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THE CRETACEOUS-EOCENE BOUNDARY IN ITALY

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THE CRETACEOUS–EOCENE BOUNDARY IN ITALY

BY

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SYNOPSIS. *Italian Upper Cretaceous is represented by three lithological facies: a deep sea facies, often calcareous, containing pelagic Foraminifera, a flysch facies much thicker than the preceding one, characterized by clastic sedimentation, and a shallow–water facies with organic limestones ("urgonian facies") containing rich faunas with Rudistae and large Foraminifera. Geographical distribution of cited facies in Italy is indicated. The passage from Upper Cretaceous to Eocene occurs with continuous sedimentation, as a rule, in localities where deep-sea facies are developed in Upper Cretaceous sediments, while disconformities are often observed in outcropping areas of reef-limestones. In order to illustrate the discussed question of the Cretaceous-Eocene boundary, the author studied from a micropaleontological point of view several stratigraphic sections from outcrops where a continuous sedimentation could be supposed. Environmental conditions being constant in Cretaceous and Eocene layers, the one cause which affects faunal changes is evolution as a function of time. Presence of Danian and Paleocene stages above Maestrichtian is pointed out.*

RÉSUMÉ. *Le Crétacé supérieur italien est représenté par trois faciès lithologiques: un faciès de mer profonde, souvent calcaire, contenant des Foraminifères pélagiques, un faciès de Flysch sensiblement plus épais que le précédent, caractérisé par une sédimentation clastique, et, enfin, un faciès de mer peu profonde montrant des calcaires organiques (« Faciès urgonien ») contenant de riches faunes à Rudistes et grands Foraminifères. La distribution géographique de ces faciès en Italie est donnée par la note. Le passage du Crétacé à l'Eocène s'effectue en sédimentation continue, en règle générale, dans des localités où des faciès de mers profondes sont observables dans les sédiments de Crétacé supérieur, tandis que l'on dénote fréquemment des disconformités dans les régions où affleurent des calcaires récifaux. Afin d'illustrer la question controversée de la limite entre le Crétacé et l'Eocène, l'auteur a examiné du point de vue micropaléontologique un certain nombre de coupes stratigraphiques effectuées dans des affleurements où l'on peut supposer l'existence d'une sédimentation continue. Les conditions de milieu étant constantes dans les couches du Crétacé et de l'Eocène, la seule cause qui entraîne ces changements de faunes est l'évolution en tant que fonction du temps. L'auteur fait ressortir la présence des étages Danien et Paléocène au-dessus du Maestrichtien.*

RIASSUNTO. *Il Cretaceo superiore italiano è rappresentato da tre facies litologiche: una facies di mare profondo, spesso calcarea, che contiene dei foraminiferi pelagici, una facies di flysch sensibilmente più potente della precedente, caratterizzata da una sedimentazione clastica, ed infine una facies di mare poco profondo con dei calcari organogeni (« facies urgoniana ») contenente delle ricche faune a Rudiste e grossi foraminiferi. La comunicazione indica la distribuzione geografica di queste facies in Italia. Il passaggio dal Cretaceo all'Eocene avviene con sedimentazione continua, di regola, nelle località dove il Cretaceo superiore è rappresentato da depositi di mare profondo, mentre si osservano spesso discordanze nelle zone di affioramento dei calcari di scogliera. Per illustrare la discussa questione del limite Cretaceo-Eocene, l'autore ha studiato dal punto di vista micropaleontologico parecchie sezioni stratigrafiche provenienti da affioramenti nei quali si poteva prevedere una sedimentazione continua. Essendo costanti le condizioni ambientali sia nel Cretaceo, sia nell'Eocene, l'unica causa che influenza le variazioni faunistiche è l'evoluzione in funzione del tempo. Viene notata la presenza dei livelli Daniano e Paleocene al di sopra del Maestrichtiano.*

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The Facies of Upper Cretaceous and the Passage from Cretaceous to Eocene in Italy

In order to illustrate the Cretaceous-Eocene boundary in Italy, I obtained some series of samples from outcrops with continuous sequences and studied them from a micropaleontological standpoint. Researches, for various reasons, were restricted to northern Italy ; but in the following pages data concerning other Italian regions may be found.

I consider this bibliographical review which might be judged unnecessary by some, of great importance in illustrating the Cretaceous-Eocene boundary in Italy. The sections studied concern only sediments of deep-sea facies, while sediments of epicontinental or continental environment are not considered.

According to the scientific and practical importance of these littoral facies, I have collected data about outcrops (see following pages) and illustrated their geographical distribution (see Fig. 1).

The description begins from northern Italy, following the arc of the Alps from West to East.

Upper Cretaceous is known in PIEDMONT in the autochtonous cover of the Hercynic massif of Mercantour. Large outcrops were attributed to Upper Cretaceous, in this zone, by the old authors ; according to recent, unpublished studies of Dr. Ascheri (3) however, only the limestones with Rudistae (" Urgonian facies ") of the Argentera Pass belong to this period, whilst all the other terrains indicated as Cretaceous by Franchi (23), Parona (37) etc., must be referred to the Jurassic. At the Argentera Pass, Priaboniano (Upper Eocene) lies upon limestones with Rudistae. All the lower part of the Eocene is therefore wanting. Still in Piedmont, indeterminate Cretaceous (flysch with *Orbitolina* sp.) has been recently cited by Elter (18) in the basal flysch of the " external subbriançonnese zone " near Courmayeur (Aosta).

Cretaceous is probably present, with metamorphic facies, in the comprehensive series of " schistes lustrés " of the Piedmont zone, well represented in the western and central Alps.

In LOMBARDIA begins the band of subalpine outcrops in normal facies, uninterrupted as far as Friuli.

The facies of Upper Cretaceous follow one another with a certain regularity from West to East, in this order : flysch, scaglia, flysch, reef limestones. The flysch facies, very thick, is known in Varesotto, Brianza, Bergamasco and Bresciano. The section of Merone, described later on, comes just from Brianza.

For other provinces, see the recent, detailed works by Cita (8), Geranzani (24), Orlini (36), Venzo (48), Vialli (49).

The passage from Cretaceous to Eocene occurs with continuous sedimentation. Single stages with scaglia facies have been noticed in Varesotto (of Albian-Cenomanian age), in Brianza (of Maestrichtian-Danian age) etc. But this facies is developed throughout the Upper Cretaceous series only East of the western coast of the lake of Garda. This facies lasts in Eocene (following to, with continuous sedimentation, Upper Cretaceous), with lithological change in Middle Eocene (see Cita : 9).

In TRENTINO outcrops penetrate the inner part of the Alpine chain. From this region come the two sections of Molveno and of the Non Valley (this last is the most northern outcrop of the Italian Alps) which are described later on.

In some localities of Trentino (Val Sugana, according to Fabiani (20) Lower Eocene is lacking, Middle Eocene lying directly upon Cretaceous scaglia, in a transgressive position.

In the provinces of Verona and Vicenza (VENETO), Upper Cretaceous is well represented, always with scaglia facies (plate-like limestones).

The sections of Valpantena and Valrovina, as described further on, come from the band of outcrops extended along the border of the plain.

Eastward, in the province of Belluno, flysch facies begins once again to appear, with a greater thickness, of course, than that of the scaglia.

Flysch facies extends into Paleogene, with continuous sedimentation. Section 4 comes from the Belluno neighborhood. In this same province reef limestones appear, which become more important toward FRIULI (i. e. towards East) ; near the boundary between Friuli and Veneto, at Monte Cavallo, there is the famous outcrop of the Col dei Schiosi, referred to the Turonian. *Rudistae*-bearing limestones develop also in the Senonian (see Parona: 37, page 545,

and his bibliography). The well-known calcareous outcrop of Vernasso, the fossil fauna and flora of which have been largely studied, is, too, of Senonian age (see fossil lists and bibliography in Parona: 37).

Selli (44), in a recent work on the high Isonzo Valley describes the Cretaceous sequence there. Upper Cretaceous has flysch facies; the youngest stage present in the sequence examined is Upper Campanian. There is no transition to Eocene, according to the emersion of the entire zone, which occurred before the beginning of that period.

Scaglia facies is also represented in Friuli, in a band which runs North of the reef-facies outcrops.

I had the opportunity to examine a series of samples collected by Dr. Baldazzi near Pulfero (eastern Friuli) at the Cretaceous-Eocene boundary. Upper Cretaceous is represented by scaglia-like reddish calcareous marls, bearing a *Globotruncana* and *Gümbelina* foraminiferal fauna of characteristic Upper Senonian age. The passage to Eocene is underlined by both a lithological and microfaunistical change: detritic limestones with typically neritic foraminiferal fauna (*Miliolidae* only are represented) actually replace the pelagic deposits described above.

In ISTRIA the " Liburnico " stage is particularly interesting at the passage from Cretaceous to Eocene ; in its classic definition (see Stache : 46) this stage would represent a continental environment (fresh- and brackish water limestones with *Melania*).

I had the opportunity to examine some samples kindly offered to me by Dr. Perconig, who collected them in the outcrop near the river Dragogna (Buie d'Istria). These are very fossiliferous limestones, with a rich molluskian fauna. Foraminifera are present in the rock : abundant *Miliolidae*, some arenaceous forms among which I could identify *Coskinolina* sp. This speaks for an epicontinental environment more than for a continental one.

In the underground of the Po Valley two stratigraphic wells perforated by AGIP reached Upper Cretaceous.

In the Vincenza Nuova well near Ferrara (see section 5) Upper Cretaceous appears at the depth of 1492 meters, with scaglia facies. Its thickness is much greater than that of corresponding facies, in outcrops ; this fact may be interpreted as an effect on accentuated subsidence in this portion of the Cretaceous basin.

The passage from Cretaceous to Eocene occurs with continuous sedimentation : both Danian and Paleocene stages have been individuated. In the Castenedolo well near Brescia, on the contrary, calcareous marls with scaglia facies were reached, at a depth of only 948 meters (see Perconig : 38) ; they contain a foraminiferal fauna with *Globorotalia aragonensis*, *Globigerina linaperta*, *G. pseudobulloides* etc., referable to the Paleocene age, but contain also a certain number of specimens belonging to the genus *Globotruncana*, presumably reworked. The well was interrupted at the depth indicated above ; the underlying Cretaceous series is therefore not known. Paleocene is followed by Lower Pliocene, all the interposed terms of the Tertiary series being absent.

Outcrops of Upper Cretaceous age along the Italian peninsula are frequent especially in the Central Apennines, which are called also Paleoapennines according to their large Mesozoic outcrops. Upper Cretaceous is much less extended in surface both in northern and in southern Apennines, where chiefly Tertiary terrains outcrop and the "Argille Scagliose" formation, considered as allochtonous by the majority of modern authors.

Upper Cretaceous occurs, autochtonous, in the northern Appennines, only in restricted outcrops on the Tyrrhenian side (Eastern LIGURIA, TOSCANA).

It presents scaglia facies (variegated marls often very rich in clay) ; it is a comprehensive series which goes from Cretaceous to Eocene and even to Oligocene.

Upper Cretaceous is devoid of foraminifera, while Lower Eocene is characterized by the apparition of *Globigerina* and *Globorotalia*.

In Liguria it outcrops near La Spezia, with the characters described above (see Rigo de Righi F. : 42). In Toscana it outcrops in the Apuane Alps, and appears in the mesozoic " rughe " (wrinkles) at Monsummano, Lucolena, Rapolano, Cetona (see Merla : 32). Monsummano and Lucolena sections were studied by Gandolfi (see Merla : 32, page 175), who found the Cretaceous series exceedingly reduced in thickness (10 meters) and devoid of fossils. It seems (Merla cit. w., page 174) that the passage from Cretaceous to Eocene is continuous, although

Fig. 1. Geographical Distribution of Upper Cretaceous Facies in Italy

pelagic, deep-sea facies throughout Upper Cretaceous («scaglia» in northern and central Italy, «lattimusa» in Sicily)

flysch facies in northern Italy; transitional facies (= facies umbro-meridionale) in central Apennines; coarse clastic facies («pseudoverrucano») near Grosseto

reef-limestones (= urgonian facies)

1. *Section 1st:* Merone
2. *Section 2nd:* Quinto Valpantena
3. *Section 3rd:* Valrovina
4. *Section 4th:* S. Antonio Bellunese
5. *Section 5th:* Vicenza Nuova
6. *Section 6th:* Molveno
7. *Section 7th:* Val di Non
8. *Section 8th:* Gubbio

Age represented by cited facies is comprehended between Turonian and Maestrichtian. Autochtonous outcrops only are represented. Delimitation of outcrops is only indicative

the presence of Upper Cretaceous is documented only by the occurrence of reworked *Globotruncanae* in Paleogene (Cretaceous scaglia is devoid of fossils, see above).

In Central Apennines, as indicated above, Upper Cretaceous is more extended in surface than in any other Italian region.

The authors who studied this part of the country distinguished two regional facies : the " umbra " facies towards west, the " abruzzese " towards east, separated by a line running approximately north-southward.

The first is characterized by scaglia-like calcareous deposits, the second by reef limestones with Rudistae.

Renz in his wellknown publication (41) on the scaglia facies in the Central Apennines considered a third facies, with characters that are intermediate between the others, namely the " umbro-meridionale " facies.

We shall not retain this name, because outcrops with lithological and paleontological characters perfectly corresponding to those described by Renz for his " umbro-meridionale " facies have been found very far from southern UMBRIA, so that we prefer to call it " transitional facies " ; this facies has some affinities with a calcareous flysch, and possibly corresponds to real flysch facies developed elsewhere.

From the cited work by Renz we extracted section 8 taking into account also Reichel's recent observations (42) on *Globigerinidae* from the Cretaceous-Tertiary transitional beds in the Apennines. The Gubbio section is characterized by typical " umbra " facies (calcareous scaglia about 500 meters thick). This section is typically a continuous one, both Danian and Paleocene stages being represented above Maestrichtian.

The " transitional facies " defined above is very like the scaglia ("umbra ") facies. The main difference is represented by calcareous beds with large foraminifera alternated with scaglia-like beds, bearing a pelagic microfauna. Among large foraminifera cited by Renz, there are *Orbitoides media*, *Siderolites* etc. (Maestrichtian) ; *Miscellanea*, *Discocyclina* cf. *seunesi*, *Operculina*, *Lituonella*, *Alveolina* of eocenic type (Paleocene).

This facies of Upper Cretaceous is indicated by Renz south of the lining Terni-Spoleto-Camerino. Upper Cretaceous series with similar characters were later described by Marchesini (31) at Monte Conero near Ancona, by Bally (4) in the Maiella tableland and at Monte Morrone near Sulmona, by Dr. Barbieri (unpublished data) in the Foro Valley south of the Maiella, in the Maielletta etc.

The Cretaceous-Eocene boundary in the transitional facies is often accompanied by continuous sedimentation according to Renz, Marchesini, and Barbieri. Bally indicates, in the Maiella group, an unconformity between Lower Eocene and Maestrichtian, but without an accentuated hiatus.

The " abruzzese " facies is characterized by calcareous deposits of great thickness. Upper Cretaceous is represented by clear limestones containing *Orbitoides media*, *Siderolites calcitrapoides*, *Omphalocyclus macropora*, fragments of *Rudistae*.

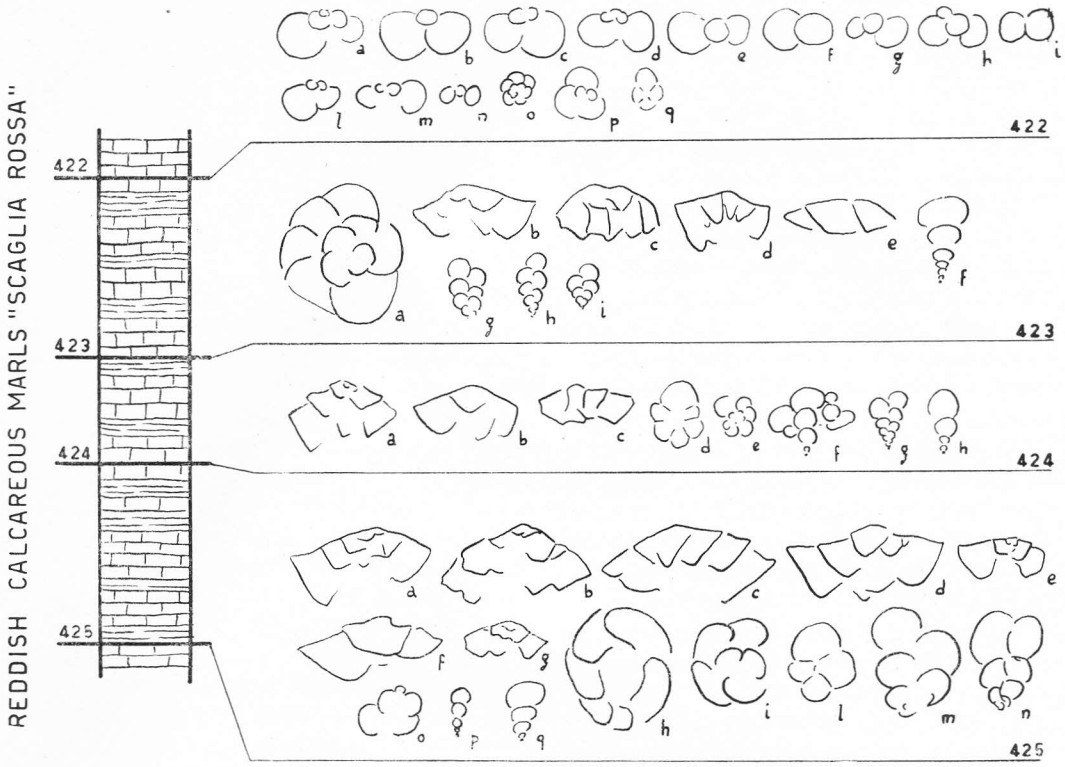
Terrains attributed by Renz to Paleocene occur above Cretaceous limestones : brecciated limestones with *Discocyclina* cf. *seunesi*, *Miscellanea*, *Operculina*, *Alveolina*, *Miliolidae* containing reworked Cretaceous fossils (*Globotruncanae*, fragments of *Rudistae*). Compact limestones with microforaminifera (gen. *Globigerina* and *Globorotalia*) are interbedded sometimes with brecciated limestones described above.

Before going on to describe the outcrops in the southern Apennines, it should be recalled that along the Tyrrhenian coast some Cretaceous deposits very interesting for paleogeographical purpose were recently described; they indicate a close or near proximity to the shore-line. " Pseudoverrucano " conglomerates of Cretaceous age are noticed by Merla (32) in some localities of the Grosseto province ; Signorini (45) discovered similar rocks in the Monti dell'Uccellina.

Finally, near Tarquinia, that is to say southeast of the above–mentioned localities, Alberti (1) signalled quite recently a *Globotruncana appenninica*-bearing Cenomanian with flysch facies.

In the southern Apennines autochtonous terrains form two linings which correspond approximately to the Tyrrhenian and Adriatic coasts, while the central part of the peninsula is covered for wide areas by the " Argille Scagliose " formation.

In both linings Upper Cretaceous is represented by reef limestones ("Urgonian facies ").



Section 1st: Merone

On the Tyrrhenian coast the largest outcrops are in Lepini and Ausoni mountains, in the Sorrentino, in the Salernitano and in the Cilento mountains. Massive limestones, very thick, containing *Rudistae* and *Alveolinae* are covered by transgressive deposits of Middle Eocene age. Along the Adriatic lining (Adriatic foreland) Upper Cretaceous outcrops in the Gargano peninsula and in PUGLIE, over wide areas ; it is represented by porous, whitish or yellowish limestones, more seldom compact and white, with oolithic interbeddings, *Hippurites*-bearing, with passages and intercalations to *Actaeonellae*-bearing limestones, with limited horizons with *Orbitoides*. The thickness of these limestones may reach a thousand meters.

Reef limestones close the Cretaceous cycle, followed by emersion of the land (bauxite layers of Gargano). Outcrops of Lower Eocene age have not yet been noticed, but does not mean this stage is not represented in the region.

Upper Cretaceous rocks of different facies are signaled at Capri : reef limestones are present in the island near a flysch-like deposit containing *Globotruncana mayaroensis* and *Gümbelina* sp. of Maestrichtian age (see Ducci : 16).

Marchesini (30) described a section composed of marls with *Globotruncana*, *Gümbelina*, *Planoglobulina*, *Globigerina* etc. associated with coarse organic limestones with *Siderolites calcitrapoides*, *Omphalocyclus macropora*, *Orbitella media*, *Simplorbites gensacicus* etc. This section, the age of which is indicated by Marchesini as Maestrichtian, closely recalls the transitional facies of the Central Apennines.

In the Bradanic fosse, before the Adriatic foreland, Upper Cretaceous was met in the well of Gaudiano (Iaboli : 28) at a depth of 250 meters (compact limestones with *Globotruncana* sp.).

All the outcrops cited above may be considered as autochtonous, according to available information.

But rocks of this Upper Cretaceous age or foraminiferal faunas were noticed inside the formation of " Argille Scagliose ". The main interest is in foraminiferal faunas contained in the clay itself, rather than in " exotics " included in the " Argille Scagliose " formation.

Globotruncana-bearing foraminiferal faunas from " Argille Scagliose " were noticed by Lipparini (29) and Emiliani (19) in the Apennines near Bologna.

Still from the northern Apennines, but from the neighborhood of Voghera (Costa Delle Forche, 3º 25' 32" long. E, 44º 52' 21" lat. N), a foraminiferal fauna with *Globotruncana lapparenti* and related species has been recognized by Dr. Barbieri in a sample collected by Dr. Lucchetti. Also from Parmense Apennines Dr. Barbieri described a foraminiferal fauna with *Globorotaliae* and *Globotruncanae* (5). The Cretaceous-Eocene passage would possibly be present in the Monte Dosso formation, according to this author.

An Upper Cretaceous foraminiferal fauna of Senonian age was noticed quite recently by Ippolito, Lucini and Spada (27) from Monticchio in the Agri Valley (southern Apennines).

Without entering into the question whether " Argille Scagliose " have to be separated in ophiolit-bearing (" teleallochtonous ") and in those without ophiolits, of proximal origin, it is evident that we cannot consider this formation from its structural characters only. From a stratigraphical point of view we must define " Argille Scagliose " as a comprehensive series of Mesozoic and partly of Tertiary age.

Their origin may be supposed far from the Tyrrhenian sea or nearer, as a number of authors now begin to believe.

Bally (4) considered " Argille Scagliose " near Sulmona as an equivalent of Cretaceous and Tertiary scaglia. It may be that elsewhere they correspond to Cretaceous and Tertiary flysch. In both cases it is a question of facies characteristic of geosynclines.

A general correspondence between typical, ophiolits-bearing " Argille Scagliose " and a most discussed Italian formation (" scistes lustrés ", a comprehensive, metamorphic series of Mesozoic and partly Tertiary age, typical geosyncline sedimentation, containing uprooted masses of ophiolits) is without doubt.

Knowledge of Upper Cretaceous of SICILY is somewhat poor, because old geological and stratigraphical work is in great part obsolete, while new studies are little publicized according to their practical purpose. The facies of Upper Cretaceous from Sicily known in outcrops are the following ones : reef limestones (" urgonian facies "), " lattimusa ", scaglia.

Reef limestones are developed mainly along the northern coast of the island (Trapanese, Capaci, Monte Pellegrino near Palermo, Termini Imerese, Cefalù). At Monte dell'Aspra near Bagheria (Palermo), De Stefani (14) indicated a calcareous outcrop with *Orbitella media* and perhaps *Simplorbites gensacicus* attributable to Maestrichtian.

Reef limestones generally close the Cretaceous cycle ; it seems that there is no continuity in sedimentation at the Cretaceous-Eocene boundary ; neither Paleocene nor Lower Eocene were described in contact with reef-limestones of Upper Cretaceous age.

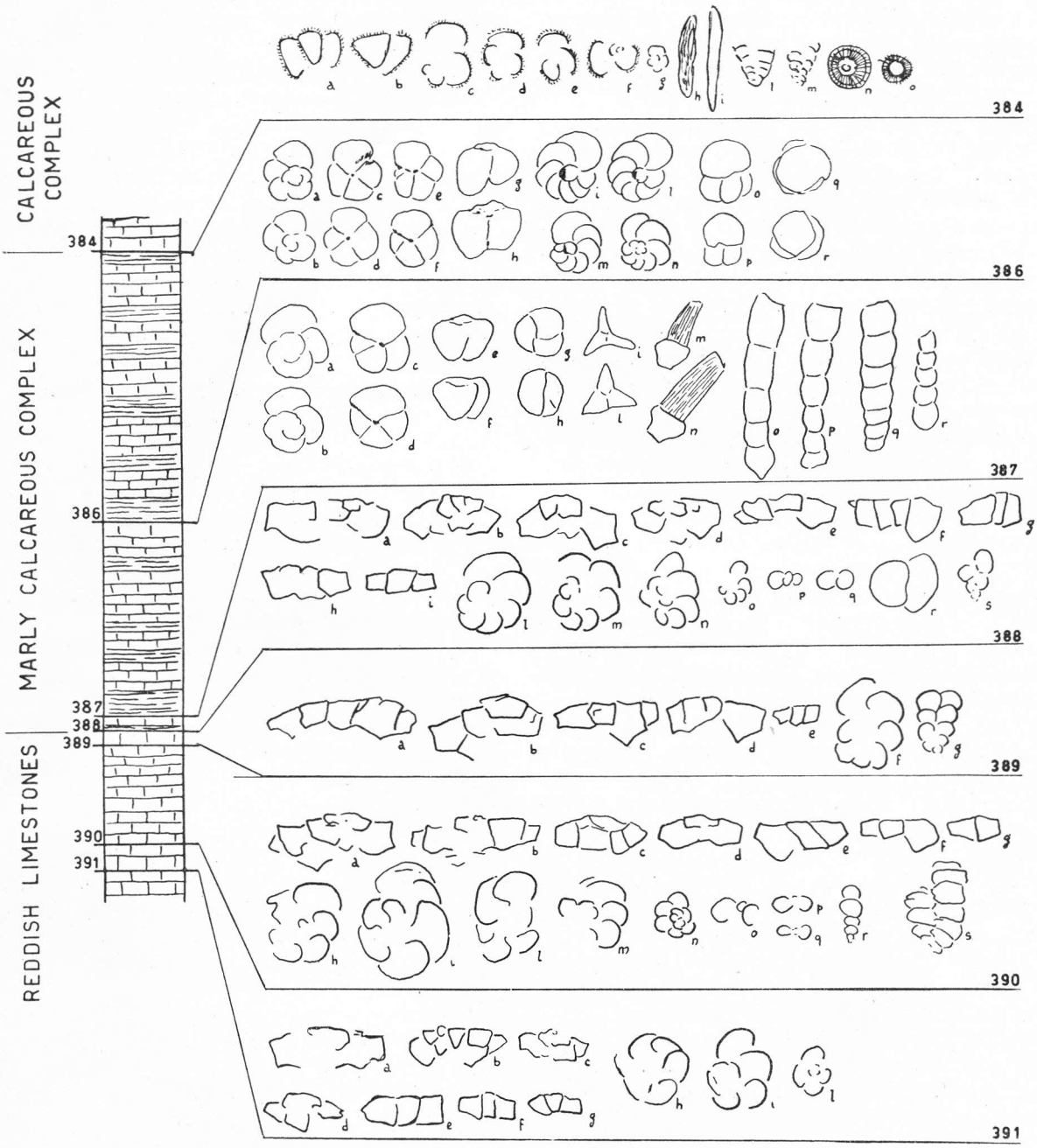
At Monte Pellegrino upon *Hippurites*-bearing limestones we find limestones with *Nummulites* and *Alveolina* of Middle Eocene age.

Always with reef facies, in the southern part of the island, the porous whitish limestones of Capo Passero with *Hippurites cornucopiae* and *Orbitoides gensacica* is wellknown.

An outcrop previously unknown was recently described by Allison (2) near Priolo (Siracusa). Upper Cretaceous is represented by thin limestone intercalations (containing *Globotruncanae* of Upper Senonian age) in volcanic rocks. The stratigraphical section continues with reef limestones passing locally to a marly facies. Reef limestones contain a large-foraminifera fauna with *Omphalocyclus macropora*, *Siderolites calcitrapoides*, *Simplorbites gensacicus* etc., while marls are characterized by a pelagic microfauna with *Globotruncana tricarinata* and *G. stuarti*. The age of this complex is Maestrichtian. Massive crystalline limestones of Paleocene age (with *Aleolina primaeva*, *Miscellanea miscella* etc.) lie unconformably upon Maestrichtian.

The " lattimusa " facies is represented by a compact, white limestone, somewhat like scaglia, characterized by a pelagic foraminiferal fauna with *Globotruncana*, *Globigerina* and *Gümbelina*.

This deep facies is present in the Trapanese (see Fabiani : 29 and De Stefani : 15), near Sciacca (limestones containing turonian *Globotruncanae* pointed out by Motta: 33), north of Menfi (see Rigo de Righi M. : 43), at the Monte Iato (" lattimusa " with *Globotruncana lapparenti* and *G. stuarti* pointed out by De Stefani) etc.



Section 2nd: Quinto Valpantena

In past times the " lattimusa " facies was considered of pre-Cretaceous age ; on the basis of new micropaleontological discoveries however, with this local name we indicate a comprehensive series which lasts from the Titonic to Middle Eocene age.

Works illustrating the paleontological sequence of " lattimusa " have not yet been published. Dr. Barbieri, according to the study of the Monte Bonifato section (near Alcamo), came to the conclusion that there is a continuous sedimentation at the Cretaceous-Eocene boundary : both Danian and Paleocene stages would be present in that section. M. Rigo de Righi (43) lately came to the same conclusion for the zone north of Menfi and De Stefani (15) for other localities from western Sicily.

The scaglia facies was signaled by Floridia (22) near Castelvetrano (Trapani), in the neighborhood of Scillato and Campofiorito (Palermo), in central Sicily. It is represented by schistose marls of rose color, with a typical *Globotruncana*-bearing foraminiferal fauna.

Upper Cretaceous, represented in autochtonous outcrops by the cited facies, is also present in Sicily – with " exotics " – in allochtonous formations (" Argille Scagliose " auctorum).

The *Rudistae*-bearing limestones of Ioppolo (Agrigento), considered as autochtonous in past times, are in fact indicated as exotics by Beneo (6). Ogniben (35) also pointed out uprooted masses of *Rudistae*-bearing limestones in the " Argille Brecciate " formation. From central and southern Sicily also " exotics " of Cretaceous age, with scaglia facies are known.

The flysch facies is not represented in the Sicilian Cretaceous in stages younger than Cenomanian; flysch with *Globotruncanae* was pointed out by di Napoli Alliata (17) at Caltavuturo near Termini Imerese and at Troina near Enna, in the " Cenomaniano a facies africana ".

In SARDINIA Upper Cretaceous with prevalent reef facies is known in the St. Antioco island, near Alghero and in the Nuorese (Monte Santo etc.).

The foregoing comments about Upper Cretaceous facies in the various regions of Italy are represented graphically in the annexed chart (see Fig. 1).

In autochtonous outcrops we distinguished bathyal facies (scaglia, " lattimusa "), flysch facies (typical flysch facies from northern Italy and " transitional facies " from Central Apennines included) and neritic facies (reef limestones etc.).

The facies corresponding to the maximum depth might be the argillaceous scaglia from the Appennino Toscano, assuming that its lower part is really Cretaceous. The outcrops characterized by this facies would then indicate the basin-bottom (minimum of sedimentation).

Observing the geographical distribution of the facies corresponding to the various depths, we may have an idea of Upper Cretaceous paleogeography. Observation of the chart may serve more purpose than words.

Micropaleontological Study of Eight Stratigraphical Sections

The sections which I chose to illustrate the Cretaceous-Eocene boundary interest, as previously said, deep-sea sediments. In these conditions in fact it may be remarked that lithology has no sensible change connected with the boundary considered ; facies limits do not correspond, as a rule, with stratigraphical limits.

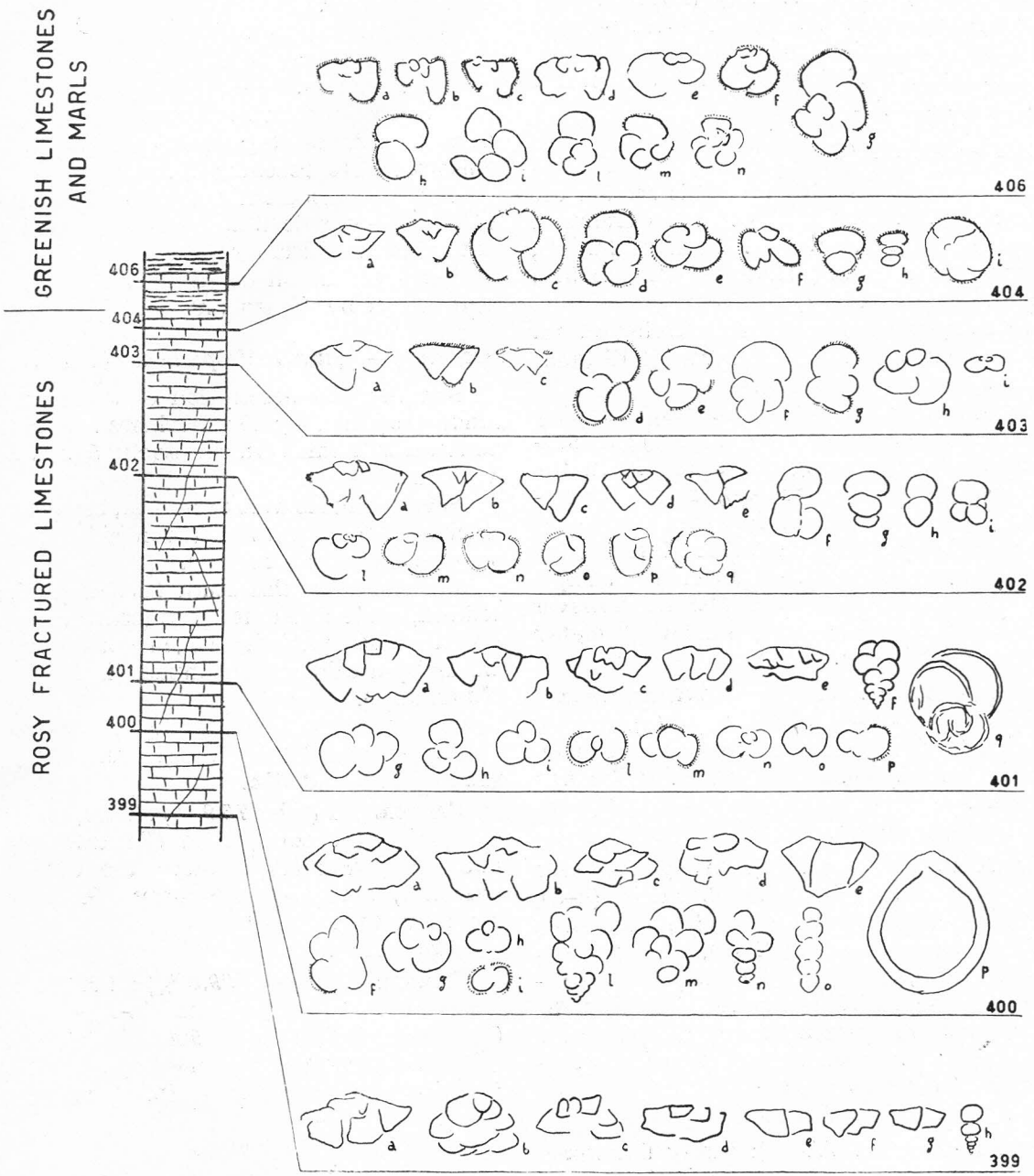
In a sequence with uniform lithology the only factor which affects faunistical changes is evolution as a function of time. We are therefore in the best condition to study succession of faunas independently from environmental conditions, time being the only variable quantity.

Six stratigraphical sections come from northern Italy. A series of samples was kindly offered to me for study by AGIP, from a stratigraphical well near Vincenza Nuova (Ferrara). Another was extracted from works of Renz (41) and Reichel (39) on Central Apennines.

I examined a total of eight stratigraphical sections.

The study was made especially over thin slides, according to the hardness of the greatest part of samples examined and, moreover, to facilitate direct comparison of the drawings. Samples from Val di Non only, and some from Valpantena, were studied over washing residues. All the drawings reported in the following pages were made with the help of a " camera lucida ", with constant enlargement.

A somewhat different enlargement may be found in the section of Gubbio, the drawings of which were reproduced from cited works by



Section 3rd: Valrovina

Renz and Reichel. Sample numbers of new sections are those of the Collection of the Geological Institute of the University (Milano).

For the section of Vincenza Nuova, we give the depths of examined bottom cores.

For the section of Gubbio, numbers reported are those given by Renz.

Section 1 – Merone (Como)

Samples and description of this section are due to Dr. M. B. Cita and Dr. C. S. Geranzani. The locality is about 30 km. north of Milano, in Brianza, in a quarry exploited by the firm " Cementi Merone ".

Four samples were examined covering a total thickness of about 50 meters (average distance between samples 15 meters).

Lithologically this section is characterized by reddish calcareous marls (scaglia rossa) ; no sensible changes occur along the section. In the same locality, some years ago, Prof. Vonderschmidt from Basilea found rare thin arenaceous layers containing large foraminifera interbedded within calcareous marls. The oldest sample among those described from Merone however (n. 425) comes from a level somewhat higher than those mentioned.

SAMPLE 425 (*calc. 69.6 %*): with *Globotruncana* (a–l), *Gümbelina* (m–q), *Globigerina* (o).

Maestrichtian species of *Globotruncana* are recognizable, such as *G. stuarti*, *G.* cf. *conica* and cf. *gansseri*.

Age : Maestrichtian.

SAMPLE 424 (*calc. 89.2 %*): marly limestone of rose-gray color, with *Globotruncana* (a–d), *Globigerinella* (e), *Planoglobulina* (f), *Gümbelina* (g, h). *Globotruncana stuarti* (a), *Globigerinella aequilateralis* (e), and *Planoglobulina acervulinoides* (f) may be easily recognized in the slide.

Well preserved specimens of *Globotruncana contusa* and of *G. conica* were observed in washing residue from this sample.

Age : Upper Maestrichtian.

SAMPLE 423 (*calc. 77.4 %*): marly limestones with thin schistose layers interbedded, of grey-rose color.

Micropaleontological contents: *Globotruncana* (a–e), *Gümbelina* (f–i).

Classified forms : *Globotruncana stuarti* (a–b), *G.* cf. *gansseri* (d), *Gümbelina elegans* (f), *G. globifera* (g), *G. globulosa* (i) (1).

Age : Upper Maestrichtian.

SAMPLE 422 (*calc. 57 %*) : schistose marl of dark red color.

Micropaleontological contents : *Globigerina* (a–m, p–q), *Globigerinella* (n, o).

Age : Danian.

This section is a continuous one – Maestrichtian and Danian stages being represented – but finishes before reaching Eocene.

The passage from Upper Cretaceous scaglia to detrital-organic limestones of Eocenic age is not visible in outcrops west of the River Adda.

For information about that section, see recent works by Venzo (48) and Vialli (49).

Section 2 – Quinto Valpantena (Verona)

Samples and description of this section were kindly supplied by Dr. A. Marzi. Quinto Valpantena is a small village about 5 km. north of Verona.

Seven samples were examined, covering a total thickness of 78 meters (average distance between samples 13 meters).

Lithologically this section is characterized by reddish, plate-like limestones (scaglia rossa), followed above by marls and limestones and afterwards by a calcareous complex (Eocene without Nummulits).

A lithological change may be observed between samples 388 and 387 ; another between samples 386 and 384.

SAMPLE 391 (*calc. 73.9 %*) : hard, marly limestones of rose color, with *Globotruncana* (a–i), and *Globigerina* (1). Among the Globotruncanas, flat, double–keeled forms (*G. lapparenti*) are prevailing.

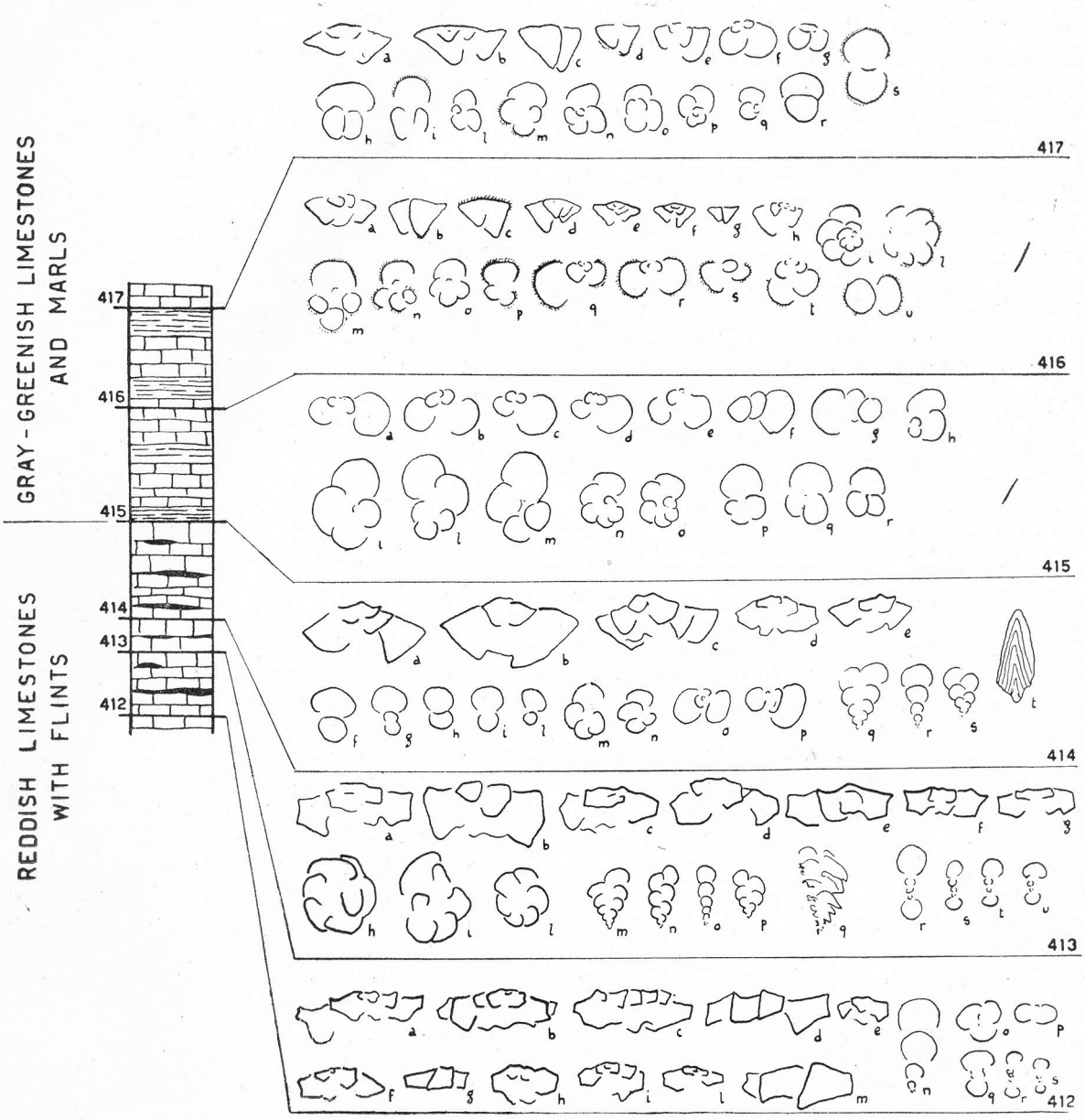
Age : Turonian.

SAMPLE 390 (*calc. 99.2 %*) : hard, red limestone with *Globotruncana* (a–n), *Globigerina* (o), *Globigerinella* (p, q), *Gümbelina* (r), *Guadryina* (s ?). *Globotruncana lapparenti* (a, b, d, f,) and *Globigerinella aequilateralis* (p, q) may be identified.

Age : Lower Senonian.

SAMPLE 389 (*calc. 76.8 %*) : marly, red limestones with *Globotruncana* (a–f) and *Gümbelina* (g).

SAMPLE 388 (*calc. 100 %*) : whitish limestone with Globotruncanas (a–e), Globigerinas (p–r ?), *Gümbelina* (s). The prevalent form is always *Globotruncana lapparenti* which gives a rather



Section 4th: S. Antonio Bellunese

old character to the microfauna. *Gümbelina globulosa* (s) may be recognized.

Age : Lower Senonian.

SAMPLE 387 (*calc. 97.5* %) : marly, whitish limestone with Globorotalias (a–f), *Globigerinoides* (g–h), sponge spicules (i, l), echinid radiolis (m, n), *Nodosaria* and related forms (e–r).

Classified forms : *Globorotalia crassula* (a–f), *Globigerinoides mexicanus* (g–h). Washing residue.

Age : Middle-Upper Eocene.

SAMPLE 386 (*calc. 78.8* %) : marly whitish limestone with *Globorotalia crassula* (a–f), *Cibicides* sp. (i–n), *Globigerina triloculinoides* (o–p), *Globigerinoides mexicanus* (q, r). Washing residue.

Age : Middle-Upper Eocene.

SAMPLE 384 (*calc. 100* %) : slightly fossiliferous detritic limestone, with *Globorotalia* aff. *crassula* (a, b), *Globigerina* sp. (c–g), sponge spicules (h ?, i ?), arenaceous forms (l, m), etc.

Age as above.

This section, which seemed to be a continuous one, revealed a sudden passage from Lower Senonian (sample 388) to Middle-Upper Eocene (s. 387). An important hiatus in sedimentation would be necessary to explain the lack both of Uppermost Cretaceous and of Paleocene stages, should a probable tectonic discontinuity not make this hypothesis rather doubtful.

Some specimens belonging to genus *Stensiöina* were observed in washing residues from samples of the Upper Cretaceous age. According to available knowledge, the geographical distribution of this genus, typical in Upper Cretaceous from northern Europe, seems to be very restricted, in Italy. I found it at Sirmione, 30 km. west of Verona, some years ago (10), whilst it was never pointed out from other provinces of Italy.

Section 3 – Valrovina (Vicenza)

Samples were collected by Dr. A. Marzi near Bassano del Grappa, in the Brenta Valley.

Seven samples were examined, covering a total thickness of 66 meters (average distance between samples 11 meters).

Lithologically this section is characterized by reddish limestones (samples 399-405), followed by greenish marls and limestones.

A lithological change may be observed above sample 405 (apparent boundary Cretaceous-Eocene lies between samples 404 and 405). Once more we may notice that facies limit does not correspond as a rule to statigraphical limit.

SAMPLE 399 (*calc. 94* %): reddish, hard limestone with Globotruncanas (a–g) and *Gümbelina* (h). *Globotruncana lapparenti* (d) and *G.* cf. *stuarti* (a) may be recognized.

Age : Senonian.

SAMPLE 400 (*calc. 90.6* %): reddish, hard limestone, a little marly, with Globotruncanas (a–e) Globigerinas (f–i), Planoglobulinas and Pseudotextularias (l–o), *Lagena* (p).

Globotruncana stuarti (a, c) and *Pseudotextularia varians* (1) may be recognized.

Age : Upper Senonian (Maestrichtian).

SAMPLE 401 (*calc. 92.6* %): reddish, hard limestone, a little marly, with Globotruncanas (a–e), Globigerinas (g–p), *Pseudotextularia* (f).

Globotruncanas belong to the *G. stuarti* group. Globigerinas offer a certain Danian aspect. In spite of the absence of typical conical forms of Globotruncanas, this sample seems to be Upper Maestrichtian.

SAMPLE 402 (*calc. 67* %): reddish, marly limestone with Globorotalias (a–e), *Globigerina* and related genera (f–q).

Globorotalia aragonensis (a, b), *Globigerina eocaena* (l) may be recognized. Lower Eocene (Paleocene) age.

SAMPLE 403 (*calc. 65.3* %) : reddish, marly limestone with keeled Globorotalias (a–c) and great, rough Globigerinas (d–h).

Middle-Lower Eocene age.

SAMPLE 404 (*calc. 86.1* %) : hard, reddish, marly limestone with few keeled Globorotalias (a, b) and many rough Globigerinas (c–i).

Globigerina eocaena (d) and *Globigerinoides mexicanus* (i) may be recognized.

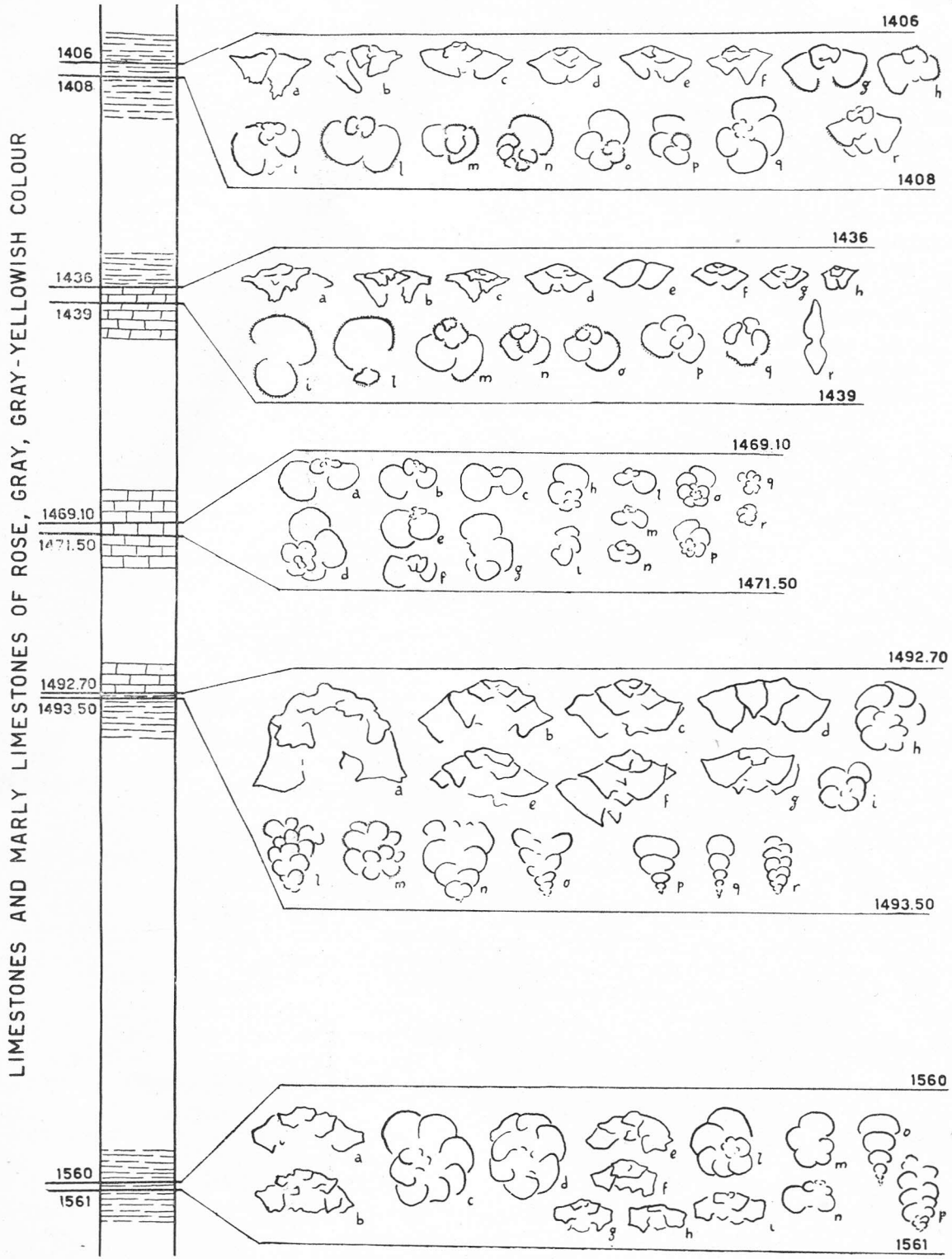
Age : Middle Eocene.

SAMPLE 406 (*calc. 74.4* %) : marly limestone of grey-greenish color, with Globorotalias of the *G. crassula* group (a–d), *Globigerina* cf. *eocaena* (e), other Globigerinas and Globorotalias (f–n).

Middle-Upper Eocene age.

This series may be considered as a continuous one, notwithstanding the absence of the characteristic level with Globigerinas (Danian age).

Globigerinas of Danian aspect have been observed in sample 401. Since the distance between sample 401 (Upper Maestrichtian) and 402 (Paleocene) is somewhat great (25.2 meters), it



Section 5th: Vincenza Nuova

may be that the characteristic *Globigerina*-horizon is comprised between the two observed samples.

Section 4 – Sant'Antonio Bellunese

Samples and description of this section are from Dr. A. Marzi. The locality is about 12 km. south-west of Belluno, in the Piave Valley.

Six samples were examined, covering a total thickness of 55 meters (average distance between samples 11 meters).

Lithologically this section is characterized by reddish limestones with thin flint intercalations (samples 412-414) and by limestones and marls of gray-greenish color (samples 415-417).

A lithological change may be observed between samples 414 and 415.

Sample 412 (*calc. 92.3*) : marly limestone of red-violet color, with Globotruncanas (a–m), *Gümbelina* (n), *Globigerina* and related genera (o–s). The genus *Globotruncana* is represented by large, flat, double–keeled forms of ancient aspect. *G. coronata* (a), *G. lapparenti* (l) and *G.* cf. *cretacea* (f) have been recognized among them. Another classified form is *Globigerinella aequilateralis* (q–s).

Age : Lower Senonian.

Sample 413 (*calc. 98.3 %*): reddish limestone with flints.

Microfaunistical contents : Globotruncanas (a–l), Gümbelinas (m–p), *Globigerinella aequilateralis* (r–u).

Globotruncana lapparenti (f), *G.* cf. *tricarinata* (a), *Gümbelina globulosa* (m, p) have been recognized.

Age : Lower Senonian.

Sample 414 (*calc. 100 %*): detritic limestone with Globotruncanas (a–e), *Globigerina* and related genera (f–p), *Gümbelina* (q–s), *Frondicularia* (t). Some of the two-chambered forms indicated as *Globigerina* (see f, h, i) might be transverse sections of Gümbelinas.

Globotruncanas chiefly belong to the *G. stuarti* group (a–c).

Globigerinas have a distinct Danian aspect.

For the chronological interpretation of this sample, we may consider the microfauna as Maestrichtian with Danian affinities or as Danian containing reworked specimens of Maestrichtian age. According to the lithological character of this sample (microbreccia), the second hypothesis might be the more probable.

Sample 415 (*calc. 57.2 %*): greenish marl containing a microfauna formed only by Globigerinas and Globigerinellas with thin shell.

Danian age.

Sample 416 (*calc. 55.2 %*): grey-greenish marl with small–keeled Globorotalias (a–l) and Globigerinas with rough surface (m–u).

Globorotalia cf. *simulatilis* (a) and *Globigerina eocaena* (q) have been recognized.

Age : Lower Eocene (Paleocene).

Sample 417 (*calc. 56.2 %*): grey greenish marl with keeled Globorotalias (a–d), *G. crassula* (e), Globigerinas and related genera (f–s).

Age: Lower-Middle Eocene.

This series, which seemed to be a continuous one, revealed the absence of Upper Senonian levels (Santonian, Campanian, Maestrichtian). We spoke before about the interpretation of sample 414. A hiatus in sedimentation is needed to explain the phenomenon observed. This does not mean that there has been a strong regression or emersion (which would be in contrast both with lithological and micropaleontological facies), but that there was no deposition for a sufficiently long time, or that submarine erosion took place.

Section 5 – Vincenza Nuova (Ferrara)

This is a subsurface section, obtained by bottom cores. The well of Vincenza Nuova, near Ferrara, was drilled by AGIP in 1937.

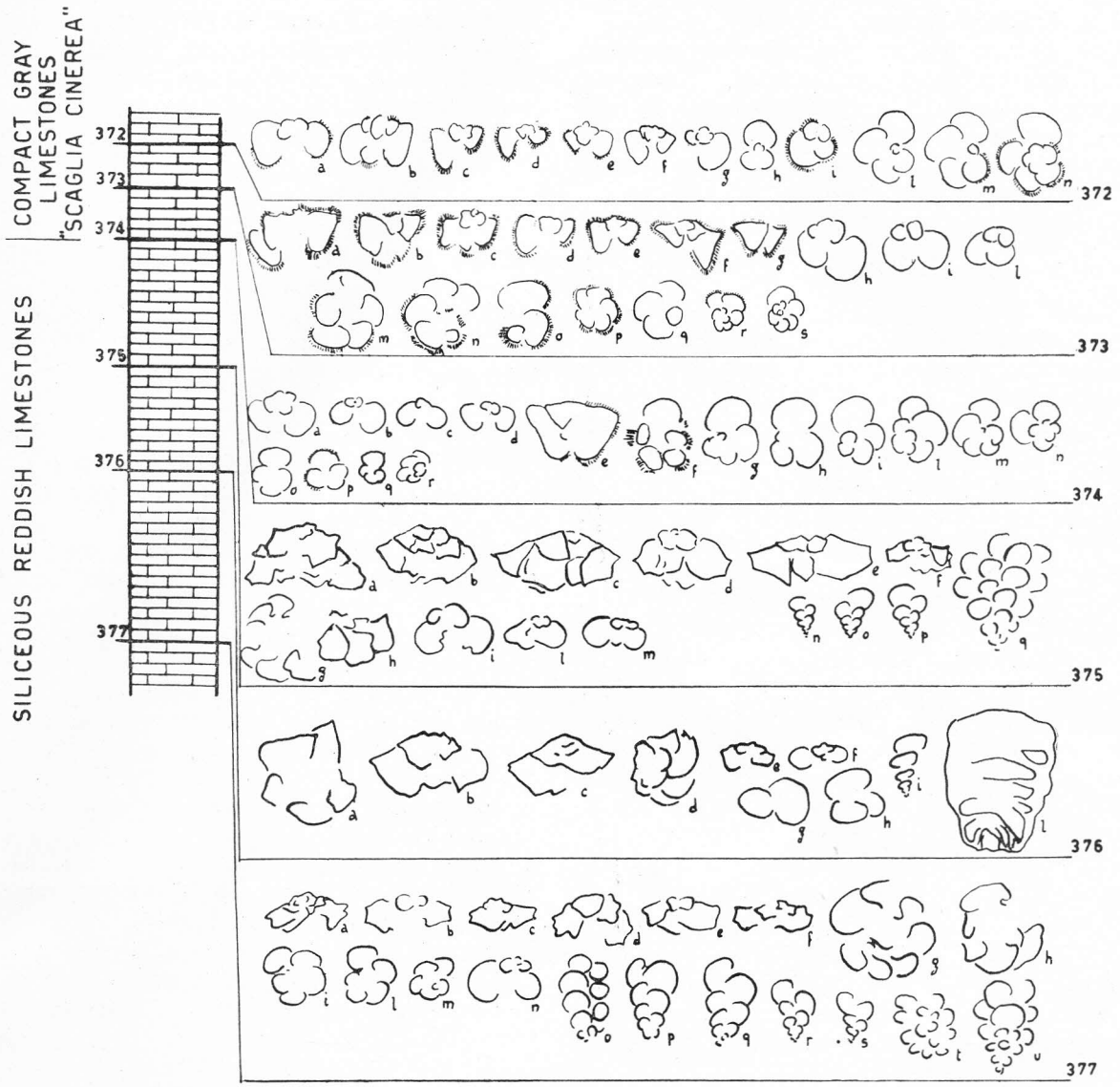
Five samples were examined covering a total thickness of 155 meters (average distance between samples about 40 meters).

Lithologically this section is characterized by marly limestones, scaglia-like, of rose color, followed above by gray-yellowish limestones somewhat marly ; the passage from one lithological type to the other is gradual.

Core m. 1560-1561: slightly marly limestone, light rose, with some thin dark gray layer with laminated surfaces ; it contains a foraminiferal fauna with *Globotruncana arca* (a), *G.* aff. *conica* (b), *G. tricarinata* (g, h), *G. lapparenti* (i), *Globigerina cretacea* (m, n), *Gümbelina elegans* (o), *G. globifera* (p).

Age: Upper Senonian (Campanian).

Core m. 1492.7-1943.5: rose–brownish limestone, slightly marly, scaglia-like; foraminiferal fauna with *Globotruncana contusa* (a), *Globotruncana stuarti* (b–f), *Globotruncana* cf. *gansseri*



Section 6th: Molveno

(g), *Pseudotextularia varians* (l–o), *Gümbelina elegans* (p), other Gümbelinas (q, r).

Age: Uppermost Senonian (Upper Maestrichtian).

Core m. 1496.1-1471.5 (*calc. 81 %*): marly, sandy limestone of gray-yellowish color. Foraminiferal fauna formed only by Globigerinas and related genera with thin shell.

Age : Danian.

Coer m. 1437-1439 (*calc. 71 %*): gray-yellowish limestone with Globorotalias (a–h, q). Globigerinas (i–p), *Cibicides* (r ?). Globorotalias belong chiefly to *G. velascoensis* group ; Globigerinas are large and have a rough surface.

Age : Lower Eocene (Paleocene).

Core m. 1406-1408 (*calc. 89.5 %*): slightly marly limestone with various small micaceous-siliceous elements, color rose-yellowish.

Microfauna containing *Globorotalia aragonensis* (a, b), *Globorotalia* sp. (c, d, e), *Globorotalia* cf. *crassata* (f), *Globorotalia* of the *G. crassula* group (g, h, r), *Globigerina eocaena* (o).

Age : Middle Eocene.

This section shows a continuous sequence from Cretaceous to Eocene, through Danian and Paleocene stages. This notwithstanding the distance between samples being rather great; more, at any rate, than the distance between samples of the other sections examined.

For interpretation of this fact, see pag. 429.

Section 6 – Molveno (Trento)

Samples were collected by Dr. M. B. Cita along the road which coasts the lake of Molveno, at the passage from " scaglia rossa " to " scaglia cinerea ".

Six samples were examined, covering a total thickness of 60 meters (average distance between samples about 12 meters).

Lithologically this section is characterized by siliceous or marly limestone, of dark reddish color (samples 377-374), and by compact limestone of gray (cinder) colour (samples 373-374).

A lithological change may be observed in correspondence with sample 374, as shown later on.

SAMPLE 377 (*calc. 58.6 %*) : compact, siliceous limestone of red (wine) color, with Globotruncanas (a–m), *Globigerina* (n), Gümbelinas (o–s), Pseudotextularias (t–u).

The following species may be identified: *Globotruncana* aff. *arca* (a), *G.* aff. *mayaroensis* (b), *G.* aff. *calciformis* (d), *G. lapparenti* (e, f), *Globigerina cretacea* (n), *Gümbelina globifera* (o), *G. globulosa* (r, s), *Pseudotextularia varians* (u).

Age : Upper Senonian (Maestrichtian).

SAMPLE 376 (*calc. 69.5 %*): compact, subcrystalline limestone of red (wine) color, with Globotruncanas (a–e), Globigerinas (f–h), *Gümbelina* (i), *Vulvulina* (l).

One may recognize *Globotruncana contusa* (a), *G. stuarti* (b, c), *Gümbelina elegans* (i).

Age : Upper Senonian (Maestrichtian).

SAMPLE 375 (*calc. 64.5 %*) : hard limestone, with fine texture, color dark violet to gray.

Foraminiferal fauna with Globotruncanas (a–h), Globigerinas (i–m), Gümbelinas (n–p), *Pseudotextularia* (q). Identified specimens: *Globotruncana contusa* (a), *G. stuarti* (b, c), *G.* cf. *mayaroensis* (d), *Globigerina cretacea* (i–m), *Gümbelina globulosa* (n–p), *Pseudotextularia varians* (q).

Age : Uppermost Senonian (Upper Maestrichtian).

SAMPLE 374 (*calc. 45.7 %*) : marly compact limestone of reddish-violet color. Foraminiferal fauna characterized by small Globigerinas with thin shell ; a single transverse section of *Globorotalia* (of the *G. angulata* group) may be observed (e).

Age : Danian.

SAMPLE 373 (*calc. 70.3 %*): massive limestone of rose color zoned in gray. Foraminiferal fauna with Globorotalias (transverse sections a–g) and Globigerinas (transverse sections h–l). Globorotalias belong chiefly to the *G. crassula - G. angulata* group (with rounded external border a–e). Other specimens seem to be *G. crassata* (f–g).

Age : Lower-Middle Eocene.

SAMPLE 372 (*calc. 62.4 %*) : compact limestone of gray (cinder) color. Foraminiferal fauna with Globorotalias (transverse sections a–f, horizontal sections l–m) and Globigerinas (g, h, i).

Globorotalias belong to the *G. angulata* group.

Age : Middle Eocene.

This section may be considered as a continuous one, although samples referable to Paleocene have not been recognized. This is due to the absence of Globorotalias belonging to the *G. aragonensis - G. velascoensis* group. Globorotalias with rounded external border (*G. angulata* and similar species) appear in this section soon after the disappearence of Globotruncanas and other Cretaceous genera (s. 375).

Sample 374 shows a typical association of Danian Globigerinas, accompanied by a species of *Globorotalia* which elsewhere does not appear before Middle Eocene.

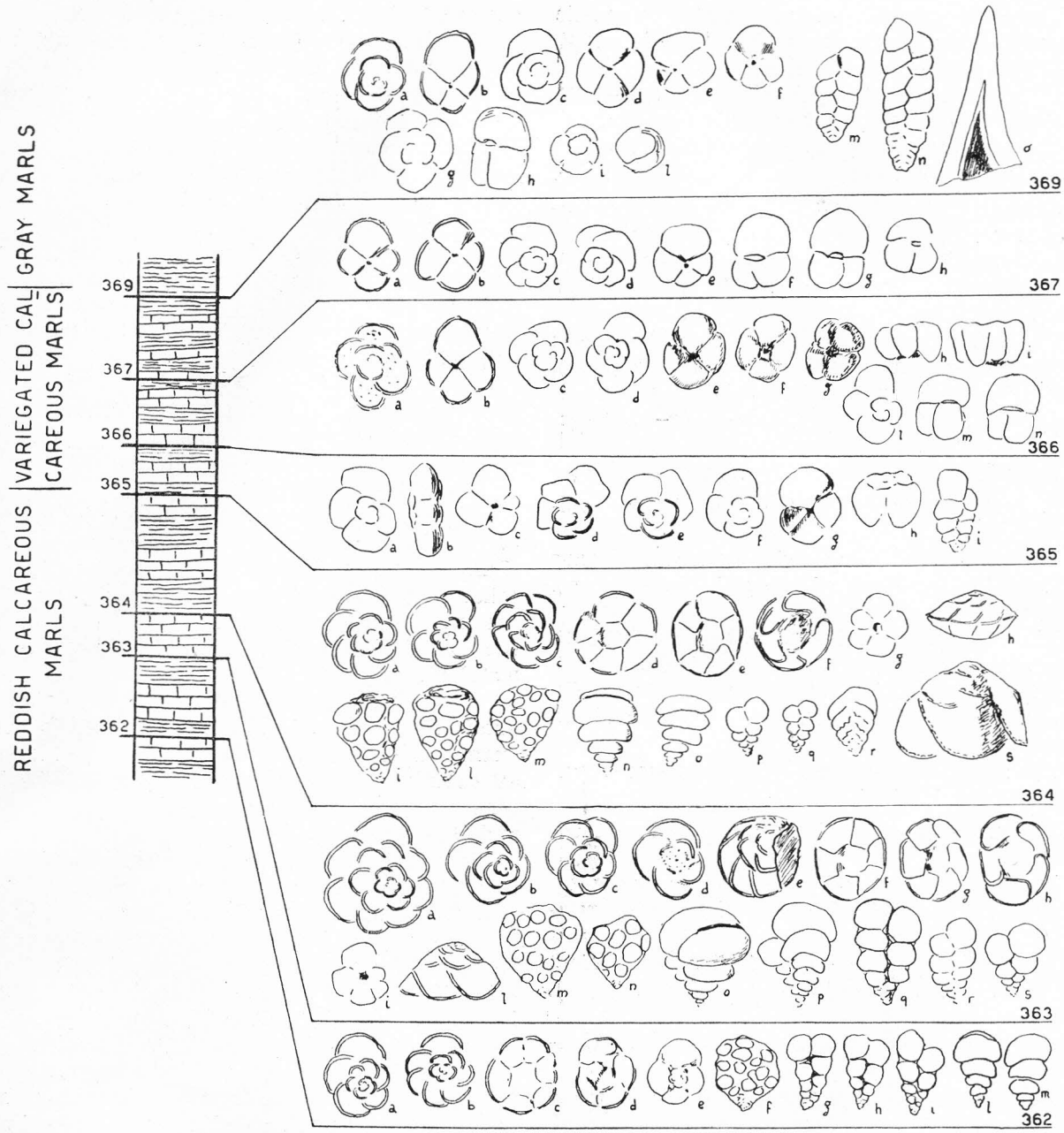
Besides this anomaly, the section of Molveno shows another difference from other sections examined, that is the greater richness of Globorotalias and the smaller number of Globigerinas which are present in Eocene stages.

Section 7 – Non Valley (Trento)

Samples were collected by Dr. M. B. Cita along the cut north of the village of Romallo, in the high Non Valley.

Seven samples were examined covering a total thickness of about 60 meters (average distance between samples 10 meters).

Lithologically this section is characterized by reddish calcareous marls (samples 362-364), by



Section 7th: Val di Non

variegated calcareous marls (365-367), by gray, tender marls (369).

The last sample belongs to the " scaglia cinerea ", the others to the typical "scaglia rossa" (362-364), or to the transitional zone from " scaglia rossa " to " scaglia cinerea " (365-367).

Foraminiferal faunas from this section have been studied upon washing residues : isolated specimens are figured in the annexed planche.

SAMPLE 362 (*calc. 63.1 %*) : compact calcareous marls rose (salmon) color. Foraminiferal fauna constitued by Globotruncanas (a–d), *Globigerina* (e), *Planoglobulina* (f), Gümbelinas (g–m).

The following species have been identified : *Globotruncana cretacea* (a, d), *G.* cf. *arca* (b, c), *Globigerina cretacea* (e), *Planoglobulina acervulinoides* (f), *Gümbelina globulosa* (g–i), *Gümbelina elegans* (l, m).

Age : Upper Senonian (Campanian).

SAMPLE 363 (*calc. 58.5 %*) : red, tender, calcareous shales.

Foraminiferal fauna with Globotruncanas (a–h, l), *Globigerina* (i), Planoglobulinas (m, n), Gümbelinas (o–s).

The following species have been identified : *Globotruncana arca* (a), *G. fornicata* (d), *G. stuarti* (e, f), *G. conica* (1), *Globigerina cretacea* (i), *Planoglobulina acervulinoides* (m, n), *Gümbelina elegans* (o, p).

Age : Upper Senonian (Upper Campanian-Lower Maestrichtian).

SAMPLE 364 (*calc. 63.7 %*): rose color calcareous shales.

Foraminiferal fauna with *Globotruncana* cf. *arca* (a), *G. stuarti* (c, d, e, h), *Globigerina cretacea* (g), *Globotruncana contusa* (s), *Pseudotextularia varians* (i, l), *Planoglobulina acervulinoides* (m), *Gümbelina elegans* (n, o), *G. globulosa* (p, q), *Bolivinoides* sp. (r).

Age : Uppermost Senonian (Upper Maestrichtian).

SAMPLE 365 (*calc. 28.3 %*) : tender variegated shales; color from violet to green.

Foraminiferal fauna constituted almost entirely by small Globorotalias with rounded external border. Three species may be recognized : *G. compressa* (a, b), *G. angulata* (d, e, with keeled internal chambers), *G. crassula* (f, g, h).

Age : Eocene. To this attribution we shall shortly revert.

SAMPLE 366 (*calc. 50.7 %*) : variegated marls with a rich foraminiferal fauna. *Globorotalia crassata* (a, b), *G. crassula* (c–i), *Globigerina eocaena* (l), *G.* cf. *linaperta* (m, n) may be recognized.

Age : Middle Eocene (?).

SAMPLE 367 (*calc. 43.9 %*) : calcareous marls of white or rose color.

Foraminiferal fauna characterized by *Globorotalia crassata* (a, b), *G. crassula* (c–e), *Globigerina* cf. *linaperta* (f–h).

Age : as above.

SAMPLE 369 (*calc. 39 %*) : very tender gray greenish marls with *Globorotalia crassata* (a, b), *G. crassula* (c–f), *Globigerina linaperta* (h), *Globigerinoides mexicanus* (i, l), *Plectina* sp. (m, n), fish teeth (o).

Age : Middle-Upper Eocene.

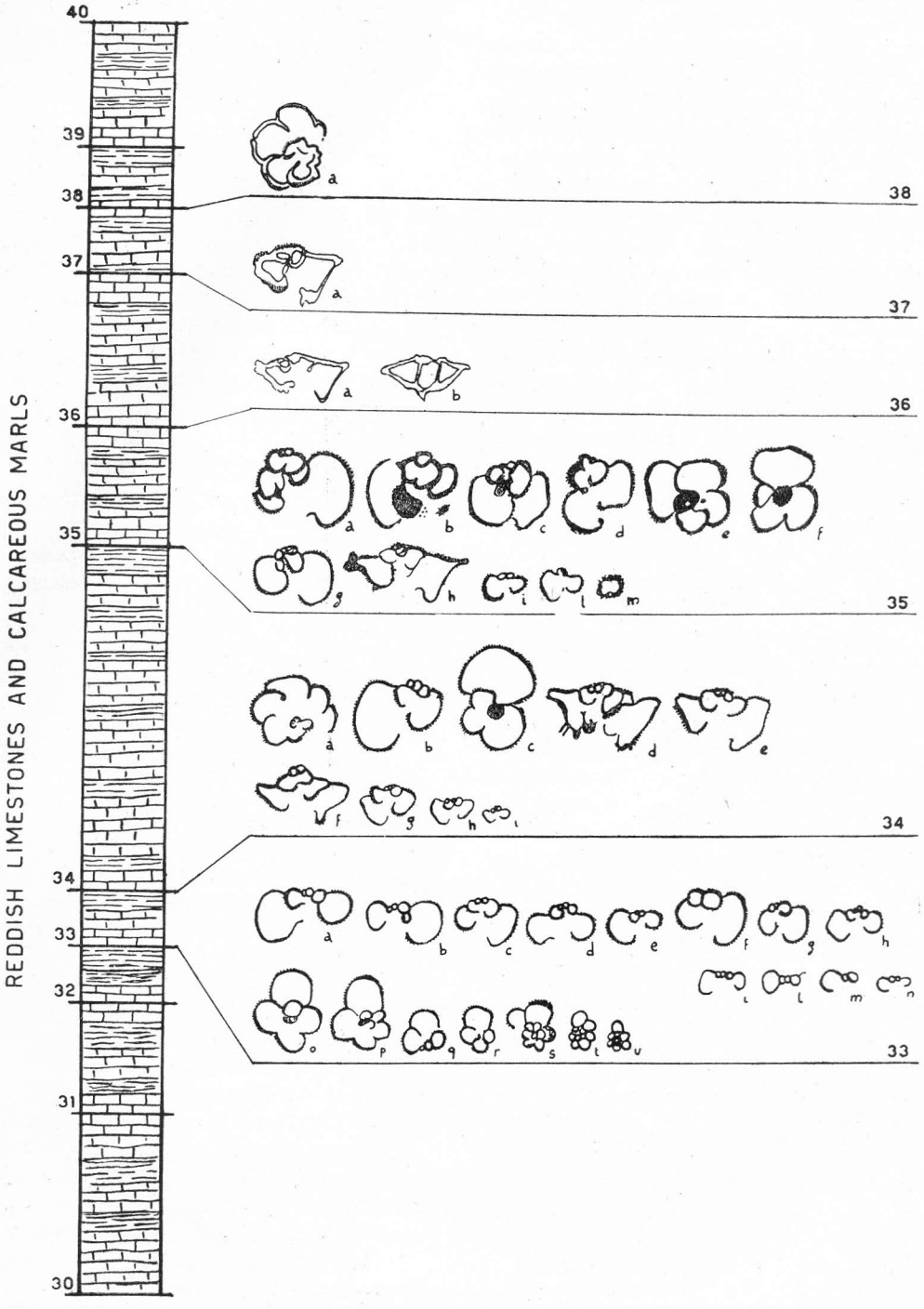
This section, which has all the characters, in outcrop, of a continuous one, shows a micropaleontological anomaly very similar to that of the Molveno section mentioned above.

That is the absence of Globorotalias belonging to the *G. aragonensis - G. velascoensis* group (Paleocene age) and the appearence of Globorotalias of the *angulata-crassula* group soon after the disappearence of Upper Cretaceous genera such as *Globotruncana*, *Planoglobulina*, *Pseudotextularia* etc.

If for the cited species of *Globorotalia* we admit the distribution which is noticed in other examined sections, then we shall conclude that all samples from 365 to 367 are of Middle Eocene age, wanting in this section both Danian and Paleocene stages.

In a third section from Trentino (Castel Toblin, not described in the present paper) I could remark the same facts, that is : absence of keeled Globorotalias of Paleocene aspect, appearence of Globorotalias with rounded external border soon after the end of Cretaceous, lack (not absence indeed) of Globigerinas with special regard to those large, rough-surfaced forms which elsewhere are characteristic of Lower and chiefly of Middle Eocene. I can hardly believe that these facts may be explained with hiatus in sedimentation because of the differences noticed above in faunistical associations of the same age from Trentino and other regions.

I think that a distribution somewhat different from the usual one may possibly be found in Trentino, but this assertion needs further study to be confirmed.



Section 8th: Gubbio

Section 8 – Gubbio (Perugia)

The present section, contrary to the others illustrated, is not original, but taken from the geological literature, namely Renz (41).

The stratigraphical column and drawings relative to strata 36, 37 and 38 have been drawn from Renz' publication, while drawings relative to strata 33, 34 and 35 have been copied from a recent paper by Reichel (39).

The total thickness of the section reported (from stratum 30 to 39 included) is about 150 meters.

Average distance between samples with figured microfauna (from 33 to 38) is about 15 meters.

STRATA 30, 31 AND 32 (without represented microfauna): may be referred to Upper Cretaceous, containing *Globotruncana stuarti* etc.

Upper Maestrichtian would be probably present.

STRATUM 33: which belongs to the stratigraphical complex called by Renz " Scaglia without Globotruncanas and without Globorotalias ", contains a foraminiferal fauna with small Globigerinas and Globigerinellas.

Globigerina pseudobulloides (b, a, h, m, i), *Globigerina hornibrooki-linaperta* (o, g, c, f) and *Globigerinella* (t, u, l) are recognized by Reichel. The great analogy between this microfauna and the one described by Brönniman (8) from the typical Danian stage of Denmark is pointed out by the author.

STRATUM 34: which belongs to the complex called by Renz " Scaglia with Globorotalias " is characterized by microfauna with Globigerinas and Globorotalias. Reichel indicates the presence of *Globigerina linaperta* (c, b), *Globorotalia simulatilis-angulata* (d, g, a), *Globorotalia velascoensis* (f, d), *Globorotalia* sp. n. (h, i).

Age : Paleocene.

STRATUM 35: which is very like s. 34 in its foraminiferal fauna, contains *Globorotalia aragonensis* (h).

Age : Paleocene.

STRATA 36 AND 37: belong to Paleocene, according to Renz. Some Globorotalias (probably *G. aragonensis*) are figured, from this author's work.

STRATUM 38: (one horizontal section of *Globorotalia* sp. has been reported) is referred to Eocene.

This section is typically a continuous one, all stages from Upper Cretaceous to Eocene (Maestrichtian, Danian, Paleocene, Eocene) being here represented.

Correlations and Conclusions

Many micropaleontological studies were carried out in the last few years on Upper Cretaceous faunas from northern Africa, near East, Europe (France, Switzerland, Germany, Italy etc.) so that we have a good knowledge of species and of their stratigraphical distribution.

On the basis of this knowledge, I subdivided Upper Cretaceous as follows :

Uppermost Senonian (Upper Maestrichtian) with *Globotruncana stuarti*, *G. contusa*, *Pseudotextularia varians* etc.

Upper Senonian (including Campanian and Lower Maestrichtian) with *Globotruncana arca*, *G. tricarinata*, *G. stuarti*, *G. fornicata*, conical forms, *Planoglobulina acervulinoides*, *Gümbelina elegans* etc.

Lower Senonian (including Santonian and Coniacian) with *Globotruncana lapparenti*, *G. tricarinata*, *G. arca*, *Gümbelina globulosa*, *Globigerinella aequilateralis* etc.

Turonian, with *Globotruncana lapparenti* and related forms.

Pelagic microfaunas younger than Upper Cretaceous ones, on the contrary, were little studied from a descriptive point of view, so that species identification, especially in thin slides, is not easy.

Considering that the present work is of a stratigraphical more than of a descriptive character, I arranged the forms present in slides studied in the following groups :

Gen. *Globorotalia :*

sharp-keeled forms;

forms with rounded external border.

Globorotalia velascoensis, *G. aragonensis*, *G. crassata* and other indetermined species (some probably new) belong to the first group. *Globorotalia angulata*, *G. crassula* (for the distinction between these species see Cita: 11), *G. compressa* belong to the second.

With regard to stratigraphical distribution of Globorotalias, my experience brings me to consider sharp-keeled forms (*G. velascoensis*, *G. aragonensis*) as the oldest ; forms with rounded borders on the contrary would appear only a

little later. *G. crassata* appears typically in the Middle Eocene.

Among Globigerinas I distinguished only well characterized groups, not all the species which are present. I think that this may be justified by the fact that there is a certain confusion in classification of Globigerinas and related genera (several species are little differentiated or synonymous) and according to the difficulty of their identification in a thin section. It is important however to realize that Globigerinas and related genera are interesting time-markers in Upper Cretaceous and Eocene stages.

The greatest change is noticed at the passage from Maestrichtian (*Globigerina cretacea, Globigerinella aequilateralis*) to Danian (*Globigerina pseudobulloides, G. linaperta, Globigerinella* sp. etc.).

Danian forms last during Paleocene (excluded Globigerinellas), whilst in this stage the large forms with a rough surface (*G. eocaena*) which will be characteristic of Middle Eocene begin to appear.

In the Middle Eocene a spherical form referable to *Globigerinoides mexicanus* makes its appearance ; this species may be considered as characteristic of the Middle-Upper Eocene.

This sequence of forms is so constant that it is possible to distinguish the various stages from Danian to Upper Eocene considering only Globigerinas and related genera.

So much for principles adopted in classification ; let us see now which biostratigraphical units may be distinguished at the passage Cretaceous-Eocene. Our observations will particularly concern the Section of Vincenza Nuova (see page 14) which is complete and very characteristic, but can be extended to other sections examined ; stratigraphic references may be found, however, at the end of the description of every sample.

Beginning from the highest part of the Maestrichtian stage (for inferior stages doubts do not exist, both stratigraphy and correlations being well known) I was able to distinguish the following four biostratigraphical units :

1. The first unit is characterized by a foraminiferal fauna with specimens of exceptional dimension for the most abundant genus, which are : *Globotruncana, Pseudotextularia, Gümbelina* (with ornamented shell). Also gen. *Globigerina* is present, without exceptional dimensions of specimens.

Characteristic species may be considered *Globotruncana stuarti, G. contusa, Pseudotextularia varians, Gümbelina elegans.*

No doubt exists about its reference to Upper Maestrichtian.

2. The second biostratigraphical unit has a fauna which is entirely constituted by pelagic genera, as revealed by thin slides, where rare forms often escape : *Globigerina, Globigerinella, Gümbelina.* Gümbelinas of this unit are much smaller than those of the preceding unit, and without ornamented surface.

Species identification has not been possible in thin slides, because knowledge about similar faunas is inadequate.

Faunistical differences from Maestrichtian are extremely marked : some typically Cretaceous foraminiferal genera as *Globotruncana, Planoglobulina, Pseudotextularia* disappear suddenly at the end of that age.

Faunistical change is so rapid and without transition that passing from one sample to another, collected at a few meters' distance, we find faunas completely different from one another. This change, which is not connected with any mutation in environmental conditions (all studied sections, in fact, concern pelagic sediments in continuous sequences), has to be ascribed solely to evolutional phenomena.

We shall shortly discuss the attribution of this unit to Danian stage.

2. An equally marked and sudden change exists at the passage from the second stratigraphical unit and the successive one, which I referred to Paleocene. The main faunistical difference is the disappearence, in Paleocene, of Globigerinellas and Gümbelinas and the appearance of genus *Globorotalia* (*G. velascoensis* is the first species which we may find). No transition exists from the foraminiferal fauna referred to Danian to that referred to Paleocene.

A gradual change occurs on the contrary in foraminiferal faunas as soon as they rise in the eocenic series.

We shall shortly revert to the distinction between Paleocene and Lower Eocene and its applicability in pelagic sequences without large foraminifera.

4. The fourth biostratigraphical unit is characterized by a foraminiferal fauna fairly similar to that of Paleocene ; new species of Globorotalias were appearing little by little (*G. aragonensis,*

G. angulata, G. crassata in suite) ; Globigerinas, which have in this stage characteristic species such as *G. eocaena, Globigerinoides mexicanus* etc. flood.

This stratigraphical unit, isolated faunas of which I studied years ago from the Lake of Garda (11), is much richer in forms than the two preceding ones.

Its attribution to Middle Eocene is quite sure ; in the mentioned locality, gen. *Hantkenina, Nummulites* and *Ortophragmina* are in fact present, with species characteristic for Middle Eocene.

A further discussion will follow on biostratigraphical units 2 and 3, which are at the same time the most interesting to illustrate the boundary Cretaceous-Eocene and the less documented paleontologically.

Danian

UNIT 2: the paleontological characters which we described previously is represented by marls or limestones for a total thickness of a few meters. Notwithstanding the small thickness of this stage, which moreover is not distinguished lithologically by adjacent layers above and beneath, its diffusion in Italy appears extended to the whole peninsula.

In Northern Italy it has been indicated in Brianza (Merone, Adda) on the western coast of the Lake of Garda, in the neighborhood of Belluno, that is to say for an extension from west to east of about 250 km.

It was found besides in the underground of the Po Valley (Vincenza Nuova) and in Central Apennines. In Sicily it has been recognized in various localities, especially in the western part of the island (Trapanese).

In all these localities, as was often reiterated, it represents a pelagic environment of deep sea (scaglia in northern and central Italy, " lattimusa " in Sicily).

The paleogeographical importance of a stage the extension of which is as large as the whole of Italy is beyond doubt.

Its stratigraphical position is always between Upper Maestrichtian beneath, and Paleocene above, as occurs in the Section of Vincenza Nuova.

No doubt exists therefore about the position which it occupies in the stratigraphical sequence, at the passage from Cretaceous to Eocene.

In the same stratigraphical position, in the north-eastern part of Italy (Istria and Friuli), where biohermal facies are present, we find Liburnico stage, about which the opinions of scientists were formerly somewhat discordant (see Desio and Martinis : 19).

I think that a correlation between Danian, as defined above (deep-sea facies) and Liburnico (epicontinental or continental facies) is valid.

While Danian is widely extended throughout Italy, where Upper Cretaceous is characterized by deep-sea facies, Liburnico instead seems to be limited to the regions mentioned from the North-East of Italy. Its presence in fact has never been signalled in other regions where Upper Cretaceous outcrops with biohermal facies (see Abruzzi, Campania etc.) are nevertheless present.

We must now revert to the chronological significance of the Danian stage, which till now has not been well illustrated.

Since I could not arrive at any specific determination, working on thin slides, I have no paleontological elements for a chronologic reference, but only stratigraphical ones. I tried therefore to correlate my biostratigraphical unit with others, and this was possible within the limits of the Mediterranean region.

For the definition of Danian, I based myself first of all on Reichel's observations (39) on paleontological affinities noticed between *Globigerina*-zone of the Section of Gubbio (Central Apennines) and *Globigerina*-faunas of typical Danian from Faxe (Denmark). Globigerinas illustrated by Brönnimann (8) from Danian of Denmark were also taken into consideration, as well as some illustrations given by Cuvillier (12), regarding *Globigerina*-faunas of Danian age from Aquitania.

The same *Globigerina*-zone, intercluded between the zone with Globotruncanas and Gümbelinas beneath and the zone with Globorotalias above, was recognized by Nakkady (34) in Egypt and by Reiss (40) in Palestina. The first author attributes it to the Danian, on the basis of his paleontological determinations, the second author considers it as the lower part of the Danian-Paleocene complex, which he is not able to distinguish. Tromp (47) instead does not admit the existence of Danian in Near East.

I think that on the basis of these correlations the reference to Danian of biostratigraphical *unit 2* may be justified.

Paleocene

The biostratigraphical *unit 3*, the main paleontological character of which is the appearence of genus *Globorotalia*, is worth some observations.

Scarce knowledge about faunas with small foraminifera from this stage and my impossibility of obtaining isolated specimens, have much limited my study, so that I could not reach the conclusions which I hoped to draw.

The question was actually to define whether Paleocene was distinguishable paleontologically from Lower Eocene or it was to be considered as synonymous.

Renz (41) and Bally (4), who studied sections at the passage from Cretaceous to Eocene in the " transitional facies " of Central Italy, where large foraminifera are present, could distinguish Paleocene from Lower Eocene.

In pelagic sections like those studied by myself this distinction is not easy.

In reality a slight change may be noticed from the lowest levels (typical Paleocene with large *Globorotalia velascoensis*) to those near Middle Eocene, where a greater richness of forms is observed. In order to reach a distinction, however, a much deeper knowledge of these faunas than we now have is required. Study on isolated specimens, not only on thin slides, is needed to reach this aim.

As a conclusion I think that Paleocene and Lower Eocene exist as distinct stages and that there is a faunistical transition from one to another, in pelagic faunas. At the present state of knowledge, however, a distinction is not practically possible in sections with small foraminifera only.

Other conclusive observations may be summarized as follows :

a. In all the sections examined as well as in other localities not considered in the present work, we may notice that stratigraphical limits do not as a rule correspond to facies limits.

It follows that in geologic surface mapping it is impossible to draw limits with real stratigraphical value. All the limits between Mesozoic and Tertiary (i.e. between Upper Cretaceous and Lower Eocene) which are indicated on geologic maps in outcrops with continuous sequences, are generally inexact.

The difference between stratigraphical and facies limit may be much more than ten meters.

b. In some sections, I noticed the lack of one or more of the biostratigraphical units individuated elsewhere.

This lack, which is accompanied by no evident trouble in the deposition of sedimentary series, may be interpreted as the effect of a hiatus in sedimentation or of submarine erosion. Though it is not quite easy to explain the phenomena referred to in a typically pelagic environment such as that in which the sedimentation of " scaglia " was taking place, yet this fact has been noticed by other workers besides myself, in seemingly continuous sequences. In foraminiferal faunas contained in layers immediately overhanging the supposed hiatus, old forms are often mixed with younger ones.

c. The succession of forms documented in the eight illustrated sections may be usefully compared with successions illustrated from other parts of the world.

It should be noted that the majority of identified species is characteristic of south-eastern United States, Mexico or Central America.

The stratigraphical distribution of Globorotalias and Globigerinas, as indicated by Bolli (7) and Grimsdale (26) is very similar to the one found by myself.

Foraminiferal faunas rich in pelagic forms are indicated in southern Europe as well as in countries bordering the Mediterranean sea (Algeria, Egypt, Israel etc.). I found interesting data in recently published papers by Cuvillier (12) and di Napoli Alliata (17) (for other publications concerning Italy see the first part of the present work). But I found particularly interesting the consultation of three works by Tromp (47), Nakkady (34) and Reiss (40), which deal with the Cretaceous-Eocene passage in the Near East.

Good correlations may be established among transitional Cretaceous-Eocene stages from Italy, Egypt, Turkey and also from Caucaso (see Glaessner: 25). This is a very important conclusion, which demonstrates the value of pelagic foraminifera both in scientific and economic geology.

I point out that none of the authors mentioned indicated the presence of Globotruncanas (which, according to some American authors, would survive until Lower Tertiary) in layers younger than Maestrichtian.

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This paper was presented on June 15th, 1955 by M. Scarpa (*AGIP Mineraria – Milano, I*) on behalf of the Author.

Discussion

F. Brotzen (*Sveriges Geoligiska Undersökning – Stockholm, S*). The stratigraphic results of the work of Mr. Cita are very similar to the results shown yesterday in the collective work of Mr. Cuvillier and his collaborators. In principle, the stratigraphic results are very similar also to the sections observed in Israel which I have had the possibility to study during the last years. The most interesting problems of this lecture were the discordances in the sections which are only represented by the foram associations, but are not indicated in the sediments. Such typical discordances only represented by the foram associations and not in the rock types, will be one of the most interesting sedimentation problems for all fossil sediments in the Mediterranean. Mrs. Cita means that these gaps are caused by a lack of sedimentation during certain periods. I have the impression that it is not a lack of sedimentation, there are also disturbings caused by slight tectonic movements of the ground.

F. R. S. Henson (*Iraq Petroleum Co. Ltd., – London, GB*). Supplementing what Mr. Brotzen has said of Israel, I would like to remark that throughout the Middle East there are frequent examples of sections showing sharp microfaunal breaks between Cretaceous and Paleocene without visible signs of unconformity

and often without facies changes of any apparent significance.

There is however some evidence of very gentle, regional movements at and towards the end of the Cretaceous, which may have resulted in condensed or interrupted deposition without observable discordance, over those relatively elevated areas which are most commonly accessible for study. Nevertheless, many "basinal" sections are known in which all indications point to continuity of deposition and of pelagic facies; and in these cases the transition beds are usually unfossiliferous or they contain a poor microfauna of small Globigerinas distinguished by negative rather than by positive characters.

According to Dr. A. H. Smout (verbal communication) who has worked on this problem, most Maestrichtian pelagic foraminifera died out abruptly at the presumed end of the Cretaceous, while a few survived into the Paleocene. In the neritic facies the contemporaneous extinction of Cretaceous larger foraminifera is even more complete.

In the earliest Paleocene, new (Ranikot) species are few but populations are abundant.

These various circumstances suggest that some catastrophic changes of an ecological nature must have played their part in the extinction of Cretaceous species, in addition to the normal changes of environment due to diastrophism and sedimentation.