pp.

RAWSON, P. 1983. The Valanginian to Aptian stages. Current definitions and outstanding problems. *Zitteliana*, **10**, 493-500.

ROTH, P. H., 1978. Cretaceous nannoplankton biostratigraphy and oceanography of the northwestern Atlantic Ocean. *In*: *Initial Reports of DSDP* (eds. BENSON, W. E., SHERIDAN, R.E. *et al.*), **44**, 731-759.

SLITER, W. V. 1992. Biostratigraphic zonation for Cretaceous planktonic foraminifers examined in thin section. *Journal of Foraminiferal Research,* **19**, 1-19.

TARDUNO, J. A., SLITER, W. V., BRALOWER, T. J., McWILLIAMS, M., PREMOLI SILVA, I. & OGG, J. G. 1989. M-sequence reversals recorded in DSDP sediment cores from the western Mid-Pacific Mountains and Magellan Rise. *Geological Society of America Bulletin*, **101**, 1306-1316.

TARDUNO, J. A., SLITER, W. V., KROENKE, L., LECKIE, M., MAYER, H., MAHONEY, J. J., MUSGRAVE, R., STOREY, M., & WINTERER, E. L. 1991. Rapid formation of Ontong Java Plateau by Aptian mantle plume volcanism. *Science,* **254,** 399-403.

THIERSTEIN, H. R. 1973. Lower Cretaceous calcareous nannoplankton biostratigraphy. *Abhandlungen der Geologischen Bundesanstalt A,* **29**, 1-52.

TORNAGHI, M. E., PREMOLI SILVA, I. & RIPEPE, M. 1989. Lithostratigraphy and planktonic foraminiferal biostratigraphy of the Aptian-Albian ''Scisti a Fucoidi'' in the Piobbico core, Marche, Italy: background for cyclostratigraphy, *Rivista Italiana di Paleontologia e Stratigrafia,* **95**, 223-264.

VASICEK, Z. & RAKUS, M., 1995. Lower Aptian ammonites from the Medziholie locality (the Malà Tatra Mountains, Slovakia). *Memorie Descrittive della Carta Geologica d'Italia*, **51**, 173-183.

WEISSERT, H. 1989. C-isotope stratigraphy, a monitor of paleoenvironmental changes: a case study from the Early Cretaceous. *Survey in Geophysics.*, **10**, 1-61.

WEISSERT, H., & LINI, A. 1991. Ice Age interludes during the time of Cretaceous greenhouse climate?, in *Controversies in modern Geology*, edited by D. W. MULLER, J. A. McKENZIE & H. WEISSERT, pp. 173-191, Academic Press, London.

WEISSERT, H., McKENZIE, J. A. & CHANNELL, J. E. T. 1985. Natural variations in the carbon cycle during the Early Cretaceous. *In*: The Carbon Cycle and Atmospheric CO_2: Natural variations Archaean to Present (eds. SUNDQUIST, E. T. & BROECKER, W. S.), pp. 531-545 (*Geophysic Monograph* **32**).

Address for correspondence:
Elisabetta ERBA
Dipartimento di Scienze della Terra
via Mangiagalli 34
I - 20133 Milano, Italy