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Biostratigraphy, Variability and Facies Relations of some Upper Eocene Nummulites from Northern Italy

By RENÉ HERB[1]) and HEINZ HEKEL[2])

ABSTRACT

Three Nummulite groups – *Nummulites fabianii*, *N. garnieri* and *N. variolarius–N. incrassatus* – were studied in the Upper Eocene sections of Possagno, Priabona and Mossano, using biometric and semistatistical methods. In the upper Priabonian of Possagno the *fabianii*-group is represented by *N. fabianii fabianii* and *N. fabianii retiatus*. It can be demonstrated, that the occurrence of one or the other form is related to facies. Evolutionary trends with respect to the coiling ratio, the diameter of the protoconch, the development of the reticulation and the size of the B-Forms can be recognized from the uppermost Middle Eocene (Biarritzian) at Mossano to the top of the Upper Eocene at Possagno for all three groups mentioned above. These general trends may be interrupted however, by assemblages which deviate considerably and may show a more "primitive" or more "advanced" stage of evolution than expected according to their stratigraphic position. It is thought, that environmental conditions may be the cause of such patterns, although in some cases no changes in lithology could be seen. *Nummulites incrassatus* is considered to originate from *N. variolarius* at the base of the Upper Eocene. Two subspecies, *N. incrassatus ramondiformis* and *N. incrassatus incrassatus* have been recognized and distribution patterns of this group in the section of Mossano are discussed. In the *garnieri*-group one new subspecies, *N. garnieri inaequalis* is described from the uppermost Priabonian of Possagno.

Introduction

Nummulites are some of the best paleogene shallow water index fossils, particularly in Alpine-Mediterranean areas. Detailed biozonations based on evolutionary lineages of various groups of Nummulites have been established by SCHAUB (in HOTTINGER, LEHMANN and SCHAUB 1964) mainly for the Upper Paleocene-Middle Eocene interval. For the Upper Eocene and the Oligocene the zonations so far published seem to be less detailed. This can be explained in part by a slower rate of evolution of the relatively small Upper Eocene and Oligocene species, compared with the rapid evolution of some of the large Lower and Middle Eocene forms. However, a valuable zonation for the Upper Eocene has been proposed by BOMBITA and MOISESCU (1968) by subdividing this interval into three zones. The lowermost is characterized by *Nummulites striatus* and *Nummulites praefabianii*, and is placed by BOMBITA in his Napocian stage, because this interval is not represented in the type section of the

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Priabonian at Priabona. This zone is overlain by the *Nummulites fabianii*-zone and the *Nummulites retiatus*-zone which also has forms transitional to *Nummulites intermedius* (= *N. fichteli*). Both of these zones belong to the Priabonian stage in its restricted sence.

Similar zonations were proposed by PAVLOVEC (1966) and CITA and CASTELLARIN (1969) and were adopted by the Eocene Colloquium in Paris 1968. There, contrary to the concept of BOMBITA the definition of the Priabonian stage is extended below the type section of Priabona, and the Priabonian therefore is intended to cover the whole Upper Eocene time interval. In practise, however, recognition of these zones, in particular the zonation proposed during the Eocene Colloquium, still raises a number of problems because of the lack of accurate paleontological descriptions of most of the species which are zone indicators. BOMBITA and MOISESCU (1968) have well illustrated the assemblages from the transsylvanian sections they studied, but for Northern Italy only a few modern paleontological works have been published. Therefore the Paris Eocene Colloquium recommendations turn out to be not well defined and are difficult to apply because the necessary paleontological data are not available yet.

ROVEDA (1970) published a taxonomic revision of one of the most important Upper Eocene and Oligocene group of Nummulites, the group of *Nummulites fabianii*, giving a critical review of the primary types and determining the validity of the species. The taxonomy of ROVEDA will be largely followed in this paper, particularly the subspecific distinction of *Nummulites fabianii fabianii* and *N. fabianii retiatus*.

A joint research project by several workers on the biostratigraphy and micropaleontology of the Paleocene-Eocene sequence of Possagno (Treviso) has provided the opportunity for study of the Upper Eocene Nummulites from this location. Comparative material has also been obtained from various other localities in Northern Italy, in particular from Priabona and from Mossano (Colli Berici). Special attention has been given to the problem of morphologic variation within a population using biometric methods. A biometric approach to the problem of the transition from *N. fabianii* to *N. fichteli* has been undertaken by FRASCARI (1967). The numbers of specimens measured by her are too small, however, to permit of definitive conclusions to be drawn.

The present paper is intended to draw attention to the important problem of defining and evaluating morphologic variation within given populations and within an evolutionary sequence. *Nummulites fabianii*, *Nummulites garnieri* and the *Nummulites variolarius–N. incrassatus* group have been chosen for this study because they show easily recognizable features on the outer surface as well as in the equatorial section of the test. These external and internal parameters may be assumed to be independent of each other, and they both show distinct evolutionary trends throughout the Upper Eocene. Such trends are well known for the development of the surface reticulation in the *fabianii*-group (BOUSSAC 1911, ROVEDA 1959).

Stratigraphy

This study is mainly based on an investigation of the Nummulites of the Possagno section. In addition, parts of the well known sections of Priabona and Mossano (Colli Berici) have also been studied for comparison.

Possagno

A joint paper by several co-authors on the detailed biostratigraphy and micropaleontology of the Paleocene and Eocene of the Possagno area is currently in preparation. Some data and preliminary results have already been published by various authors (CITA and BOLLI 1966, CITA et al. 1968, TOUMARKINE and BOLLI 1970, ROTH, BAUMANN and BERTOLINO 1971). The geology of the area was described by BRAGA (1971). The location of the Upper Eocene sections on which the present paper is based, are shown on Figure 1.

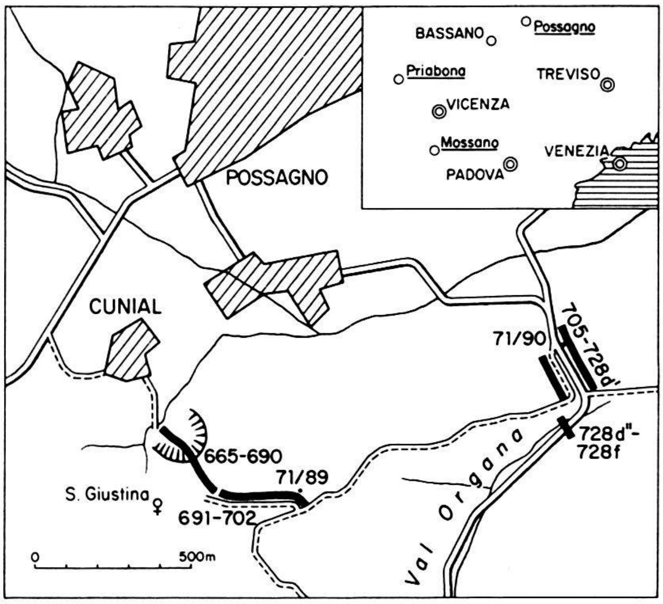


Fig. 1. Scetch map of the Possagno area showing the location of the Upper Eocene sections and the samples investigated for this paper.

In the Paleocene and Lower-Middle Eocene portion of the section we find predominantly pelagic sedimentation of the Scaglia type (Scaglia rossa and Scaglia cinerea) with abundant planktonic Foraminifera. The Upper Eocene has a total thickness of approx. 400 m and shows a progressive transition from deepwater facies at its base into shallow water deposits in the upper part. The basin was rapidly filled with about 300 m of blue clays, called the Marna di Possagno. These are being quarried in series of clay pits which permit the observation of an almost continuous stratigraphic section. These clays have long been well known for their rich and well preserved fauna of molluscs and solitary corals (VINASSA DE REGNY 1897, OPPENHEIM 1901). They also contain rich assemblages of smaller benthonic Foraminifera (see BRAGA in CITA et al. 1968, p. 68) which are presently the subject of a paleoecologic study. In the upper part of this formation we also find rich and well preserved assemblages of larger Foraminifera belonging to the genera *Nummulites*, *Operculina*, *Discocyclina* and *Spiroclypeus*. Presence of these forms indicates a further decrease of the water depth towards the top of the formation.

The Possagno clays are followed by shallow water limestones with coralline algae, colonial corals and abundant larger Foraminifera *(Nummulites*, *Discocyclina*, *Operculina*, *Spiroclypeus*, *Pellatispira)*, called the Calcare di S. Giustina. The lower and middle part of this formation is well exposed in a roadcut between the upper Val Organa and the plain south of Possagno, the upper part in the S. Giustina-Col dell'Asse segment of the western section. The total thickness of these limestones reaches approx. 80 m (see also BRAGA 1971).

The limestones are overlain by approx. 5 m of "marne siltose" which are composed of argillaceous silts or silty clays with *Turritella* and *Nummulites*. On top of these there is a breccia with *Nummulites* and *Discocyclina*. According to their fossil content these marne siltose still belong to the Upper Eocene.

The Oligocene disconformably overlies these beds in the form of argillaceous silts, siltstones and conglomerates, the "siltiti e conglomerati di Col dell'Asse". The Upper Oligocene age has been determined from a molluscan fauna found in the conglomerates (VENZO 1938) as well as from bryozoans (BRAGA 1965).

The stratigraphic sequence of the Cunial-S. Giustina-Col dell'Asse section is also shown in Figure 6 from the uppermost part of the Marna di Possagno upwards. It will be described in detail in the forthcoming joint publication mentioned above.

A biostratigraphic subdivision of the Upper Eocene of Possagno has been published by TOUMARKINE and BOLLI (1970), based on the evolution of *Globorotalia cerroazulensis* and related forms. According to these authors, *Globorotalia cerroazulensis cunialensis*, the index form of the uppermost zone of the Upper Eocene, is found considerably below the first occurrence of larger Foraminifera in the Marna di Possagno, and therefore all the Nummulites from the Possagno section must also belong to the upper part of the Upper Eocene (Upper Priabonian). The Possagno section is therefore not suitable for the study of evolutionary trends over longer time intervals. However, it offers an opportunity to observe possible evolutionary trends within a short time interval, morphologic variations within a species, changes in the composition of populations across lithologic boundaries and eventually to detect variation of the test morphology caused by changes of the environment.

Priabona

The stratigraphy of the type area of the Priabonian has recently been summarized by HARDENBOL (1968). These sections were also sampled in detail for comparison with the material from Possagno but a further description is not attempted here. For the present investigation only the lower part of the type section at Priabona with *Nummulites fabianii fabianii* and the upper part of the Boro-Granella section with *Nummulites fabianii retiatus* are of interest. The lower part above the basalt was sampled below the village of Priabona, at the road to Malo above a spring (see Fig. 2).

Mossano

The section of Mossano in the Colli Berici is probably the most complete Priabonian sequence in the Vicentino area. It has been described by SCHWEIGHAUSER (1953) and UNGARO (1968, 1969) and is therefore not discussed in detail here. The section is summarized in Figure 4. Our samples were collected along the small road leading from Mossano village to M. Stria (see Fig. 3).

Specimens of the *Nummulites fabianii* group are restricted to the lower part of the section and do not occur in the higher levels which might be correlated with the Nummulite bearing part of the Possagno section.

The main value of the Mossano section with respect to the aim of this paper consists in a complete record of the *Nummulites variolarius–N. incrassatus* group,

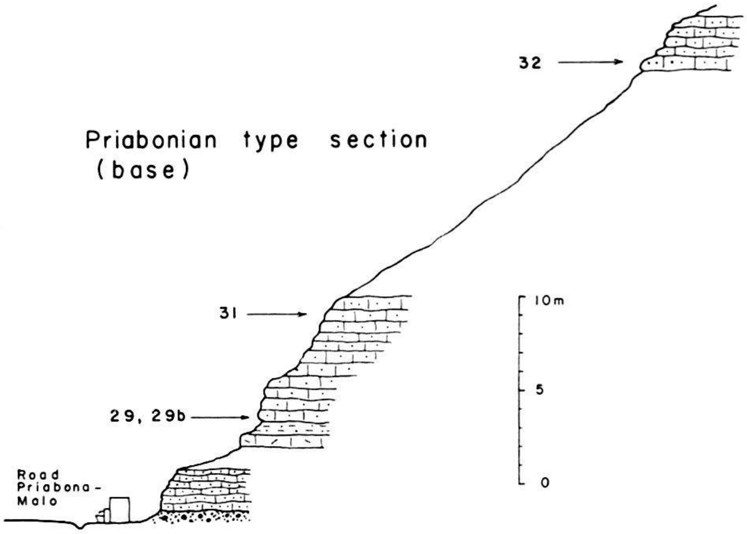


Fig. 2. Section of the outcrops at the base of the Priabonian type section NE of Priabona village, at the main road to Malo.

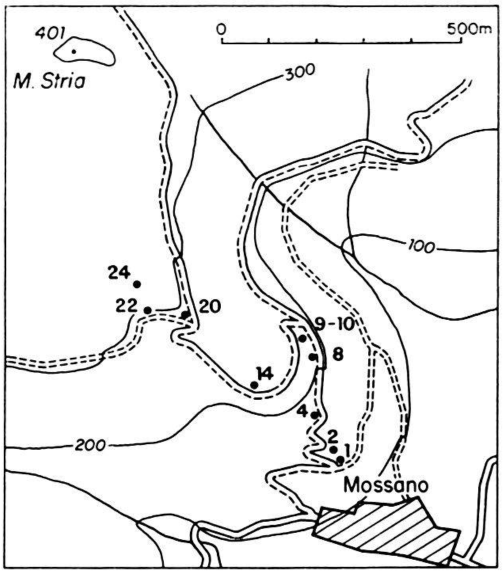


Fig. 3. Scetch map of the Mossano area (Colli Berici) showing the location of the samples (see also Fig. 4 and Plate I).

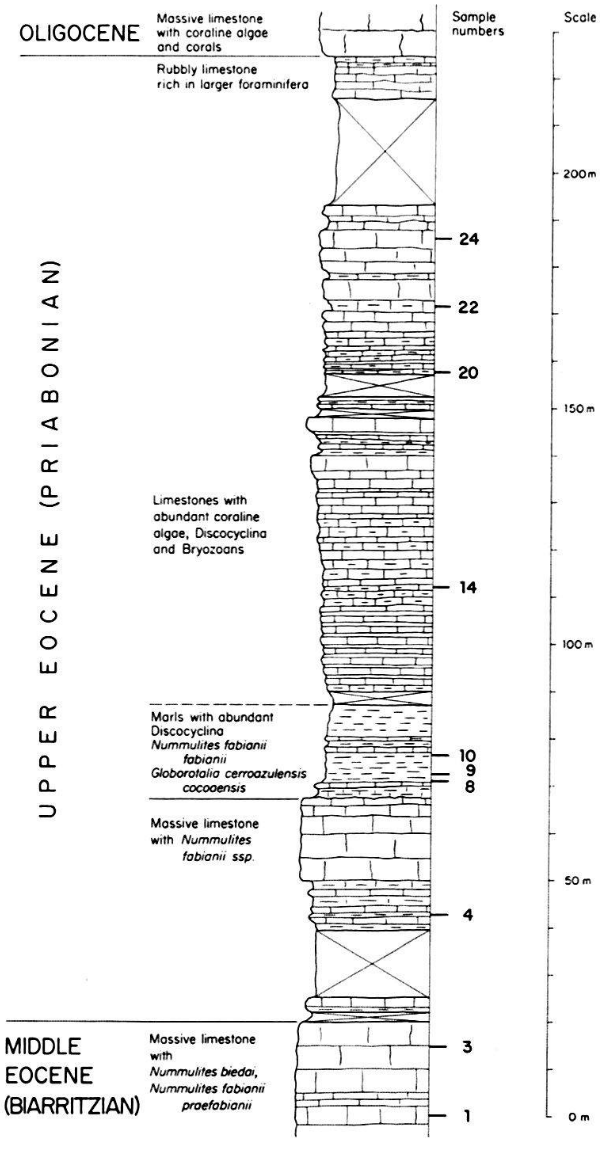


Fig. 4. Stratigraphic section of the Eocene near Mossano (Colli Berici) with indication of the samples used for this paper (see also Fig. 3 and Plate I).

beginning in the uppermost Middle Eocene (Biarritzian, samples 1–3, Fig. 3, 4 and Plate I) and ranging throughout the Priabonian (samples 4–24).

The occurrence of *Globorotalia cerroazulensis cocoaensis* in sample 10, at the same level as already noted by UNGARO (1969), is of some importance since it suggests a great thickness of upper Priabonian sediments in this section, whereas the lower part of the Priabonian (*G. semiinvoluta*-zone) is quite reduced in its thickness. A hiatus between the limestones with *N. praefabianii* and the softer sediments above (samples 7–10) cannot be excluded and is in fact suggested by the brecciated nature of the top of the limestone sequence.

Methods of investigation

A statistical or at least semistatistical approach is needed if the range of variation of a certain species is to be evaluated. Significant parameters have to be found which are consistently available for the particular taxonomic group and which at the same time are suitable for this kind of analysis. In *Nummulites* such parameters are: diameter and thickness of the specimen, the diameter of the protoconch of the megalospheric generation, and certain other features of the equatorial section such as the mode of coiling which can be illustrated in a coiling diagram.

Under ideal circumstances at least 200 specimens should be measured per species per sample for a statistical evaluation. It is evident that the amount of time involved in preparation and measurement of large numbers of equatorial sections is beyond the scope of a research project, unless they proved to be indispensable. In the present study between 15 and 30 specimens were usually measured for each species in each sample, and the results were plotted. The general trends from this data can be followed with sufficient accuracy. Experience has shown that the increase in precision by measuring larger numbers of specimens would be small compared with the additional work involved.

Following are a few comments regarding the measurements taken.

Coiling diagram

In megalospheric forms the half of the maximum distance between the outer walls of the protoconch and the deuteroconch has been chosen as the center of the spiral. From this median point the radius of the whorls are measured on a radial line passing through the deuteroconch (see Fig. 5).

For the microspheric forms the generally good preservation allowed the observation of the initial chamber in many cases. Since the central part of the spiral shows only little variation in its coiling, the centerpoint has been determined by extrapolation in those cases where the protoconch could not be observed.

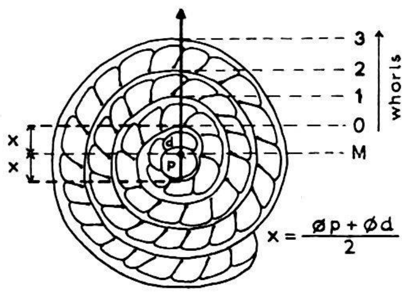


Fig. 5. Equatorial section of a megalospheric Nummulite showing the measured parameters for the coiling diagram.

In plotting the diagrams a single curve has been traced for each measured specimen of the microspheric generation, since the number of specimens per sample was usually low. For the megalospheric generation, where more specimens were available, this presentation had to be abandoned, because the separate curves could not have been distinguished in the diagrams anymore. The measurements were therefore plotted in frequency histograms for each whorl and a curve connecting the median values has been superimposed.

Distribution of Nummulites in the Upper Eocene of Possagno

Marna di Possagno

The Nummulites of this formation are generally small; in most cases the diameters of the microspheric forms are hardly greater than in the megalospheric forms of the same species. *Nummulites incrassatus* and *N. chavannesi* are predominant, but in several samples *Nummulites garnieri* ssp., *N. stellatus*, *N. pulchellus* and other small forms can be recognized. *Nummulites fabianii*, however, is virtually absent; only one specimen was found in sample 675.

In the uppermost part of this formation there are however layers of hard siltstones with abundant *Nummulites fabianii retiatus* (sample 685a, see Fig. 6).

Calcare di S. Giustina

The most frequent Nummulites of this formation are *Nummulites fabianii fabianii*, *N. incrassatus* and *N. chavannesi*. Unlike the small size B-form specimens in the Marna di Possagno, the microspheric forms here reach their normal dimensions. *Nummulites garnieri* does not occur.

Marne siltose

At a first glance the marne siltose seem to represent a facies similar to that of the upper part of the Marna di Possagno. However, they differ from each other in their megafauna as well as in their Nummulite assemblages. In the marne siltose we find rich assemblages of *Nummulites fabianii retiatus*, *Nummulites incrassatus*, *N. chavannesi* and *N. garnieri inaequalis* n.ssp. In some of the samples there are relatively large specimens of these species, particularly B-forms. *N. stellatus*, on the other hand, has not been found.

Discussion of biometric data

Nummulites fabianii Prever

Possagno

The main biometric data obtained from the Cunial-S. Giustina-Col dell'Asse section are summarized in Figure 6. In accordance with Roveda (1950) and based on the present data, *N. fabianii fabianii* and *N. fabianii retiatus* are separated on a subspecific level.

In the siltstones which are intercalated in the upper part of the Marna di Possagno (sample 685a), the specimens of this species are extremely thin and flat. The megalospheric generation shows a relatively advanced stage of the reticulation and the coiling

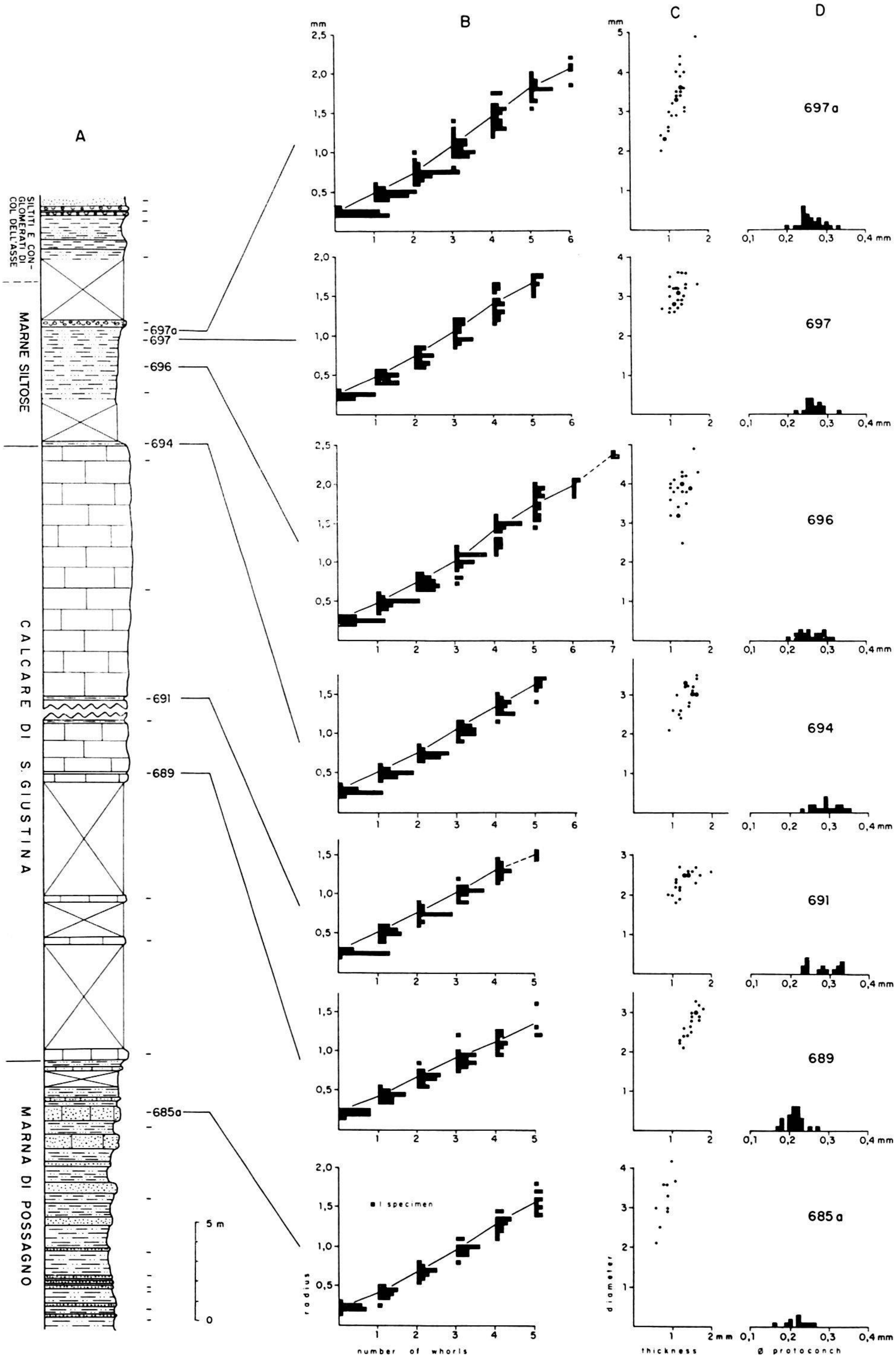


Fig. 6. Stratigraphic section of the uppermost Eocene at Possagno (Cava di Cunial–S. Giustina–Col dell'Asse, see Fig. 1) and biometric data of the *Nummulites fabianii* group (megalospheric generation). A. Stratigraphic section with sample numbers. B. Coiling diagrams. C. Diameter/thick ness ratio. D. Histograms of protoconch diameters.

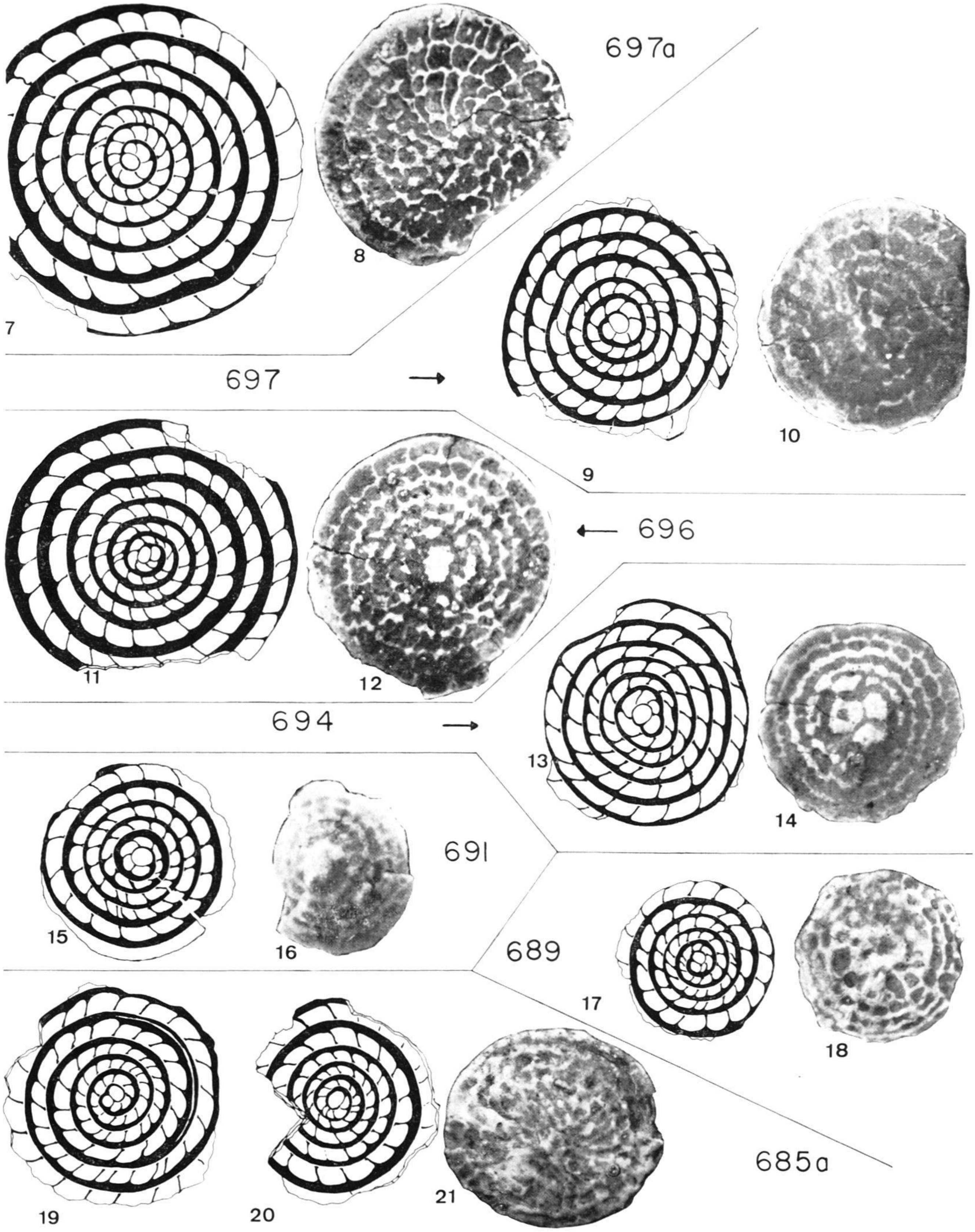


Fig. 7–21. Equatorial sections and surfaces of typical representatives of the *Nummulites fabianii* group from Possagno. Fig. 7–12. *N. fabianii retiatus* ROVEDA. Fig. 13–17. *N. fabianii fabianii* PREVER. Fig. 19–21 .*N. fabianii retiatus* ROVEDA. 10×. For sample locations see Fig. 6.

is slightly looser than can usually be observed in *N. fabianii fabianii*. The form is therefore called *Nummulites fabianii retiatus*. In the corresponding siltstone levels of the Val Organa section, the same form was also found in great numbers. Here it is somewhat less flat but otherwise shows the same diagnostic features.

In the Calcare di S. Giustina, particularly in the lower part of the section (sample 689), the specimens are considerably thicker and the megalospheric specimens show a tighter coiling than in the siltstones just mentioned. The surface structures cannot be easily recognized, but in most of the specimens radial and spiral elements are about equally developed. In the concept of ROVEDA (1970) these specimens should therefore be called *N. fabianii retiatus* based on their surface morphology, but *N. fabianii fabianii* when considering the inflated nature of the test. The coiling diagrams are in good general agreement with *Nummulites fabianii fabianii* from the lower part of the Priabona section, but differ considerably from *N. fabianii retiatus* from its type locality (p. 433).

Finally, in the marne siltose, there are large forms showing relatively loose coiling, especially in samples 696 and 697a. In 697, inbetween the two other samples, maximum diameters are smaller. Corresponding observations were made for *Nummulites garnieri inaequalis* from the same samples. The surface structure is typical for *Nummulites fabianii retiatus* and in some of the larger specimens a development of the reticulation towards *Nummulites fichteli* can be observed. Comparison with specimens of the latter species from Biarritz and Sangonini (locality see FABIANI 1915, p. 66) shows, however, that *N. fichteli* has a distinctly tighter coiling than *N. fabianii retiatus*.

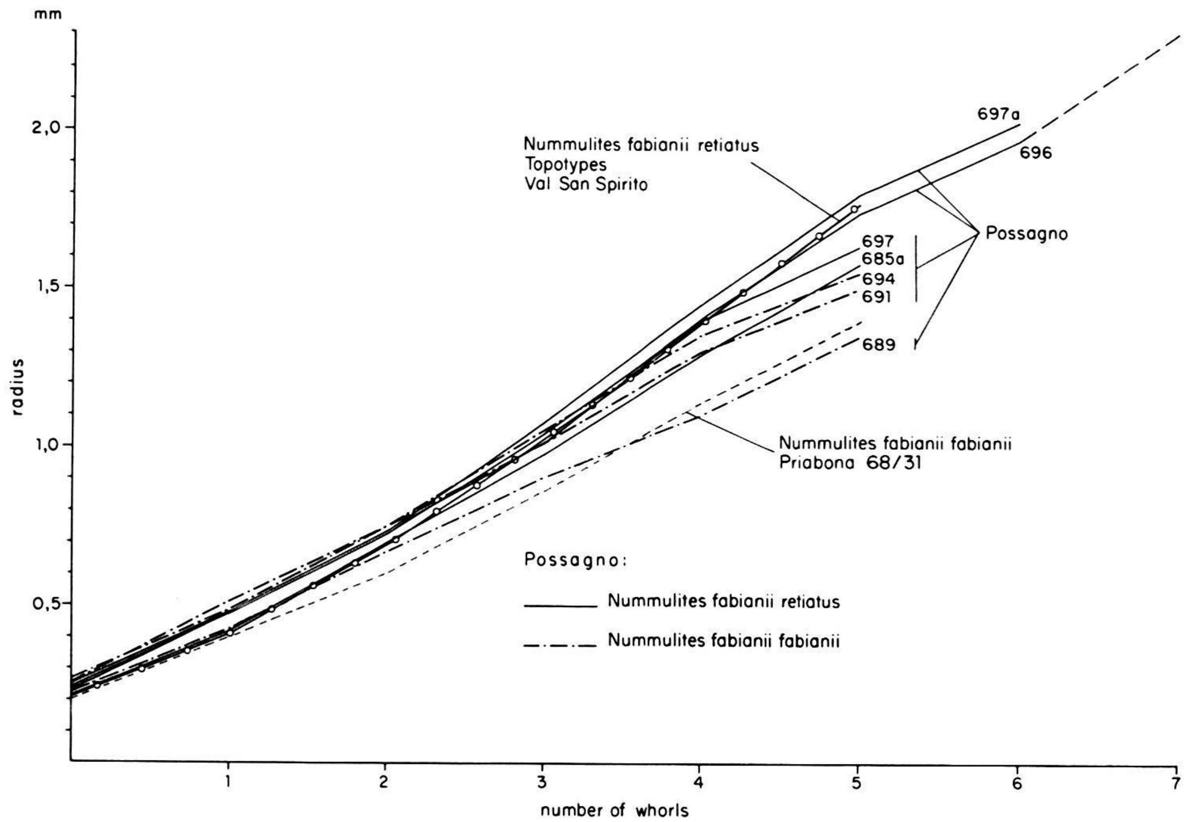


Fig. 22. Mean coiling curves of *Nummulites fabianii* sspp. from Possagno (see Fig. 6) compared with samples of *N. fabianii fabianii* from Priabona (see Fig. 3 and 24) and *N. fabianii retiatus* from Valle S. Spirito (p. 433).

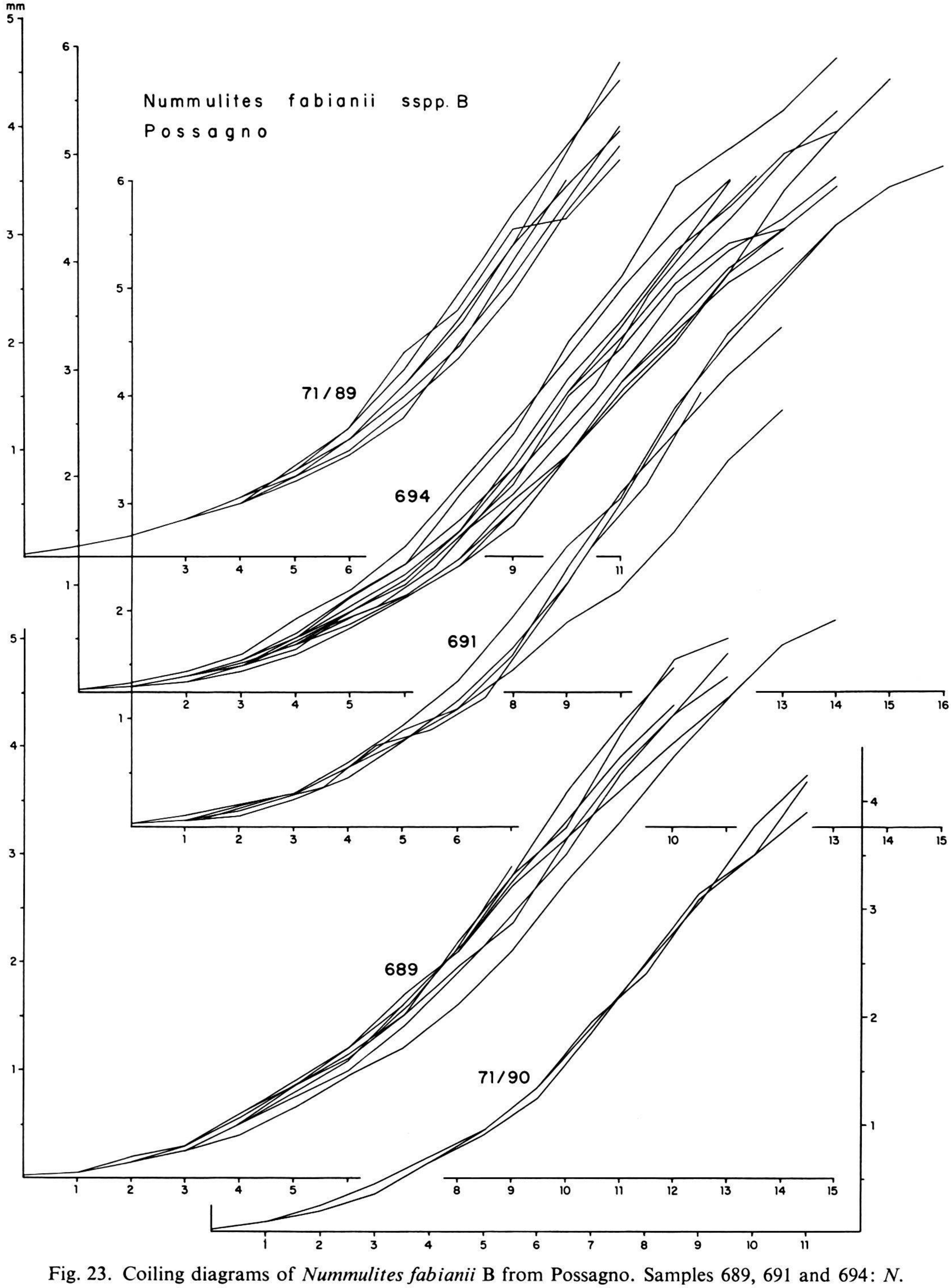


Fig. 23. Coiling diagrams of *Nummulites fabianii* B from Possagno. Samples 689, 691 and 694: *N. fabianii fabianii*, Calcare di S. Giustina. 71/90: *N. fabianii retiatus*, siltstones in the uppermost part of the Marna di Possagno. 71/89: *Nummulites fabianii retiatus*, marne siltose.

In contrast to what has just been described for the megalospheric forms, coiling diagrams of the microspheric generation do not show significant changes throughout the whole Possagno section (see Fig. 23). Equatorial sections of *N. fabianii fabianii* B and *N. fabianii retiatus* B differ only slightly from each other, the latter usually showing a thinner marginal cord. There is, however, considerable variation in the coiling diagrams of most of these samples.

Priabona

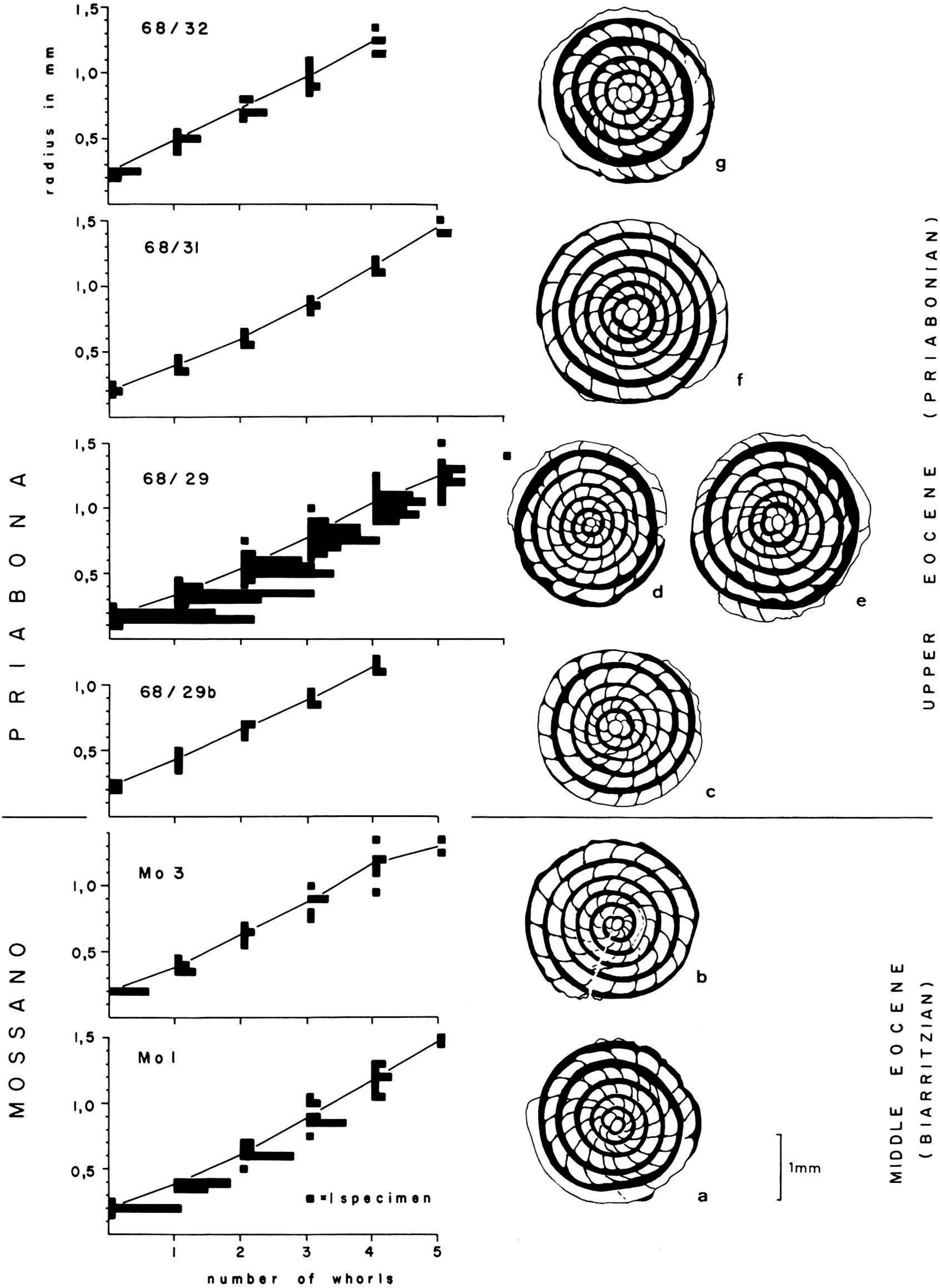
Nummulites of the *fabianii* group have been investigated in four samples from the lower part of the Priabonian type section (see Fig. 24). Only one sample (68/29), however, contained a rich assemblage of this species, and allowed preparation and measurement of 41 specimens. In the remaining three samples the number of good specimens was much lower and only an approximate quantitative interpretation can be made.

Despite this limitation the considerable variation in the mean values of the coiling diagrams (Fig. 24, 25) and of the protoconchs (Fig. 26) becomes obvious. The coiling diagrams of samples 68/29 b, 31 and 32 can well be compared with the values obtained for *N. fabianii fabianii* in the Possagno section and would there range inbetween samples 689 and 691. The diameters of the protoconchs vary considerably, but do not differ from the measurements of the Possagno material. A slight difference can be seen in the surface structure: in the Priabona material the spiral elements predominate in the reticulate structure, as already noted and figured by ROVEDA (1961).

One sample (68/29), however, from the lowermost part of the section deviates considerably from the three others: the spiral shows a tighter coiling, the diameter of the protoconch is much smaller (mean value 0,14 mm) and in the reticulation the predominance of the spiral structure is less pronounced. This form has definitely a more primitive aspect and it is therefore called *Nummulites fabianii praefabianii*, as will be discussed below. The separation is equally supported by comparison of the diameters observed in the microspheric generation. In sample 68/29 no B-form larger than 4 mm has been observed, while diameters in sample 68/29 b reach 9 mm.

Sample 68/29 with the more primitive population was however collected slightly above sample 68/29 b with its more advanced assemblage. This field evidence does therefore not allow the interpretation of a purely linear evolution from *N. fabianii praefabianii* to *N. fabianii fabianii* in the lowermost part of the Priabonian type section, but most probably reflects an interference of evolution and environment controlled variation in subsequent samples, as was noted in the stratigraphically higher Possagno section (see discussion below). The occurrence of *N. fabianii praefabianii* is certainly of some stratigraphic value, since this subspecies has not been observed in higher parts of the Priabonian. A coexistence of the two subspecies, if defined in a purely descriptive way, seems therefore to be characteristic for parts of the lower Priabonian.

Fig. 24. Coiling diagrams and median sections of *Nummulites fabianii praefabianii* VARENTSOV and MENNER (samples Mo 1, Mo 3, 68/29) and *Nummulites fabianii fabianii* PREVER (samples 68/29 b, 68/31, 68/32) from Mossano and Priabona. Locations of samples see Figures 2–4, 10×.


68/32
68/31
68/29
68/29b
Mo 3
Mo 1
1,5
1,0
0,5
radius in mm
1
2
3
4
5
number of whorls
■ = 1 specimen
g
f
d
e
c
b
a
1mm
PRIABONA
MOSSANO
UPPER EOCENE (PRIABONIAN)
MIDDLE EOCENE (BIARRITZIAN)

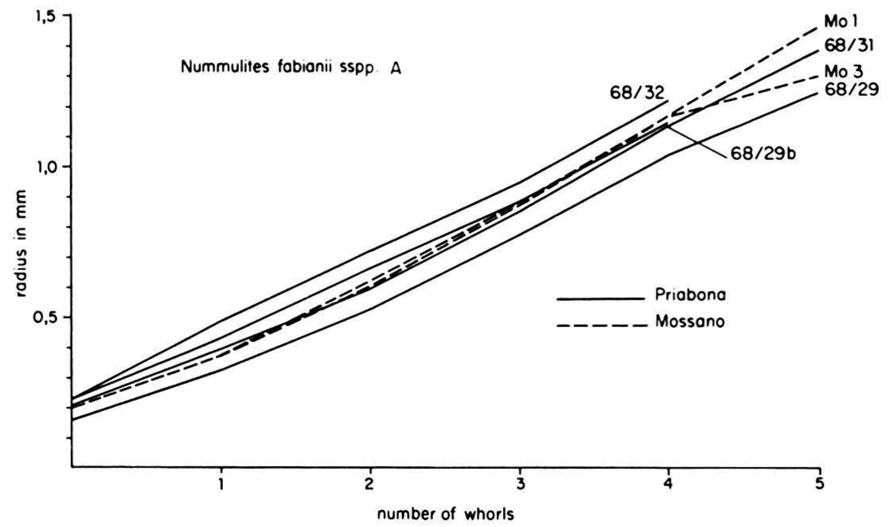


Fig. 25. Mean coiling curves of *Nummulites fabianii fabianii* and *N. fabianii praefabianii* from Priabona and Mossano (see Fig. 2, 3 and 24).

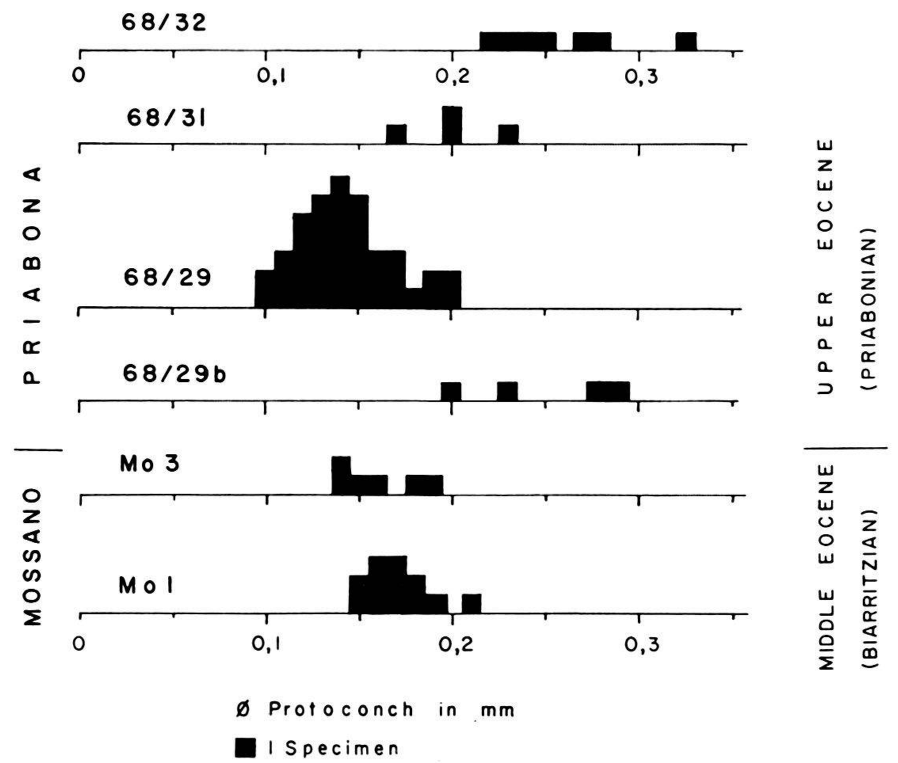


Fig. 26. Histograms of protoconch diameters of *Nummulites fabianii praefabianii* VARENTSOV and MENNER (samples Mo 1, Mo 3, 68/29) and *Nummulites fabianii fabianii* PREVER from Mossano and Priabona (see Fig. 23).

The problem of *Nummulites praefabianii* VARENTSOV and MENNER

SCHWEIGHAUSER (1953) has used this name for the first time in Northern Italy in his description of the Mossano section, however without further discussion. It should obviously designate an earlier evolutionary stage in the evolution of *N. fabianii*. It has been pointed out by CASTELLARIN and CITA (1969, p. 96) that the species is insufficiently described. The use of the name was therefore rejected, and these authors, as well as UNGARO (1968, 1969) called this form *Nummulites* aff. *fabianii*. On the other hand, FERRER (1967, 1971) again used the name for designation of the early form of the *fabianii*-lineage occurring in the uppermost Middle Eocene (Biarritzian) of Northern Spain, in strata of the same age as also found in the lower part of the Mossano section. Although the critique of CASTELLARIN and CITA is certainly valid, the practise of SCHWEIGHAUSER and FERRER is followed here, since the authors of the species had obviously the specific separation of an earlier evolutionary stage in mind, a concept which corresponds to the actual use of the name today.

The delimitation of *N. praefabianii* against *N. fabianii* is not easy however. FERRER (1971) pointed out, that the main differences are the smaller protoconch and the smaller diameter of the B-Forms in *N. praefabianii*, an observation which is supported by our investigation of *N. praefabianii* from the Biarritzian of Mossano.

Both criteria, however, can only be applied in a broad sense. The diameter of the protoconch may vary considerably when subsequent populations are investigated (see also Figures 6 and 26). A gradual increase of the mean protoconch diameters from the Biarritzian to the Upper Eocene does not exist, since sample 68/29 in the lowermost part of the Priabona section shows a slightly smaller mean protoconch diameter than the two older samples from Mossano. The typical *N. fabianii*, however, has considerably greater protoconchs and therefore a distinction of the two forms based on this criterion seems generally valid.

Similarly, the maximum diameter of the B-Forms is a value which is not only a matter of evolution and age, but may also be influenced by environment, as is shown in the Possagno section (p. 425). With respect to the Mossano and the Priabona sections, however, the general rule of increasing maximum diameters can be supported and therefore seems valid with the qualifications just mentioned.

Regarding the coiling diagram, the distinction between the two forms is less clear. In general, *N. praefabianii* shows a tighter coiled spiral than *N. fabianii*, but a strong overlap between the two forms can be observed (see Fig. 25).

The surface structure of the test also shows slight differences between *N. praefabianii* and *N. fabianii*, the reticulation being more regular in *praefabianii* than in *fabianii*, where, at least in the Priabona specimens, the spiral lamina predominates.

Summarizing these observations, a distinction of the two forms is certainly difficult, but seems generally possible, if we are dealing with assemblages. However, with respect to the lack of a clearcut delimitation a separation on a subspecific level, rather than the distinction of separate species, seems more reasonable, and the two forms are therefore called *N. fabianii praefabianii* and *N. fabianii fabianii*.

Nummulites fabianii retiatus from Valle San Spirito (Apennines)

A number of samples were collected in 1967 at the type locality of this form. The specimens are in general relatively small but otherwise agree well with the material from Possagno and from the upper part of the Boro-Granella section near Priabona. This is particularly the case with respect to the coiling diagram and for the diameter of the initial chamber (which is only slightly smaller than in most of the Possagno specimens). However, the dimensions of the protoconch in the type material described and figured by ROVEDA, including the holotype, are much smaller (0.12–0.17 mm) than in all of our samples from the same locality. For this difference no explanation can be given so far, but it may be pointed out, that similar deviations of one assemblage within a suite of otherwise consistent samples have been noted at other occasions (see also *Nummulites garnieri* in sample 675 of this paper, Fig. 29).

Interpretation

The distribution of the two subspecies in the Possagno sections may be explained in one or the other of the following two ways:

1. In the uppermost zone of the Priabonian *Nummulites fabianii retiatus* evolved from *Nummulites fabianii fabianii* as a separate form while the latter still persisted. The occurrence of predominantly one or the other of the two subspecies in a given sample, as observed in the Possagno sections, would be mainly controlled by environment.
2. There is only one species of reticulate Nummulites in the uppermost Priabonian, but its morphology, particularly the diameter and the thickness of the test, the type of reticulation and the tightness of the coiling was influenced to some degree by environmental parameters which are still unknown. Dependent upon the environment, the species may therefore in some lithologic units occur as *Nummulites fabianii fabianii*, in others as *N. fabianii retiatus*, and transitional forms between the two would be expected.

The present data are so far still insufficient for making a choice between these two hypotheses. Further studies based on other contemporaneous sections with different lithologic sequences are needed. At present we are inclined to favour the second of these alternatives for the following reasons:

It has been pointed out that the equatorial sections of the microspheric forms do not show significant differences throughout the Possagno section, except for the thickness of the marginal cord. However this feature shows considerable variation within the two subspecies recognized here and it seems reasonable to suggest that it could grow thicker in a carbonate-rich environment than it would in a silty-argillaceous one. Although we have tried to classify all the reticulate Nummulites from Possagno into one or the other ot the two subspecies recognized by ROVEDA, one has to admit that in certain cases, such as in sample 694, a transitional stage between the two subspecies is observed. It may be significant that this sample was collected at the lithologic boundary between the Calcare di S. Giustina and the marne siltose above.

In addition there seems to be a general evolutionary trend present throughout the whole Possagno section in both subspecies. As may be seen in Figure 4, the coiling of *N. fabianii fabianii* as seen in the limestones, as well as of *N. fabianii retiatus* below and above, shows a tendency to become steadily looser with time. This fact can of course be explained in either of the alternatives. Along with the two explanations just mentioned there is also the obvious difficulty of precisely differentiating the two subspecies from each other. It therefore seems more reasonable to assume an overall evolutionary trend towards the following: a development of looser coiling, a more complicated reticulation, and a greater diameter of the whole test as well as of the protoconch in the megalospheric generation. Variation patterns due to environmental parameters would then be superimposed onto these general trends. Thus the evolutionary trends could readily appear to be somewhat obscured and in many instances do not show a linear trend, but rather a discontinuous and apparently even random one.

What such controlling parameters are is as yet unknown. Judging from the Possagno section alone, the character of the sediment might be significant, since we find *Nummulites fabianii fabianii* only in the limestones, and *Nummulites fabianii retiatus* in the silty-argillaceous sediments. However, the type of *N. fabianii retiatus* from the Valle S. Spirito occurs in a limestone and the same form is found in a predominantly calcareous sediment in the Boro-Granella section near Priabona (ROVEDA 1959, 1961, 1970). The presence of one or the other of the subspecies does not always appear to be explained by the lithology alone.

If the alternative of a selective influence of the environment upon certain features of the Nummulite morphology is true, we are in fact not dealing with different subspecies, but rather with form variants of one single species. However, for practical reasons and also for reaching a stable taxonomic nomenclature it seems preferable to maintain the present distinction between the two forms on a subspecific level.

Nummulites garnieri DE LA HARPE

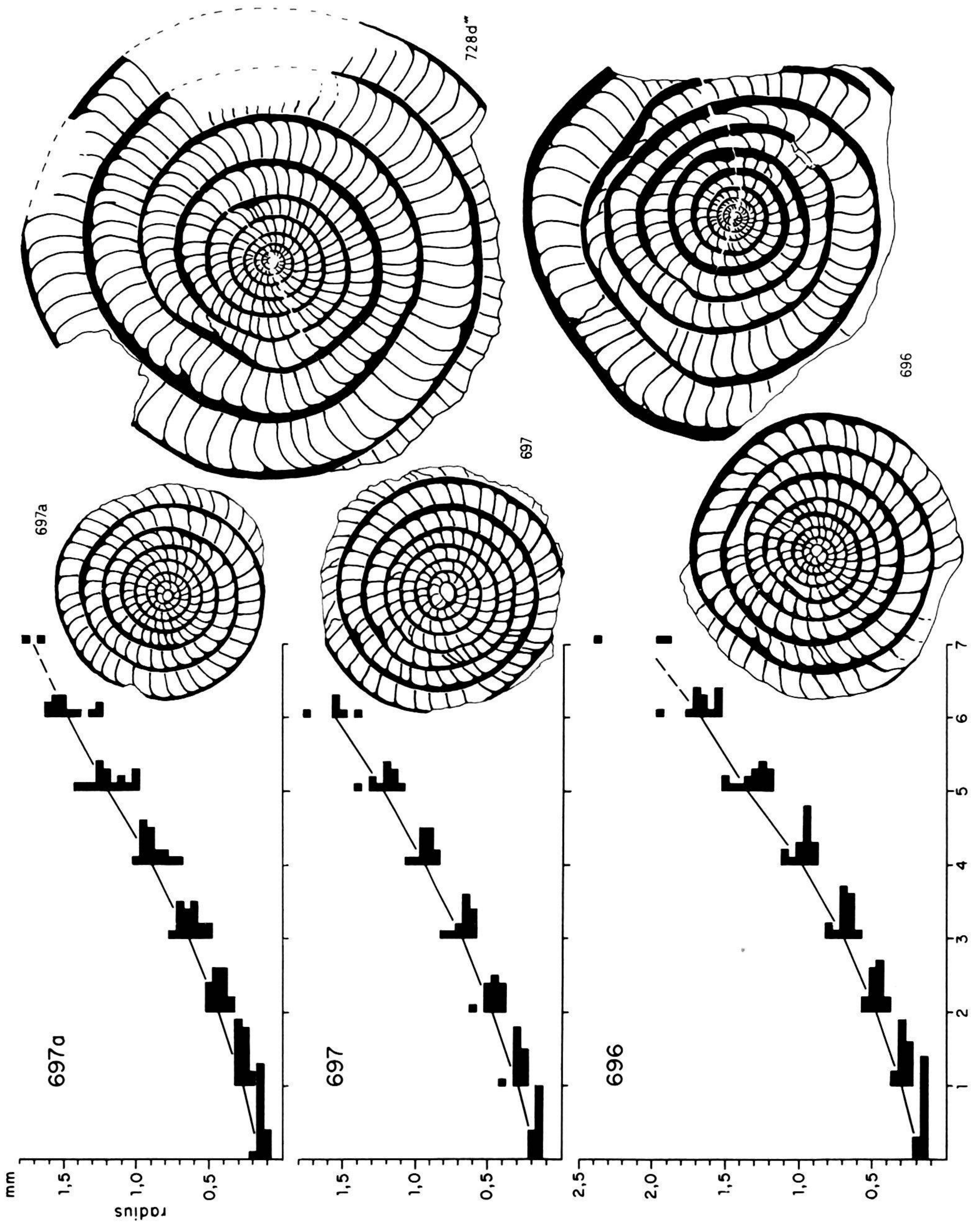
This species has been described by DE LA HARPE from the Western Alps of France (Allons, Châteaugarnier), and the type locality has subsequently been designated by BOUSSAC (1911) to be Allons. *Nummulites garnieri* is generally considered to be a good index form for the Upper Eocene (BOUSSAC 1911). BOMBITA and MOISESCU (1968) has found it to be restricted to his lower part of the Priabonian, and in the type section of the Priabonian it also occurs only in the lower part (ROVEDA 1961).

The species is a good example for facies or environment controlled occurence. This can be demonstrated in the Possagno section where it occurs in the Marna di Possagno and in the marne siltose, but not in the limestones inbetween.

Diagrams and equatorial sections are shown in Figures 27–30. As already noted, the specimens from the Marna di Possagno are small. This is true particularly for the microspheric form, which only slightly exeeds the diameter of the A-Forms. In the marne siltose, however, the specimens are much larger, especially the B-Forms. In equatorial section the latter show many similarities with *Nummulites pulchellus*.

Comparison of the Possagno material with specimens from Allons (French Alps) in the De la Harpe collection in Lausanne[3]) as well as with specimens collected by Prof. H. Schaub at Châteaugarnier show that the specimens from the marne siltose deviate distinctly from the type of this species. It is typical for *Nummulites garnieri* DE LA HARPE that the B-Forms do not greatly exceed the A-Forms in diameter, even if we are dealing with a well developed population of relatively large forms (see Fig. 12). The general appearance of the equatorial sections is similar in A- and B-Forms and both are relatively thick.

[3]) Contrary to what has been stated by BOUSSAC (1911, p. 57), the De la Harpe collection contains a good collection of specimens from this locality.



Marne siltose

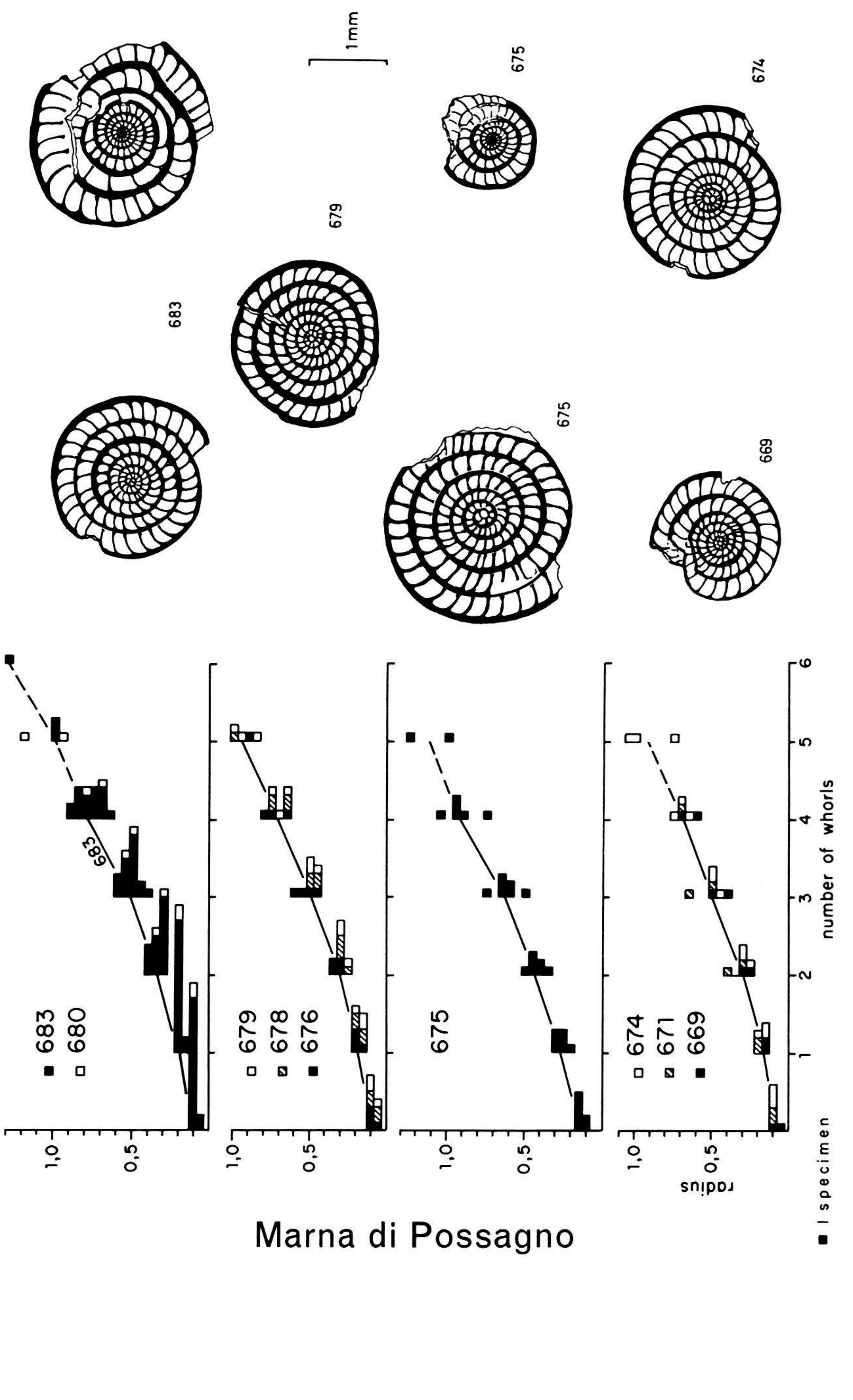


Fig. 27. Coiling diagrams and median sections of the *Nummulites garnieri*-group from Possagno, 10 ×.

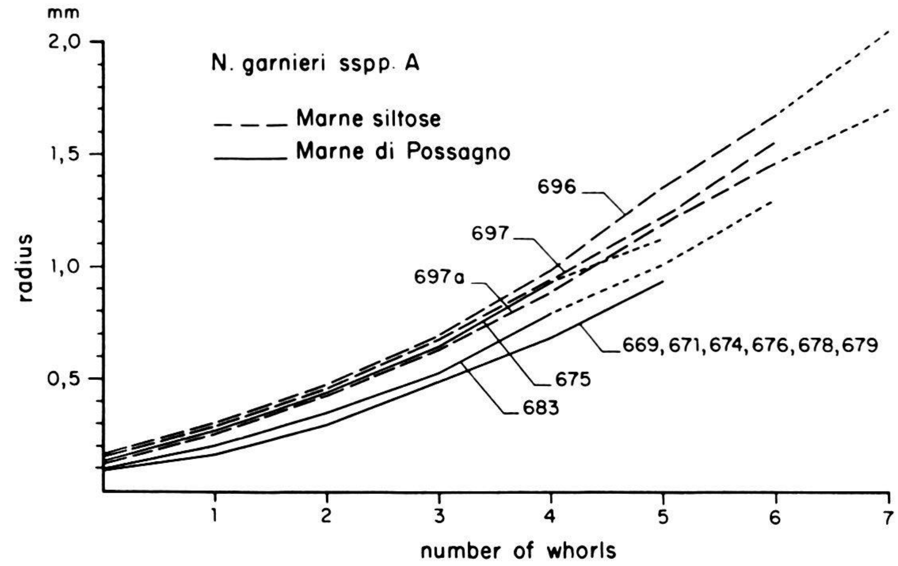


Fig. 28. Mean values of the coiling diagrams in Figure 27. *Nummulites garnieri* ssp.: 669, 671, 674, 676, 678, 679, 683; *Nummulites* cf. *garnieri inaequalis:* 675; *Nummulites garnieri inaequalis:* 696, 967, 697a.

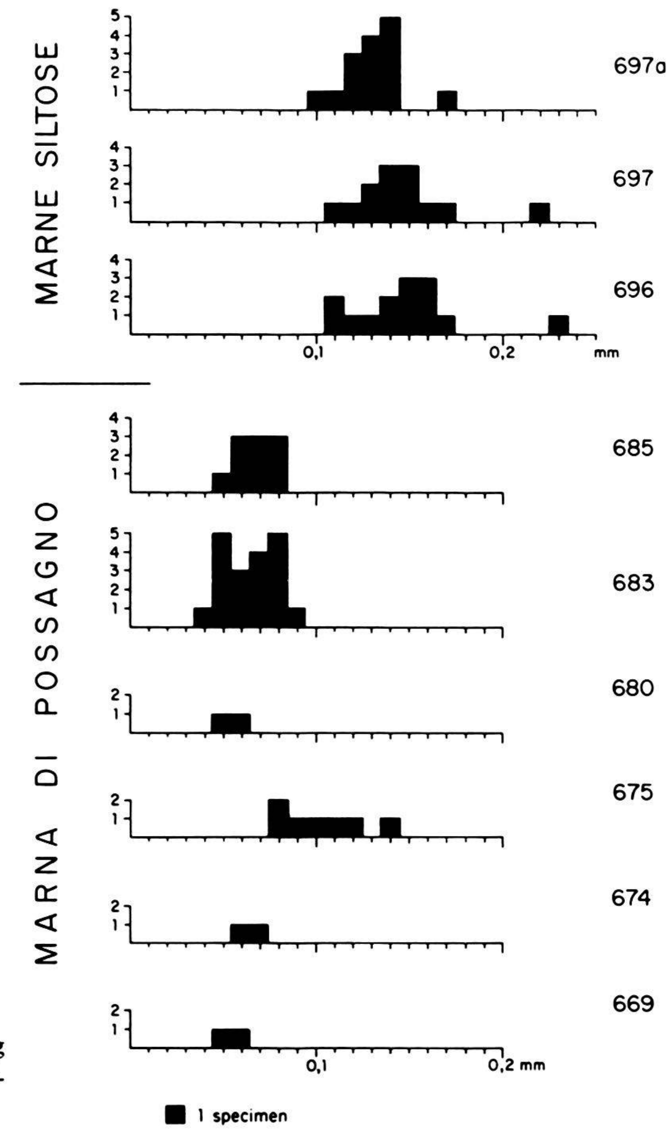


Fig. 29. Frequency histograms showing protoconch diameters of *Nummulites garnieri* sspp. A from Possagno.

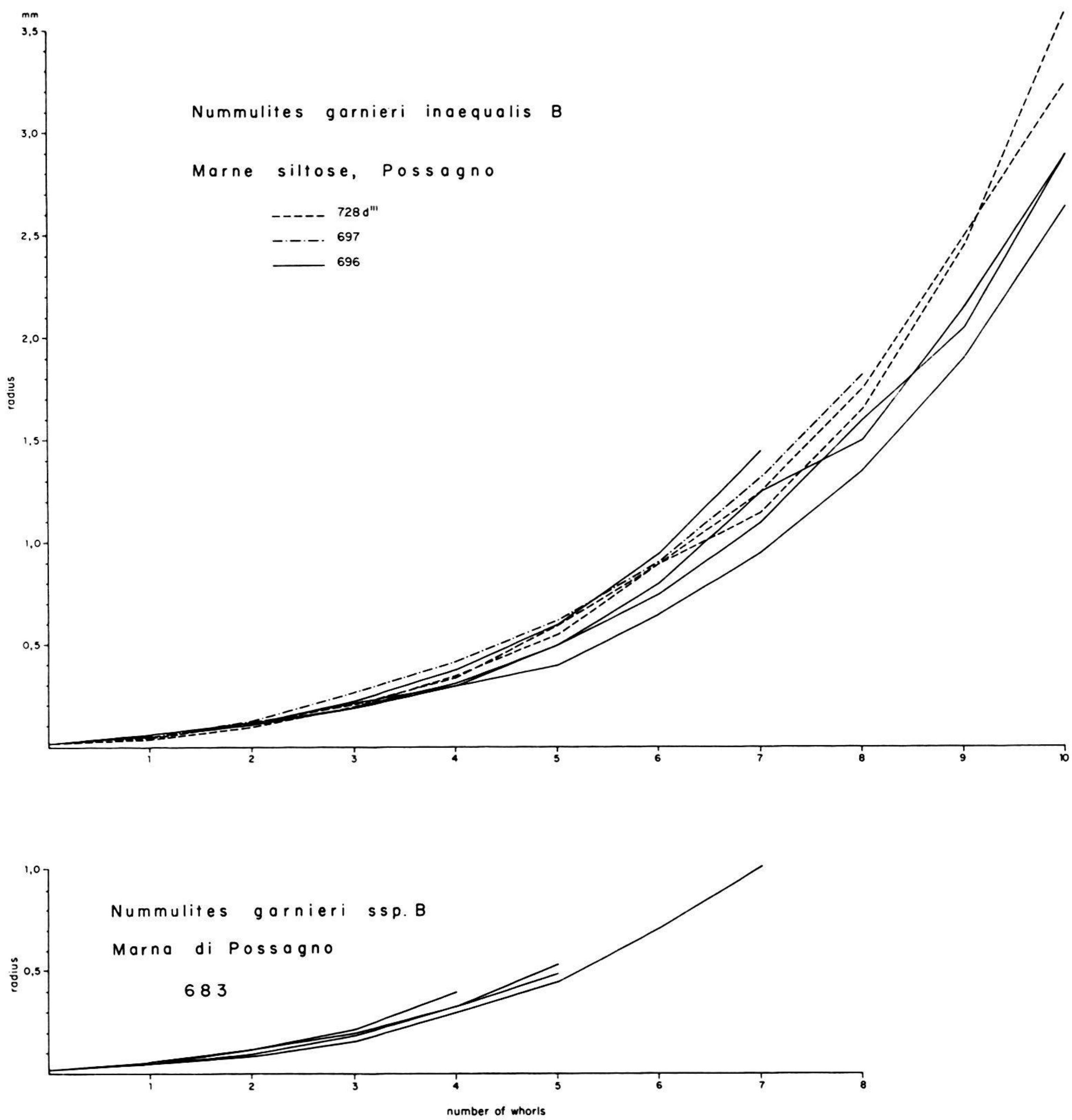


Fig. 30. Coiling diagrams of *Nummulites garnieri* sspp. B from Possagno.

The B-Forms from the marne siltose of Possagno, however, are considerably greater in diameter than the A-Forms and show a distinctly looser coiling. The tests of both generations are also flatter than the type and show fewer granules on the surface. It therefore seems justified to separate the two forms subspecifically. The form from the marne siltose is called *Nummulites garnieri inaequalis* referring to the unequal character of the equatorial section in the two generations. As explained below, the small forms from the Marna di Possagno show a closer relationship to *Nummulites garnieri garnieri* rather than to *N. garnieri inaequalis*, except for sample 675.

Nummulites garnieri garnieri DE LA HARPE

The specimens from the Marna di Possagno differ from the type in being much smaller. This however, is probably again a matter of environmental control, since in all other respects there is a good correspondence with the type. The arrangement of the septal lines and the pillars on the surface, as well as the equatorial section (including the diameter of the initial chamber) are very similar. An exception has to be made, however, for sample 675 where much looser coiling and greater diameters of the initial chambers can be observed (see Fig. 27–29). In these respects the specimens from this sample correspond well with *Nummulites garnieri inaequalis*. However, in their general shape and in their surface features they do not deviate from the specimens in the other samples from the Marna di Possagno. The form from sample 675 is here named *Nummulites* cf. *garnieri inaequalis*.

A similar problem which has already been discussed in connection with the *Nummulites fabianii* group is raised here. One single sample is an exception in a series with consistent trends. It seems that a stage of evolution which otherwise occurs much higher in the section, is reached here in just one assemblage. No change in lithology can be noted here, but we have to assume, that this is also a case of environmental control of certain morphologic features.

Unfortunately *N. garnieri* is rare in many samples from the Marna di Possagno. For this reason, specimens from several samples have been presented in one diagram on Figure 27. The small range of variation shown in the spiral diagrams from these samples may justify this otherwise unusual presentation. Measurements of the initial chambers (see Fig. 29) have been taken on very few specimens in samples 669, 674, 675 and 680, but it was still considered of some value to present these few data.

Nummulites garnieri inaequalis n. ssp.

Holotype: Figure 32, Naturhistorisches Museum Basel, No. C 29000.
Type locality: Col dell'Asse near Possagno (Treviso, Italy)
Type strata and age: Marne siltose, Upper Priabonian, sample 696.

Diagnosis

Microspheric form: Flat lenticular, acute edged nummulite with granular surface and diameters up to 7 mm. The pillars are concentrated in the central part of the test surface, and are arranged on the septal lines. The latter are radially, but somewhat irregularly arranged. Not all septal lines reach the central part of the test surface, but may join neighbouring septal lines. In the equatorial section the coiling of the spiral is relatively loose and irregular with a steady increase in the hight of the whorls. The outer whorls show particularly high chambers, the height being up to three times greater than the length. The septa are regularly curved and inclined in the inner whorls, but become straighter and more perpendicular to the next inner spiral lamella in the outer whorls.

Megalospheric form: The test is lenticular and shows sharp edges. The arrangement of the septal lines and the pillars on the surface is generally the same as described for the B-forms. Many specimens, however, show only few pillars in the center, while others, especially smaller ones, may have pillars on the septal lines over the greater

Fig. 31. *Nummulites garnieri inaequalis* n. sp. B, surface. Possagno 696. 10 ×.

Fig. 32. *Nummulites garnieri inaequalis* n. sp. B, equatorial section. Holotype. Possagno 696. 10 ×.

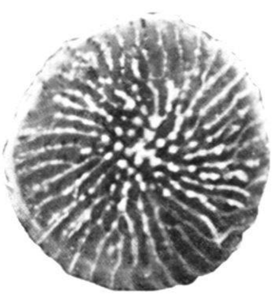


Fig. 33. *Nummulites garnieri inaequalis* n. sp. A, surface. Possagno 696. 10 ×.

Fig. 34. *Nummulites garnieri inaequalis* n. sp. A, equatorial section. Possagno 697. 10 ×.

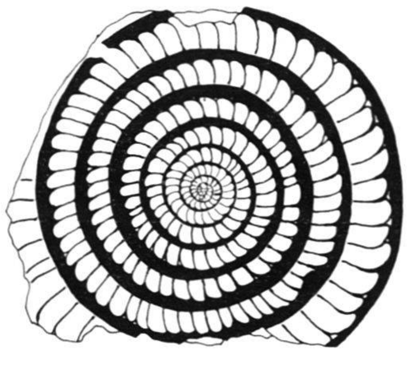


Fig. 35–36. *Nummulites garnieri garnieri* De la Harpe. Châteaugarnier.

Fig. 35. Megalospheric form.

Fig. 36. Microspheric form.

part of the test, however never close to the edge. In the equatorial section the spiral shows, in contrast to the B-Form, a regular coiling with a slow increase in the height of the whorls. The diameter of the protoconch averages 0.14–0.15 mm, but values between 0.10 and 0.23 mm were measured (Fig. 29). The deuteroconch is usually only little smaller than the protoconch. The septa are regularly arranged, inclined and slightly curved over the whole spiral.

Remarks

As noted above, this subspecies differs from the type in being larger, more flattened, showing less evidence of pillars on the surface and having a looser coiled spiral, particularly the B-Forms. Compared with the type of the species there is a considerable difference between A- and B-Forms with respect to the diameter of the test and in the equatorial section in general. The diameter of the initial chamber in A-Forms is greater than in the type.

Nummulites variolarius (LAMARCK)-*Nummulites incrassatus* (DE LA HARPE) group

These two species are usually treated separately. The main features of the equatorial section as well as of the surface structure, however, show many similarities in both species, and differences are often a question of larger dimensions in *N. incrassatus*. The form and the arrangement of the septa are virtually the same. It is therefore suggested here, that *N. incrassatus* evolved from *N. variolarius* at the base of the Upper Eocene. *N. variolarius*, which originates in the Middle Eocene, persists together with its descendant forms throughout the whole Priabonian as was already noted by several authors (e.g. ROZLOSZNIK 1929, BIEDA 1963, VAŇOVÁ 1972).

The section of Mossano is particularly suitable for studying the evolution of this group (see Plate I). In the lowermost levels (samples 1–3) which can be attributed to the uppermost Middle Eocene (Biarritzian) by the presence of *Nummulites biedai* SCHAUB, there are only small forms which, following the subspecific distinction made by PAPP (1958), should be called *N. variolarius variolarius*.

Beginning with the Upper Eocene (sample 4) a diversification can be noted: *Nummulites variolarius* persists throughout the whole Priabonian part of the section, practically without any change in its morphology. The diameter of the protoconch remains small (0.10–0.15 mm). Besides *N. variolarius* a larger form with a larger protoconch (usually around 0.2 mm) and showing looser coiling of the spiral occurs. In accordance with BIEDA (1963) this form is called *Nummulites incrassatus ramondiformis* DE LA HARPE.

In the higher parts of the section there are occasionally specimens which show a distinctly looser coiling than the forms just mentioned. These are, again corresponding to the distinction made by BIEDA (1963), called *N. incrassatus incrassatus*. Specimens of this form are less frequent than *N. incrassatus ramondiformis*, but their occurrence in the higher parts of the Priabonian seems to be stratigraphically significant, since a similar distribution could be observed in the Possagno section as well.

Transitional forms between the three taxa can be observed. However, they are less frequent between *N. variolarius* and *N. incrassatus ramondiformis* than between the latter and *N. incrassatus incrassatus*.

The frequency distribution of *N. variolarius* and *N. incrassatus* in the Upper Eocene of Mossano is quite irregular. *N. variolarius*, e.g., has not been found in samples 12 and 22 but is dominant in samples 9 and 14, and also occurs frequently in the highest sample (24). This demonstrates, that the occurence of such apparently ubiquitous and stratigraphically longranging forms as *N. variolarius* can in fact be sporadic.

The question, whether a subspecific distinction within *N. incrassatus* is justified from the point of view of reaching a "natural" taxonomy is certainly open to discussion. Similar relations may exist here, as noted before, regarding the distinction of *N. fabianii fabianii* and *N. fabianii retiatus*. However, the data so far available are not significant enough and it seems therefore appropriate to adhere for the time being to the nomenclature proposed by BIEDA (1963).

In the coiling diagrams of Plate I the limites of variation for the three forms involved are tentatively indicated. They are mainly based on the data published by PAPP (1958) for *N. variolarius*, and by measurements on specimens from the De la Harpe collection in Lausanne labelled *N. ramondiformis*.

Conclusions

The generally low numbers of measured specimens of each species in a specific sample do not allow a proper statistical treatment of the biometric data. However, a number of significant trends are obvious and some conclusions of general interest are therefore possible.

There is no doubt, that within the three groups of Upper Eocene Nummulites investigated in this study certain evolutionary patterns can be seen, and the observations may be summarized as follows:

1. A progressive increase of the protoconch diameteres with time can be observed in the megalospheric generations of the *fabianii*- and the *garnieri*-groups.
2. In the *fabianii*-group a general trend to development of a looser coiled spiral as well as an increase in the diameter of the test can be observed.
3. In the uppermost part of the Possagno section a relatively large form of the *N. garnieri*-group was found, which shows a loosely coiled spiral in the microspheric generation and is considered to be an index form of the uppermost Eocene. It is called *N. garnieri inaequalis* n. sp.
4. The detailed investigation of subsequent samples collected at short stratigraphic intervals has shown, that the evolutionary trends mentioned in points 1–3 do not follow strictly linear patterns. Within a sequence of "normally" developing features, one or several samples may deviate considerably. Such observations can be made particularly for the protoconch diameters in megalospheric forms and for the development of the coiling ratio.
5. In some cases, a correlation between the lithology and such irregular evolutionary patterns can be seen, e.g. in the *fabianii* group of Possagno. In other cases, however, such as *N. fabianii* in sample 68/29 from Priabona, or *N. garnieri* in sample 675 from Possagno, no significant changes in lithology were visible. Despite this it seems probable that certain environmental parameters which are yet unknown, are superimposed upon the general evolutionary trends.
6. On the other hand, coiling diagrams of microspheric *N. fabianii* were consistent throughout the whole upper part of the Possagno section and did not reflect the changes seen in megalospheric forms. It has to be admitted, however, that a great range of variation is seen in these samples. More measured specimens would be required if small deviations should be noticed.

7. A general increase in the size of the microspheric forms can be seen in the evolution of the *fabianii*-group from the uppermost Middle Eocene (Biarritzian) to the top of the Upper Eocene in Possagno. The Nummulite assemblages of the Marna di Possagno, however, demonstrate, that under particular environmental conditions, which can be interpreted as being rather unfavourable, the average size of microspheric forms can be much smaller than would be expected from the stratigraphic level.
8. A progressive development of the reticulation in megalospheric forms of the *fabianii*-group can be seen in the upper part of the Priabonian. In earlier stages of the evolution, however, similar trends were not noted. Surface structures of *N. fabianii praefabianii* from the Biarritzian of Mossano cannot be distinguished from some occurring in *N. fabianii fabianii* from the Upper Priabonian of Possagno. It is therefore not considered a reliable biostratigraphic tool.
9. The striate Nummulites of the *variolarius-incrassatus*-group furnish a good example of radiation. A small primitive form, *N. variolarius*, gives rise to the greater and more evolved *N. incrassatus ramondiformis* at the base of the Upper Eocene, but at the same time persists throughout the whole Upper Eocene. The investigation of subsequent samples from the Mossano section has shown an irregular distribution of these forms, however. It is thought, that the occurrence or predominance of one or the other form is also controlled by environment.
10. These results are considered important for biostratigraphic work and the validity of the Nummulites as index forms for the Upper Eocene can be generally confirmed. It has to be noted, however, that thorough measurement of single specimens or even of a single population may not necessarily be conclusive and only detailed investigation of series of subsequent samples will eventually give reliable results.

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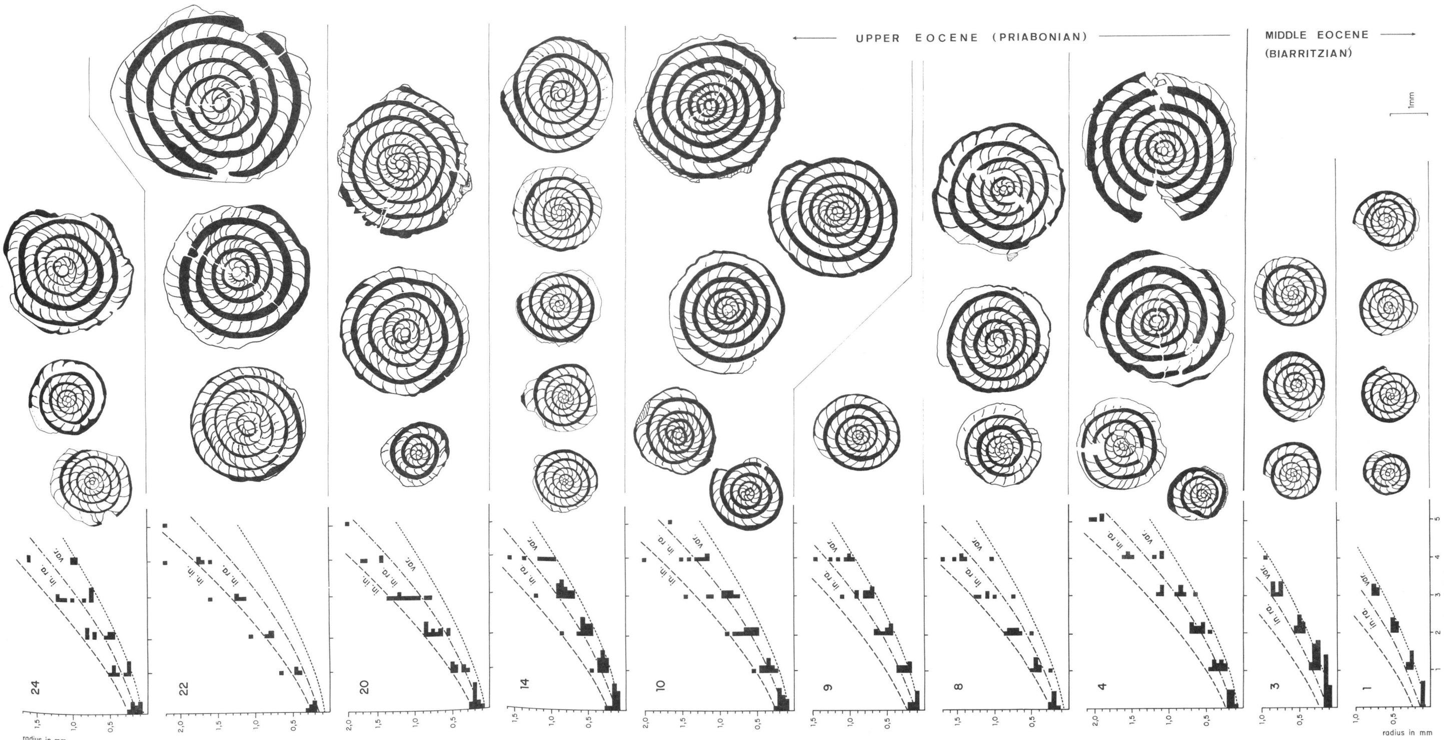

Coiling diagrams and equatorial sections of the *Nummulites variolarius-N. incrassatus* group from Mossano (Colli Berici). 10 ×