

Neanic stage biometry in *Nephrolepidina* from the Upper Oligocene of Lonedo (Lugo di Vicenza - Northern Italy)

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ABSTRACT - Two populations coming from upper Chattian outcrops near Lonedo (Lugo di Vicenza - Northern Italy), are analysed applying a new method based on the biometric analysis of the first cycles of neanic equatorial chambers, and supplying additional data about parameters and factors that had already demonstrated to be significant. The data evidence that the "Degree of stolonial distalization" (Factor FD5) and the "Shape Index" (Factor SI5), at the 5th annulus show a very slight decrease in time of their mean values, not in accordance with the stratigraphic position of the populations, however not hampering the reliability of their assignment to the same age.

The analysis of the arrangement of the equatorial chambers shows a slight decrease in time of the relative frequency of specimens with neanic equatorial chambers arranged with concentric rings. Eventually, both populations seem to have the same evolutionary degree, with a very good fitting with the previously evidenced overall trend to modify the shape of the equatorial chambers, connected with a gradually more distal position of the radial, intercytic stolons. On the contrary, a slight increase according to the "Embryonic - Nepionic Acceleration" is detected. Again, both populations can be referred to the same evolutionary stage. The specific, phylogenetic and biostratigraphic definitions could be improved by means of an integration of the embryonic-nepionic-neanic data.

RIASSUNTO - [Biometria dello stadio neanico in *Nephrolepidina* dell'Oligocene Superiore di Lonedo (Lugo di Vicenza - Italia settentrionale)] - Viene presentata una analisi biometrica del quinto "annulus" di camere equatoriali neaniche, effettuata su due popolazioni provenienti dal Chattiano superiore di Lonedo (Lugo di Vicenza - Italia settentrionale), fornendo ulteriori dati sui parametri e fattori che erano già risultati i più significativi. Il "Grado di distalizzazione degli stoloni" (Fattore FD5) e l'"Indice della Forma" (Fattore SI5), espressione della morfologia complessiva delle camere, presentano una debole diminuzione dei valori medi nella popolazione del livello superiore. L'analisi della disposizione delle camere equatoriali neaniche evidenzia una debole diminuzione nella popolazione del livello superiore della frequenza relativa di esemplari con camere disposte ad anelli concentrici, rispetto a quella della disposizione mista (archi intersecanti seguiti da anelli concentrici); la più primitiva disposizione a soli archi intersecanti è assente o molto rara. Anche l'espressione quantitativa della disposizione delle camere equatoriali presenta una debole diminuzione dei valori medi. Al contrario, le misure a livello embrio-nepionico evidenziano un aumento debole, ma statisticamente significativo, in accordo con i principi di "Accelerazione embrionica" e "Accelerazione nepionica" e con la sequenza stratigrafica delle due popolazioni.

A livello neanico, embrionale e nepionico, le due popolazioni possono essere comunque considerate appartenenti allo stesso grado evolutivo e, quindi, indicative della stessa età.

La determinazione specifica di *Nephrolepidina* nel Mediterraneo, da molto tempo basata su alcuni limiti posti nella scala dei valori medi di fattori e parametri embrio-nepionici, consente di riferire le popolazioni di Lonedo ad uno stadio evolutivo molto basso di *Nephrolepidina* tournoueri, di poco successivo a *Nephrolepidina* morgani. Le attuali definizioni specifiche, filogenetiche e biostratigrafiche sembrano migliorabili attraverso una integrazione dei dati embrionali, nepionici e neanici.

INTRODUCTION

A new biometric measurement of the neanic chambers on the equatorial layer of the *Nephrolepidina* shell gave rather encouraging first results (Schiavinotto, 1992, 1993, 1994). The characteristics measured on the neanic chambers by Schiavinotto (1992) allowed to hypothesize an evolutionary process based on a "Neanic Acceleration", with a progression of the mean values of the parameters and factors at any rate in agreement with their stratigraphic sequence.

The biometric studies of the embryonic and nepionic apparatuses, previously carried out (Matteucci & Schiavinotto, 1977; Schiavinotto, 1978, 1979; Giovagnoli & Schiavinotto, 1990; Schiavinotto & Verrubbi, 1994a, b; Giannini et al., 2007) according to the methods introduced by Van der Vlerk (1959, 1963), have evidenced: 1) phases with decrease in time of the mean values of the "Degree of enclosure" of the protoconch by the deutoconch, and of the "Number of adauxiliary chambers", 2) a frequently

impossible statistical discrimination between populations at an intermediate-high evolutionary stage (*N. morgani* - *N. tournoueri*). Consequently, these stasis appeared as a restraint to the application of *Nephrolepidina* for an extremely detailed biostratigraphy, at least at the level of the intermediate-final development of the Mediterranean *Nephrolepidina* lineage. On the contrary, the statistically significant differences that can be found between the five populations studied as yet show that the "Degree of stolonial distalization" and the "Shape Index" have an increase in time, in accordance with the stratigraphic sequence of the populations.

By these morphometric characteristics, a wide gap of mean values is evidenced between the evolutionary stage of *N. morgani* and the populations of *N. tournoueri*. The hypothesis can be put forward that within this gap it would be possible to insert a gradually increasing sequence of mean values, without the "pulsating pattern" (Drooger, 1984) characterizing the "Degree of enclosure" of the protoconch by the deutoconch (Ai) and the number

of nepionic chambers (C) in the *morgani* - *tournoueri* transition.

With this paper, a second phase of the researches at the level of the neanic chambers is started, aimed at continuing the collection of data on several populations that would represent the different evolutionary stages of *Nephrolepidina*, in order to obtain more reliable indications on the validity of the new methods in the taxonomic, phylogenetic and biostratigraphic field, with particular regard to whether the Oligocene/Miocene boundary may be identified by means of the “Neanic Acceleration” in the Mediterranean *Nephrolepidina* lineage. The populations studied here were particularly suitable for the increase of the case reports, given their free specimens in well oriented equatorial sections, coming from a defined stratigraphic position on the basis of the previous literature.

PREVIOUS WORKS

The first application of the method based on the neanic biometry (Schiavinotto, 1992), was done on two populations of *Nephrolepidina tournoueri* (Lemoine & R. Douvillé) coming from the Lower Miocene of Monte La Serra (L'Aquila, Central Apennines) (Schiavinotto, 1979) and of Ales (Sardinia) (Iaccarino et al., 1985;

Schiavinotto, 1985; Schiavinotto et al., 1985; Giovagnoli & Schiavinotto, 1990). This species is representative of the high stages of the evolutionary development of the Mediterranean lineage, based on the “Embryonic acceleration” (Van der Vlerk, 1959, 1963, 1964, 1968; Drooger & Freudenthal, 1964) and on the “Nepionic acceleration” (Tan Sin Hok, 1936a, b, 1937a, b), already widely recognized in the literature (Drooger, 1993; Drooger et al., 1976; Drooger & Laagland, 1986). These trends are characterized by stasis that seem to be a restraint to the application of *Nephrolepidina* for an extremely detailed biostratigraphy, at least at the level of the intermediate-final development of the Mediterranean *Nephrolepidina* lineage. These stasis seem to be due to trimorphism, adaptive strategies, but also to frequent excessive reworking (Schiavinotto & Verrubbi, 1994a, b; Giovagnoli & Schiavinotto, 1995; Giannini et al., 2007).

The characteristics measured on the neanic chambers by Schiavinotto (1992) allowed to hypothesize an evolutionary process based on a “Neanic Acceleration” that is effective in the discrimination between the *N. tournoueri* populations.

Schiavinotto (1993) applied the same method to the first annuli of neanic equatorial chambers in a population of *N. morgani* (Lemoine & R. Douvillé), obtained from a sample taken from an upper Chattian level in the sequence of Monte La Rocca (L'Aquila, Central Apennines)

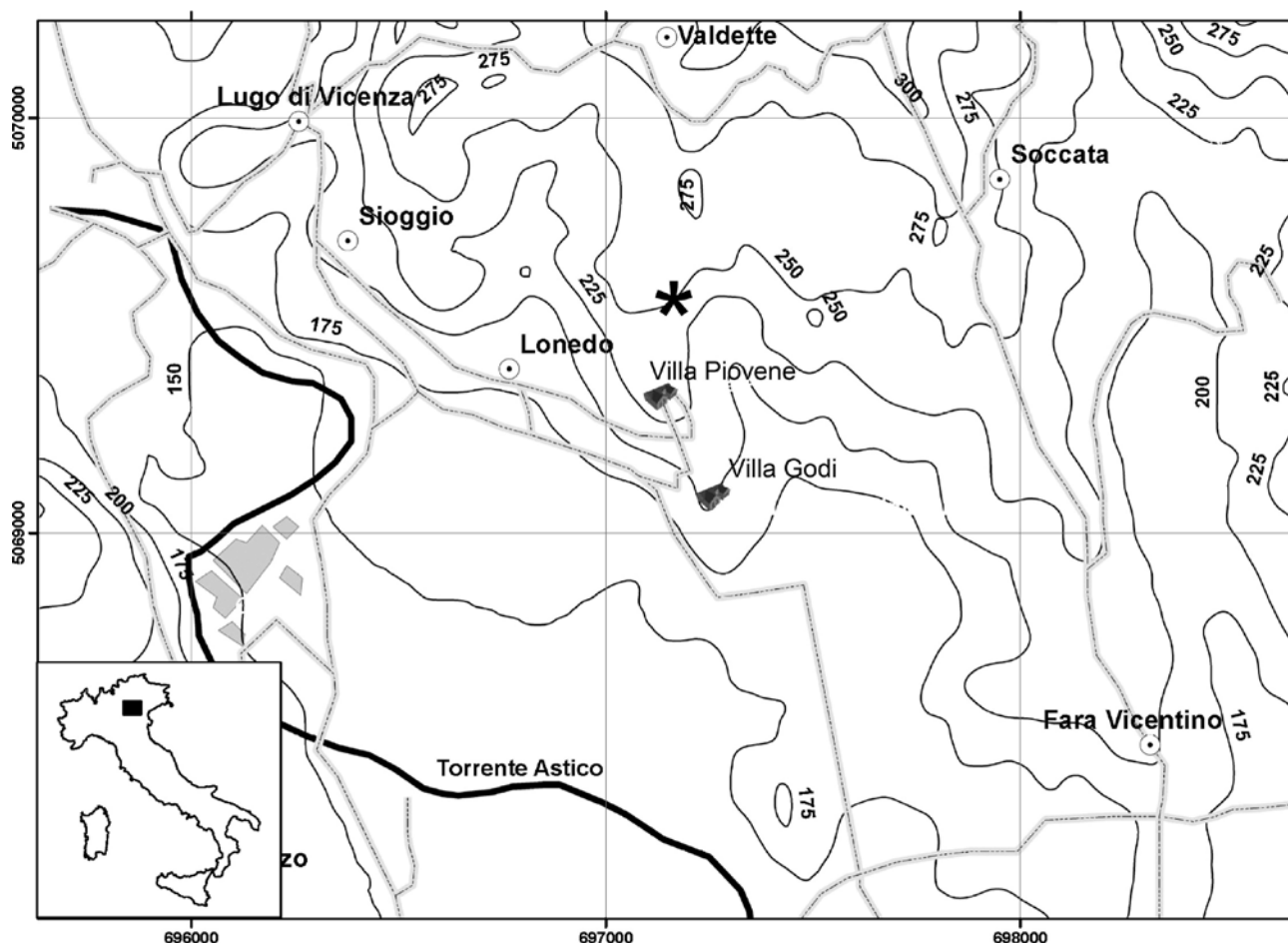


Fig. 1 - Location map of the outcrop (asterisk) (ED coordinates).

(Matteucci & Schiavinotto, 1977, 1985; Laagland, 1990). That species is representative of the intermediate stages of the evolutionary development of the Mediterranean lineage, with an embryonic-nepionic stasis that is unuseful to detect the Oligocene/Miocene boundary.

Therefore, another analysis was made to show the neanic trend (Schiavinotto, 1994) by means of a comparison between two *N. praemarginata* (R. Douvillé) populations (at the level of the early evolutionary development of the Mediterranean *Nephrolepidina*), coming from Rupelian-lower Chattian in Northern Italy (Schiavinotto, 1978) and again from Monte La Rocca, with an outcome on the possible taxonomic phylogenetic and biostratigraphic applications (Schiavinotto, 1996a). Schiavinotto (1995), in a preliminary way, detected no correlations between neanic trends and environmental variations.

MATERIAL

The material studied here consists of two samples taken from two arenaceous intercalations in the upper part of the "Calcare di Lonedo" formation (Castellarin & Gatto, 1968) outcropping near Lugo di Vicenza (Sheet 37 III SW - Thiene - of the 1:25,000 Map of Italy). For the location of the outcrop (Fig. 1) and the lithostratigraphic column (Fig. 2), references are made to Piccoli (1967, geological sheet 1:20,000, and Pl. III).

For the geological and stratigraphical setting of the Oligo-Miocene sequences in this area, references are made to Fabiani (1905, 1915), Stefanini (1915), Bosellini (1964), Piccoli (1966, 1967), Castellarin & Gatto (1968), Ungaro (1978), Antonelli et al. (1990), Bassi et al. (2007). More in detail, according to Piccoli (1967, p. 79, Pl. III), the "Calcare di Lonedo" is represented in this area by limestones with lithotamns, nummulitids and lepidocyclinids (*N. vascus* Joly & Leymerie, *Lepidocyclina dilatata* Michelotti), with some arenaceous intercalations.

In the Schio area (Sheet 36 - Schio, geological Map of Italy 1:100,000), Castellarin & Gatto (1968) indicate, as "Calcare di Lonedo", whitish limestones, sometimes coarse, nulliporic limestones with algae and corals, varying locally with calcarenites with lepidocyclinids and reef limestones (Upper Oligocene). As a local variation, the same Authors point out a continuation of the sequence consisting of arenaceous limestones and dark arenaceous marls with nummulitids, replaced or surmounted by 20 - 30 m of pale brownish calcarenites in banks and layers, with *Operculina* cfr. *complanata* Defrance, *Heterostegina* spp., *Lepidocyclina* (*Eulepidina*) spp. (Middle-Upper Oligocene; surroundings of La Becchetta, southern side of Monte Stivo, Sheet 36, Schio; IV SW of the 1:25,000 IGM Map of Italy, "Rovereto").

According to Piccoli (1967), in the studied area the "Calcare di Lonedo" is followed by the "Strati di Schio", as poorly cemented sandstones with *Lepidocyclina elephantina* (Munier-Chalmas), referred to Lower Miocene.

According to Castellarin & Gatto (1968), in the Schio area the "Calcare di Lonedo" is followed by the "Arenarie e calcari di S. Urbano" formation (Bosellini,

1964, 1967; Bosellini & Dal Cin, 1966): sandstones and grey arenaceous marls rich in *Flabellipecten*, *Clypeaster* and *Scutella*, or nulliporic limestones and grey and ash-grey sandstones with *Lepidocyclina elephantina* (Munier-Chalmas) (Lower Miocene). Near Lonedo, two *Nephrolepidina* populations have already been studied at embryonic and nepionic level: LE in Matsumaru (1971) and "Lonedo" in Van der Vlerk et al. (1973); however, the points where the samples were taken are not indicated.

Samples

Marly, arenaceous levels in the uppermost part of the "Calcare di Lonedo" can be recognised in the area, but the outcrops are discontinuous and sometimes they are hardly accessible. Despite that, it was possible to collect the samples along their vertical sequence, near the northern side of Villa Piovene (Fig. 1). Sample LND77 underlies LND88. Approximately, the vertical distance between the two samples is around 10 m (Fig. 2).

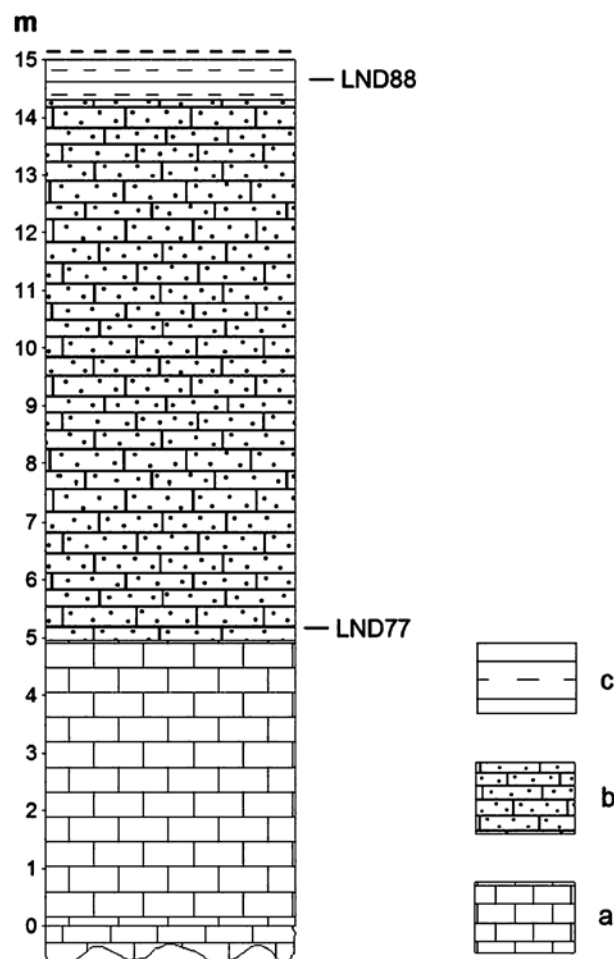


Fig. 2 - Lithostratigraphic column of the upper part of the sampled Lonedo section. The positions of the studied samples are indicated. a) Limestones with lepidocyclinids, nummulitids and lithotamns (Calcare di Lonedo, Upper Oligocene); b) Limestones with poorly cemented pale-yellow arenaceous intercalations; c) Grey arenaceous marls.

Sample	nt	% N	% OH	% E	% A
LND88	349	82.521	0.000	1.432	16.045
LND77	469	44.349	35.607	0.426	19.616

Tab. 1 - Relative frequencies of the larger Foraminifera in LND samples. Nt=total number of counted specimens; N= *Nephrolepidina*; E= *Eulepidina*; OH= Nummulitids; A= *Amphistegina*.

Lithology

LND88= grey arenaceous marls;

LND77= poorly cemented pale-yellow calcarenites.

Both layers have a thickness around 20-30 cm.

Fossil assemblages

In samples LND77 and LND88, the presence of representatives of *Nephrolepidina*, *Eulepidina*, *Operculina*, *Heterostegina* and *Amphistegina* was recognised. This faunistic association and the lithological characteristics would seem to indicate a good accordance between the sediments on the highest part of the “Lonedo Limestone” and the local variations pointed out by Castellarin & Gatto (1968) in the highest part of the outcrops in the Schio area. The relative frequencies of *Nephrolepidina*, *Eulepidina*, Nummulitids (*Operculina*, *Heterostegina*) and *Amphistegina* in washing residues of the two samples were studied; the results are shown in Tab. 1. The relative frequency can give approximate indications regarding the population density reached by the different *taxa* in the original associations, while considering the limitations and the cautions suggested by Wildenborg (1991).

In Tab. 1, it can be seen that *Nephrolepidina* undergoes a considerable variation in its relative frequency: it is the mainly dominant *taxon* in both the associations, but reaches almost a doubling of its representatives from sample LND77 to sample LND88. *Eulepidina* is always at a very subordinate level. The relative frequency of *Amphistegina* shows a slight decrease, while the representatives of the Nummulitids have a marked presence in LND77, becoming absent or very rare in LND88.

Palaeoenvironment

The palaeoenvironmental setting of the lepidocyclinids is still object of discussion (Chaproniere, 1975), since these forms have no modern counterparts. For *Nephrolepidina*, a fore-reef facies has been supposed in the Oligocene of the Salento Peninsula, Southern Italy (Bosellini & Russo, 1992). The depositional model proposed by Bosellini et al. (1987) placed the lepidocyclinids in a fore reef position, with the formation of “*Lepidocyclina* gravels” with lobes migrating along the slope; at greater depths there could be flowed specimens. Bosellini (1964) refers to an “epineritic biostromal environment”. A reference to a carbonatic platform environment with biostromal sedimentation is suggested by Bosellini & Dal Cin (1966). *Amphistegina* is a good indicator of high values of light intensity at shallow depths (Reiss & Hottinger, 1984).

The high relative frequencies of *Nephrolepidina* that are shown in Tab. 1 are quite comparable with those found

in the associations in the lower part of the Oligocene-Miocene succession of the Gran Sasso (Schiavinotto & Verrubbi, 1994a, b), referred to a productive depth corresponding to an infra-neritic environment with open circulation.

In the uppermost part of the “Calcare di Lonredo”, the environmental conditions could have had changes, going from LND77 to LND88, thus causing a variation in the relative frequencies of the *taxa* composing the two associations. In particular, the decrease of the frequency of *Amphistegina*, *Operculina* and *Heterostegina* in LND88 might suggest the hypothesis that at this level there was the deposition of an assemblage whose productive area was at greater depth than that of LND77.

Biostratigraphic setting

As mentioned above, the age assignment of the “Calcare di Lonredo” formation is Late Oligocene (Piccoli, 1967; Castellarin & Gatto, 1968). Recently, Bassi et al. (2007) studied the larger foraminiferal association in the overlain “Arenarie di S. Urbano” from some outcrops in the Venetian area (Monti Berici and Monti Lessini). The proposed age assignment of that formation is late Chattian, on the basis of the presence of *Miogypsinoides complanatus*. The biometric data obtained by Van der Vlerk et al. (1973) on *Nephrolepidina* from their sample “Lonedo”, are suggesting the presence in that area of upper levels referable to the Aquitanian.

STUDY METHODS

Biometry of the neanic equatorial chambers

The first quantitative definition of the characteristics of the neanic equatorial chambers were suggested by Schiavinotto (1992, 1993, 1994), starting from some observations reported by the literature. Eames et al. (1962, p. 294 - 298, figs. 3-5) evidenced the connection between

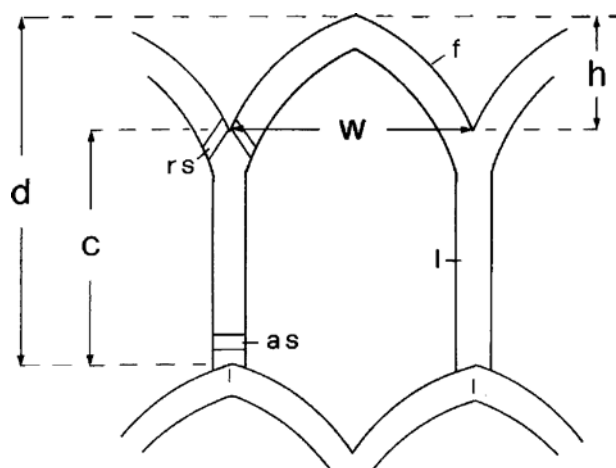


Fig. 3 - Schematic drawing of the internal features measured on the horizontally sectioned neanic equatorial chambers of *Nephrolepidina*. f= frontal wall; l= lateral (common) wall; rs= radial (intercyclic) stolons; as= annular (concylic) stolons; c= lateral length; d= protruding length; h= front height; w= front width. Lateral walls are lacking in primitive chambers (consequently: h= d) (after Schiavinotto, 1992, mod.).

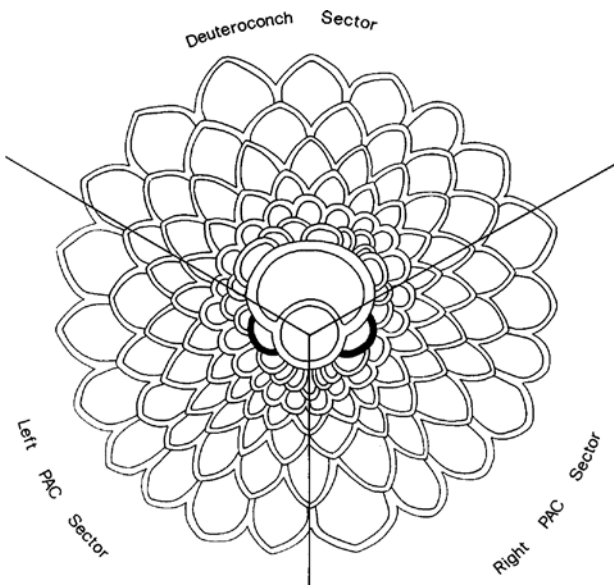


Fig. 4 - Schematic drawing of an equatorial plane of a megalosphaeric specimen of *Nephrolepidina*, subdivided in three sectors of 120°. PACs are indicated with black chamber walls (after Schiavinotto, 1992).

the sequence of morphologies of the neanic equatorial chambers and the type of stolons as seen in the median plane of *Nephrolepidina*. The shape varies from simple arcuate (not in lateral contact) and simple arcuate in lateral contact, to rhombic - ogival - exagonal.

Subsequently, Adams (1987, p. 291, 301, fig. 6) confirmed the observations of Eames et al. (1962). The arrangements of the chambers are closely connected with the extent of the lateral walls, made common between contiguous chambers of the same cycle (or "annulus"). A greater extent of these walls is connected with a more distal position of the intercycle stolons. Similar observations were done on Cretaceous Orbitoidids (Van Gorsel, 1975, 1978).

Consequently, some measurements introduced by Schiavinotto (1992, 1993, 1994) are used in this investigation (Fig. 3):

c = "lateral length" of the common walls between contiguous chambers; the case where a chamber does not have an equal extent of the two common walls with the contiguous chambers occurs frequently. Consequently, the mean value between the two measurements is considered for defining the parameter c .

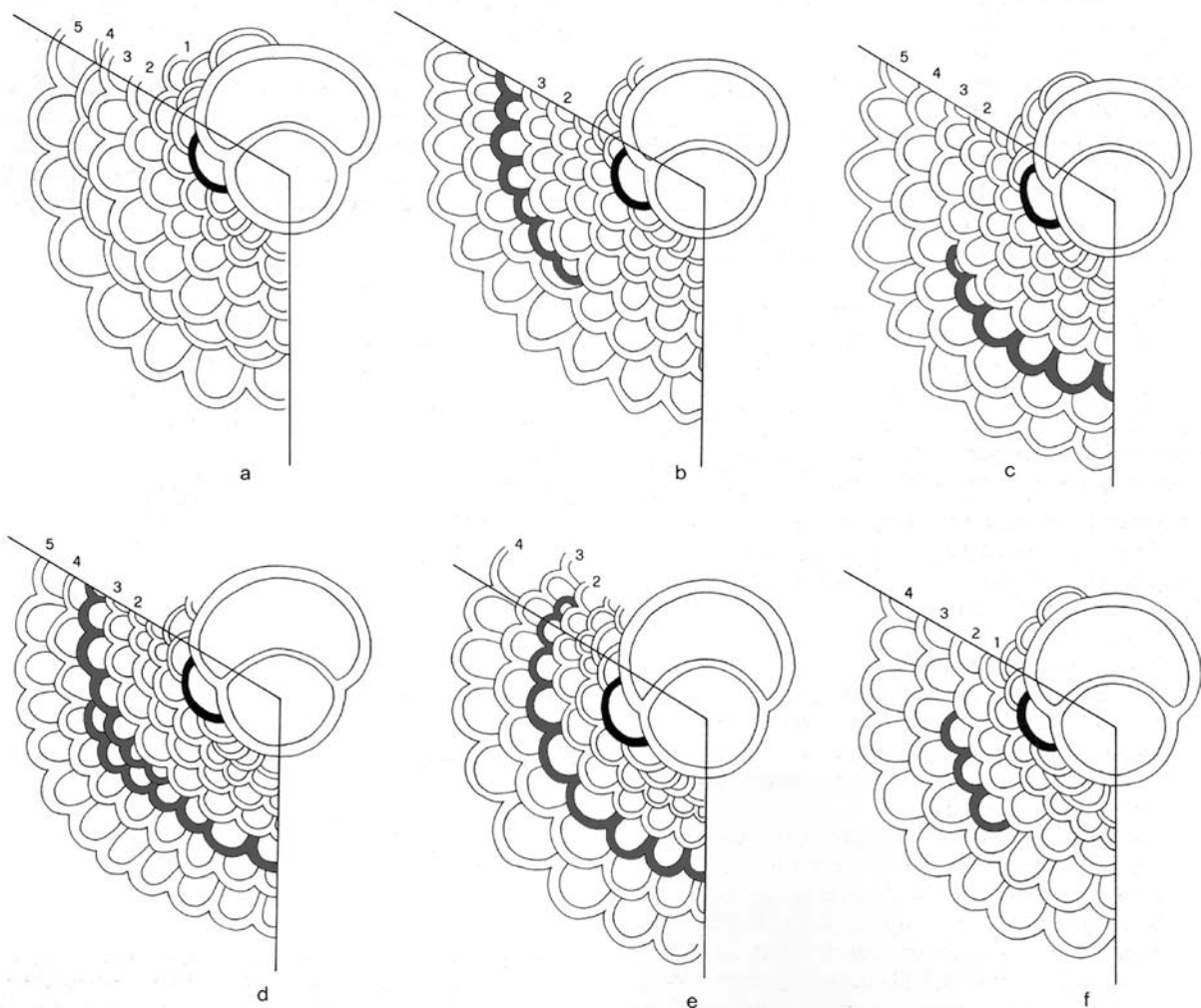


Fig. 5 - Growth anomalies that are excluded in the biometrical analysis (grey chamber walls): a) strong reduction of all chambers dimensions; b) annulus interrupted in the growth towards the protoconch sector; c) annulus interrupted in the growth towards the deuteroconch sector; d) overlap of incomplete annuli; e) annulus interrupted at the boundary of the left PAC sector; f) annulus developed exclusively between the boundaries of the left PAC sector (after Schiavinotto, 1992).

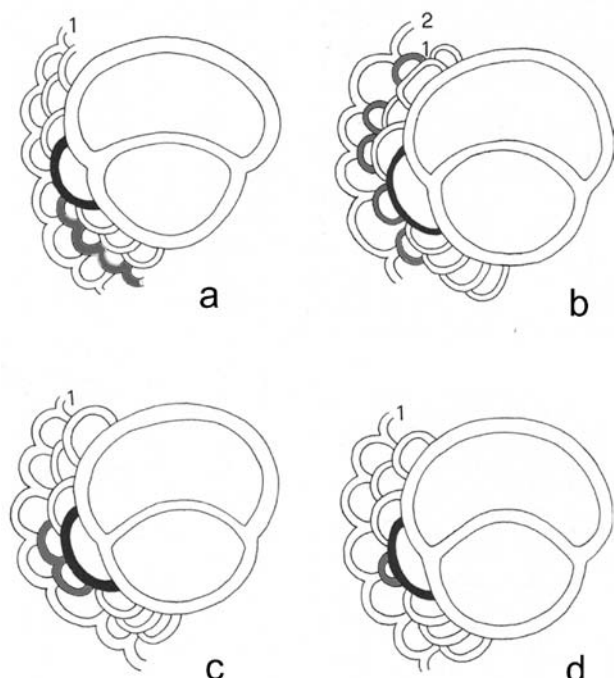


Fig. 6 - First annulus chambers arrangements: a) incomplete annulus starting from the PAC and developed around the protoconch only; b) complete annulus without common lateral walls of the chambers; c) first annulus developed around an incomplete cycle; d) first annulus starting from a single chamber developed over the PAC. Number 1 indicates the first regular annulus that is included in the 1-5 sequence (after Schiavinotto, 1992).

d = "protruding length" of the chambers, starting from the line joining the bases of the lateral walls; the front wall of the chambers is included.

h = "front height" of the chambers.

w = "front width" of the chambers, taken along the line connecting the distal ends of the common walls; w and W coincide when common walls are lacking.

$FD = c/d \times 100$ = "Degree of Stolonial Distalization"; this factor is a quantitative expression of the "degree of crowding" of the chambers of a single cycle, according to the shape-growth relations described in Eames et al. (1962, p. 295), and because of the relations between the shape of the equatorial chambers and the position of their stolon systems (Eames et al., 1962, p. 296).

$Re = h/w \times 100$ = "curvature index" of the front wall.

$SI = FD/Re \times 100$ = "Shape Index" of the chambers.

The measurements were done on drawings obtained from projections of colour slides, with an enlargement $\times 460$.

COLLECTION OF THE DATA - The data were collected taking some cautions, as suggested in the first applications of the method (Schiavinotto, 1992, 1993, 1994), in the attempt to obtain reliable measurements. However, further modifications are inserted according to the additional observations of Schiavinotto (1996a): 1) the previous analyses in Schiavinotto (1992, 1993, 1994) carried out on the sequence from the 2nd to the 7th annulus, showed that the most significant results from the taxonomic, evolutionary and biostratigraphic point of view are given by the measurements of the chambers in the 5th annulus. As suggested by the observations of Schiavinotto (1996a),

in the present analysis the measurements were taken only in the 5th annulus; 2) in the case of thin sections of well oriented equatorial planes of free specimens, the measurements were taken in a limited sector of the equatorial plane, where it is easier to find sequences of chambers that are very close to the optimal equatorial cutting; 3) in the first applications of this method, an orientation of the thin section of each specimen was therefore predetermined, as shown in Fig. 4, the equatorial plane of the test being divided into three sectors of 120° each: a right one and a left one comprising the right and left primary auxiliary chambers (PAC), as well as a north sector which includes the deuteroconch.

In the previous studies (Schiavinotto, 1992, 1993, 1994), the sector of 120° comprising the left PAC, starting from the straight line going through the centres of the embryonic chambers, was assigned randomly on each specimen, without a previous observation of the specimen. In that manner, there were cases of picking badly preserved left sectors which were excluded by the measurement. Schiavinotto (1996a) showed that the results obtainable on each sector do not have statistically significant differences. Consequently, in the present analysis, the best preserved sector, with the more regular growth of the 5th annulus, is considered as the measured sector. In rare cases of good preservation/regular growth of the 5th annulus in all sectors, one of them is picked out arbitrarily. Once the orientation of the thin section has been established, it will remain the same for any subsequent observation.

To restrict the measurements on the portions of the 5th annulus contained in a 120° sector seemed advisable also in order to make the collection of the data less time-consuming, but above all because the annuli are rarely completely developed in *Nephrolepidina*, but have growth anomalies and more than one interruption in the course of 360°.

These growth defects can greatly affect the reliability of the measurements. They are obviously points where the environmental conditions have certainly hindered the free building of the chambers, with alteration of the parameters that are most interesting for the research. Consequently, as reported in Fig. 5, the following are excluded in the biometrical analysis: a) annuli with a strong reduction of all chamber dimensions, b) annuli interrupted in their growth towards the deuteroconch sector, c) annuli interrupted in their growth towards the protoconch sector, d) overlaps of incomplete annuli, e) annuli developed exclusively between the limits of the PAC sector (see also in Schiavinotto, 1992, figs. 3a-f).

The reduction of the measurement field to the 5th annulus and to a sector limited to 120° eliminates these difficulties to a great extent: in fact, the above mentioned cases of anomaly become rare.

DEFINITION OF THE FIRST ANNULUS - It seems advisable to calculate the sequence of the annuli starting from the neanic chambers developed over the nepionic ones at the PAC-deuteroconch contact, and continuing along the limit of the PAC sector (Schiavinotto, 1992). In fact, if the calculation is started from the PAC- protoconch contact, sometimes, only the development of incomplete annuli from about the PAC and which surround the nepionic

chambers over the protoconch can be observed; these incomplete annuli fill a space difference on the equatorial plane that can be larger on this side, given the smaller dimensions of the protoconch, if compared with those of the deuteroconch (Fig. 6a). These annuli are excluded from the sequence 1-5.

The first annulus may be complete and composed of chambers not in direct contact with each other, but surrounding all the nepionic chambers: it can be included in the sequence 1-5 (Fig. 6b); the first neanic chambers can overlap either on an incomplete annulus, sometimes developed only on the PAC (Fig. 6c), or on a single chamber over the PAC (Fig. 6d): these cases are excluded from the sequence.

SIMPLIFIED DATA COLLECTION - Considering the time-consuming peculiarity of the above described methodology, a simplified data collection is tested, similarly to what is used for Discocyclinids by Less (1987), that is in only one equatorial chamber at 0.5 mm from the embryonic chambers. Picking only one representative chamber may be difficult and subjective, because the frequent irregular/asymmetric growth of the neanic equatorial chambers in *Nephrolepidina*. In the present case, the above mentioned measurements are collected in two ways, as follows:

1) in only one equatorial chamber in the 5th annulus of each specimen. The measured chamber is around at the midpoint of the annulus included in the 120° sector, displaying a more regular growth, with sub-equal lateral walls. The factors obtained with these measurements are indicated as FD5/1, Re5/1, SI5/1.

2) in three chambers of each specimen. The two chambers that are contiguous to the previous one are added. The factors obtained with these measurements are indicated as FD5/3, Res5/3, SIs5/3.

Neanic equatorial chambers arrangement

Eames et al. (1962) recognized the taxonomic value of the shape and the arrangement of the neanic equatorial chambers, exclusively at specific level. However, few biometric researches are accompanied by remarks about these characteristics (Matsumaru, 1971; Van Vesseem, 1978).

The shape of the arrangement of the equatorial chambers has assumed again a primary role in the phylogenetic and biostratigraphic definition of *Nephrolepidina* from Australia and New Zealand (Chaproniere, 1980, 1984): the phylogenetically primitive forms have equatorial chambers with an "engine-turned" pattern of intersecting curves; the phylogenetically advanced forms have equatorial chambers with a circular concentric pattern, becoming polygonally concentric and finally stellate.

A new quantitative expression of the arrangement of the equatorial chambers (Parameter F) would appear to be useful for taxonomic and biostratigraphic purposes. Chaproniere (1980, p. 168; 1984) considers the parameter F more useful than the traditional biometric parameters and factors, because the expression of the phylogenetic stage of individual specimens proves to be independent of the stage of embryonic-nepionic acceleration reached by the individual. The equatorial chambers arrangements were subdivided into five categories. A number from

F=1 to F=5 is representative of the category to which a specimen belongs.

The mean value of F expresses the evolutionary degree of a population. In this study the data were collected according to Schiavinotto (1987, figs. 1a-g) who, in a first test of the validity of this new method for the further definition of the Mediterranean lineage, modified the parameter F as follows:

Category 1 (Fm=1): for all those specimens in which the "engine turned" pattern characterizes 100% of the equatorial neanic chambers.

Category 2 (Fm=2): for those specimens in which there is both the "engine-turned" pattern and the concentric rings pattern.

Category 3 (Fm=3): for those specimens in which the concentric rings pattern characterizes 100% of the chambers in the equatorial plane of the test.

Category 4 (Fm=4): for those specimens in which the equatorial chambers are arranged in a polygonal concentric pattern.

These modifications were necessary because Mediterranean *Nephrolepidina* does not show stellate arrangements of the equatorial chambers (Chaproniere's Categories 4 and 5). Moreover, Chaproniere's categories 1 and 2 cannot be applied to both specimens with intersecting curves (or engine-turned) pattern in 100% of the equatorial plane and specimens that represent all the terms of a gradual transition to an extension of this pattern below 50% of the equatorial plane (these cases appear to be frequent in the Mediterranean material).

Embryonic-Nepionic features

The "Degree of enclosure" of the protoconch by the deuteroconch (Factor Ai of Van der Vlerk, 1959, 1963, 1964), the number of adauxiliary chambers AACII (Parameter C of Drooger & Freudenthal, 1964) and the diameters of the protoconch (DI) and the deuteroconch (DII) were measured on equatorial sections of the megalospheric specimens (Fig. 7). For a description of the biometric method and the techniques used to obtain the various measurements, reference is made to the above-mentioned papers and to De Mulder (1975).

Statistical tests

The statistical comparison between the means of the variables obtained in the LND77 and LND88 populations was done by means of the Student's t-test. The experimental values of $F=t^2$ were compared with the critical values for a number of degree of freedom d.f.=N1+N2-2 and a probability level P=95%. The normality of the distributions was checked by means of the Kolmogorov-Smirnov test (K-S), at a probability level P=95%.

BIOMETRIC DATA

Biometry of the neanic equatorial chambers

The results obtained from the measurements made on the LND77 and LND88 populations are summarized

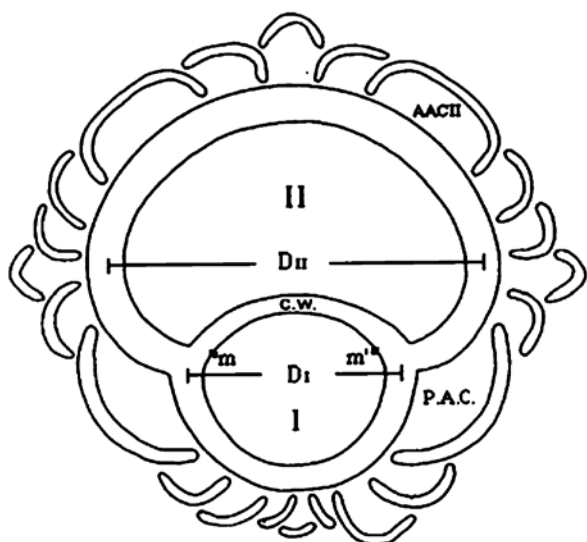


Fig. 7 - Schematic drawing of the internal features counted and measured on the horizontally sectioned embryonic-nepionic stage of megalospheric *Nephrolepidina*. I= protoconch; II= deuteroconch; PAC= principal auxiliary chamber; AACII= adauxiliary chamber (after Schiavinotto, 1987).

in Tab. 2. N is less than the total number of specimens available for the populations because of the bad state of preservation of the equatorial chambers in some specimens. The results obtained with the simplified methods are summarized in Tab. 3 and Tab. 4.

The Kolmogorov-Smirnov test (Tab. 2) evidences statistically normal distributions for all factors, at a confidence level= 95%.

In both populations the specimens with a “degree of distalization” (FD5) around 50% (Pl. 1, figs. 2-3) are predominant. Specimens with rather primitive equatorial chambers (FD5 between 15 and 25%) are very rare in LND77 (Pl. 1, figs. 1-2) and with very low frequency in LND88. Specimens with FD5 around 60% have a

good frequency, although it is subordinate, in both the populations (Pl. 1, fig. 4). In LND77, FD5 goes beyond 70%, even though in only one specimen.

Equatorial chambers arrangement

In the LND77 population Categories 2 and 3 (Pl. 2, figs. 3, 5) are equally represented (50 %); Category 1 is very rare (Pl. 2, fig. 1) in the LND77 population.

Category 2 predominates in the LND88 population (Pl. 2, figs. 2, 6), whereas Category 3 (Pl. 2, fig. 4) has a slightly lower relative frequency. Category 1 is very rare in the LND88 population.

The mean values of Fm are reported in Tab. 2. Fm is not fitting the normal distribution in both populations, with K-S test at a confidence level 95%.

Biometry of the embryo-nepionic chambers

Results of counts and measurements are reported in Tab. 5. The “nephrolepidina-type” specimens (Ai between 40 and 45%) predominate in both the populations (Pl. 3, figs. 2-4). The specimens with Ai below 40% are definitely subordinate in both the populations, with similar frequencies (Pl. 3, fig. 1). Nucleoconchs tending towards the “trybliolepidina-type”, with Ai above 50% (Pl. 3, figs. 5-6) are only in LND88.

The adauxiliary chambers are predominantly C= 4 in both the populations (Pl. 3, figs. 3-4); the specimens with C= 2 are markedly subordinate in both the populations (Pl. 3, fig. 1). Specimens with C= 6 are present only in LND88 (Pl. 3, fig. 6). According to the K-S test, C has not a normal distribution in both populations, while DI has not a normal distribution in LND88.

Comparisons between LND77 and LND88

NEANIC FEATURES - Statistically not significant differences between mean values of the LND77 and LND88 populations were found in the comparisons (Student's t test) for the Factors FD5 ($t= 0.172$), Re5 ($t= 0.139$) and

	Variable	N	nc	Range	M	S	Sm	CV	K-S	K-S c.v.
LND88		86								
	FD5	86	981	16.15 - 64.09	46.58	9.84	1.06	0.211	0.080	0.145
	Re5	86	981	26.25 - 48.81	36.69	4.81	0.51	0.131	0.077	0.145
	SI5	86	981	44.72 - 222.26	135.30	37.38	4.03	0.276	0.054	0.145
	Fm	100		1 - 3	2.20	0.58	0.05	0.260	0.348	0.134
LND77		46								
	FD5	46	536	27.33 - 71.44	46.88	8.81	1.29	0.186	0.070	0.196
	Re5	46	536	27.55 - 47.27	36.57	4.50	0.66	0.123	0.099	0.196
	SI5	46	536	70.90 - 261.14	138.31	38.15	5.62	0.275	0.126	0.196
	Fm	52		1 - 3	2.30	0.56	0.07	0.248	0.357	0.185

Tab. 2 - Results of measurements on neanic equatorial chambers (5th annulus) in *Nephrolepidina* from Lonardo. N= number of measured specimens; nc= total number of measured chambers; R= Range of the individual mean values; M= Mean value; S= Standard deviation; Sm= Standard error of the mean; CV= Coefficient of variation; K-S= Kolmogorov-Smirnov test; K-Scv= Kolmogorov-Smirnov critical value (95%).

	Variable	N	nc	Range	M	S	Sm	CV	K-S	K-S c.v.
LND88										
	FD5/1	86	86	7.69 - 75.00	48.42	12.84	1.38	0.265	0.124	0.145
	Re5/1	86	86	23.07 - 53.33	37.03	6.97	0.75	0.188	0.098	0.145
	SI5/1	86	86	21.79 - 315.77	138.06	53.19	5.73	0.385	0.075	0.145
LND77										
	FD5/1	46	46	22.91 - 75.92	47.74	11.13	1.64	0.233	0.095	0.196
	Re5/1	46	46	25.00 - 55.17	37.63	6.62	0.97	0.176	0.112	0.196
	SI5/1	46	46	54.32 - 290.65	132.22	44.82	6.60	0.339	0.104	0.196

Tab. 3 - Results of measurements on neanic equatorial chambers (5th annulus) in *Nephrolepidina* from Lonedo. One measured chamber in each specimen. Symbols as in Tab. 2.

SI5 ($t = 0.437$), and the parameter Fm ($t = 1.020$). The same results are obtained comparing the two populations on the basis of the data that have been collected reducing the number of measured chambers (Tabs. 3-4). This is useful and encouraging further researches especially on material in thin sections of hard rocks, that contains frequent specimens with incomplete preservation of 120° sectors (Schiavinotto, pers. obs.). However, many cautions are suggested in following the non time-consuming procedures, because the values of the coefficient of variation (CV) in Tabs. 3 and 4 are higher than those in Tab. 2 (higher dispersion of the data). Consequently, especially in Tab. 3 (one measured chamber), a splitting the populations in small groups gives mean values that have frequent high differences with the “true mean values”.

EMBRYO-NEPIONIC FEATURES - By comparing LND77 and LND88, significant differences between the mean values of Factors Ai ($t = 2.631$) and the mean values of parameters C ($t = 1.969$), DI ($t = 2.401$) and DII ($t = 4.717$) have been recorded.

EVOLUTIONARY STAGE

Compared material

- CVM76 population (N= 66 equatorial thin sections of free megalospheric specimens; N= 51 for neanic chambers) - Taken from a level in the Oligocene section outcropping at Carzano, in Valle del Maso (Borgo Valsugana, Northern Italy, Sheet 22, III SW of the 1:25,000 IGM Map of Italy “Borgo Valsugana”). The section is described in Venzo (1934) and in Schiavinotto (1978); the geological and stratigraphic setting is reported in Fabiani (1915, 1922), Venzo (1934) and Braga et al. (1971). Embryo-nepionic data have been obtained by Schiavinotto (1978); neanic data have been obtained by Schiavinotto (1994). Age: late Rupelian.

- TRMn and T1 populations (N= 49 and N= 160 equatorial thin sections of free megalospheric specimens, respectively; N= 44 and N= 138 for neanic chambers) - Taken from two successive levels of the Oligocene section outcropping at Tornimparte (Monte La Rocca, L'Aquila, Central Apennines; Sheet 145, I NW of the 1:25,000 IGM Map of Italy “Tornimparte”). The section is described

	Variable	N	nc	Range	M	S	Sm	CV	K-S	K-S c.v.
LND88										
	FD5/3	86	258	4.94 - 71.23	48.00	11.97	1.29	0.249	0.109	0.145
	Re5/3	86	258	26.54 - 49.59	36.49	5.66	0.61	0.155	0.083	0.145
	SI5/3	86	258	13.01 - 271.58	140.30	48.72	5.25	0.347	0.056	0.145
LND77										
	FD5/3	46	138	25.27 - 72.67	47.41	9.99	1.47	0.210	0.112	0.196
	Re5/3	46	138	25.80 - 54.51	37.44	5.90	0.87	0.157	0.081	0.196
	SI5/3	46	138	64.88 - 271.57	135.69	45.11	6.65	0.332	0.117	0.196

Tab. 4 - Results of measurements on neanic equatorial chambers (5th annulus) in *Nephrolepidina* from Lonedo. Three measured chambers in each specimen. Symbols as in Tab. 2.

	Variable	N	Range	M	S	Sm	K-S	K-S c.v.
LND88	Ai	100	33.50 - 54.37	43.95	3.72	0.37	0.094	0.134
	C	92	2 - 6	3.90	0.91	0.09	0.233	0.140
	DI	100	204 - 466	285.10	39.28	3.92	0.140	0.134
	DII	100	318 - 648	424.40	56.31	5.63	0.101	0.134
LND77	Ai	52	32.84 - 47.51	42.37	3.07	0.42	0.091	0.185
	C	51	2 - 5	3.60	0.80	0.11	0.256	0.186
	DI	52	193 - 386	269.20	37.62	5.21	0.075	0.185
	DII	52	301 - 522	381.60	46.11	6.39	0.066	0.185

Tab. 5 - Results of counts and measurements on embryo-nepionic chambers of *Nephrolepidina* from Lonedo. N= number of measured specimens; M= Mean value; S= Standard deviation; Sm= Standard error of the mean; K-S= Kolmogorov-Smirnov test; K-S c.v. = Kolmogorov-Smirnov critical value (95%).

in Matteucci & Schiavinotto (1977); the geological and stratigraphical setting is reported in Renz (1936, 1951), Baumann (1970), Parotto & Pratlun (1975), Accordi et al. (1988). These are the type levels of the two species of Mediterranean *Cycloclypeus* lineage (Matteucci & Schiavinotto, 1985). Embryo-nepionic data have been obtained by Matteucci & Schiavinotto (1977); neanic data have been obtained by Schiavinotto (1993, 1994). Age: early Chattian and middle-late Chattian, respectively.

- TLS76 population (N=62 equatorial thin sections of free megalospheric specimens; N=48 for neanic chambers) - Taken from the Oligocene-Miocene section outcropping on Monte La Serra, again in Tornimparte locality. Geological and stratigraphical setting as TRMn and T1. Embryo-nepionic data have been obtained by Schiavinotto (1979); neanic data have been obtained by Schiavinotto (1992). Age: early Burdigalian.

- AC5 population (N=65 equatorial thin sections of free megalospheric specimens; N=50 for neanic chambers) - Taken from the upper part of the Miocene section outcropping near the village of Ales (Marmilla area, central-southern Sardinia; Sheet 539, IV NW of the 1:25,000 IGM Map of Italy "Ales"). Geological and stratigraphical setting in Boccaletti & Guazzone (1974), Cherchi & Montadert (1982a, b), Iaccarino et al. (1985),

Variable	Populations	N	nc	Range	M	S	Sm
FD5	AC5	50	438	37.95 - 74.38	61.42	6.92	0.98
	TLS66	48	417	20.03 - 72.54	57.69	10.87	1.56
	T1	138	1514	0.00 - 64.45	43.02	12.57	1.07
	TRMn	44	405	10.87 - 57.10	33.78	11.72	1.76
	CVM76	51	432	2.16 - 49.45	27.34	11.87	1.66
SI5	AC5	50	438	92.48 - 288.90	192.77	44.02	6.22
	TLS66	48	417	41.07 - 278.42	173.94	46.27	6.67
	T1	138	1514	0.00 - 213.34	119.28	40.78	3.47
	TRMn	44	405	34.06 - 197.97	95.31	41.04	6.18
	CVM76	51	432	4.47 - 149.61	70.55	34.62	4.84

Tab. 6 - Summarized results of measurements on neanic equatorial chambers (5th annulus), obtained from previously studied *Nephrolepidina* populations (after Schiavinotto, 1992, 1993, 1994).

Schiavinotto et al. (1985). Embryo-nepionic data have been obtained by Giovagnoli & Schiavinotto (1990); neanic data have been obtained by Schiavinotto (1992). Age: middle-late Burdigalian.

The neanic data on the above mentioned populations are summarized in Tab. 6.

Neanic acceleration

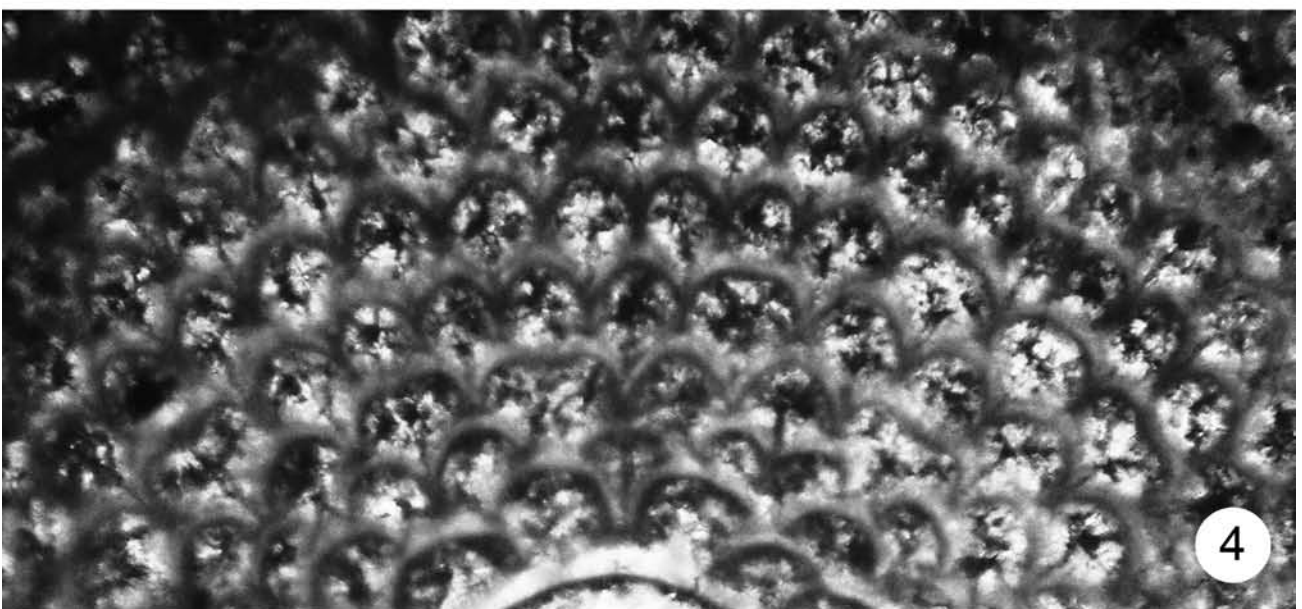
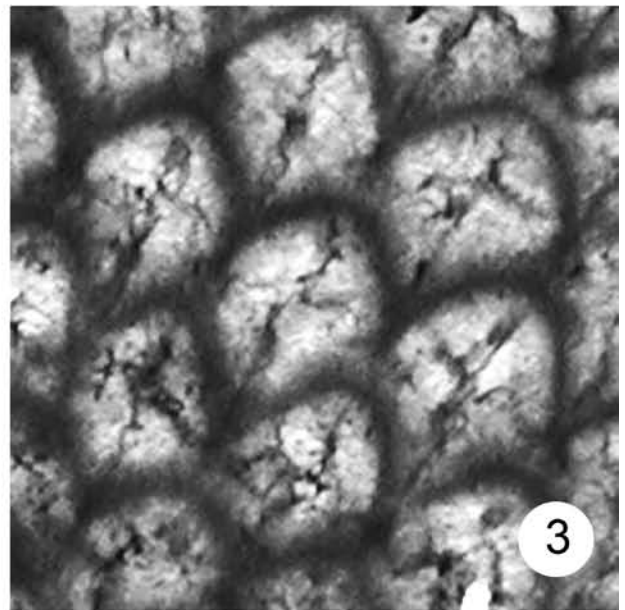
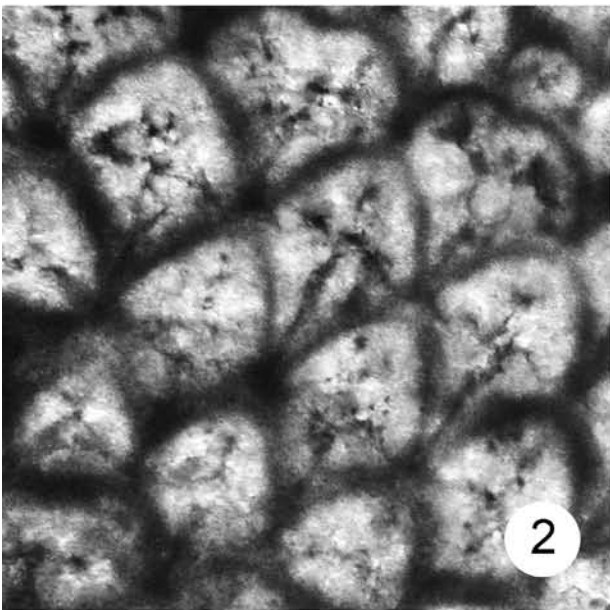
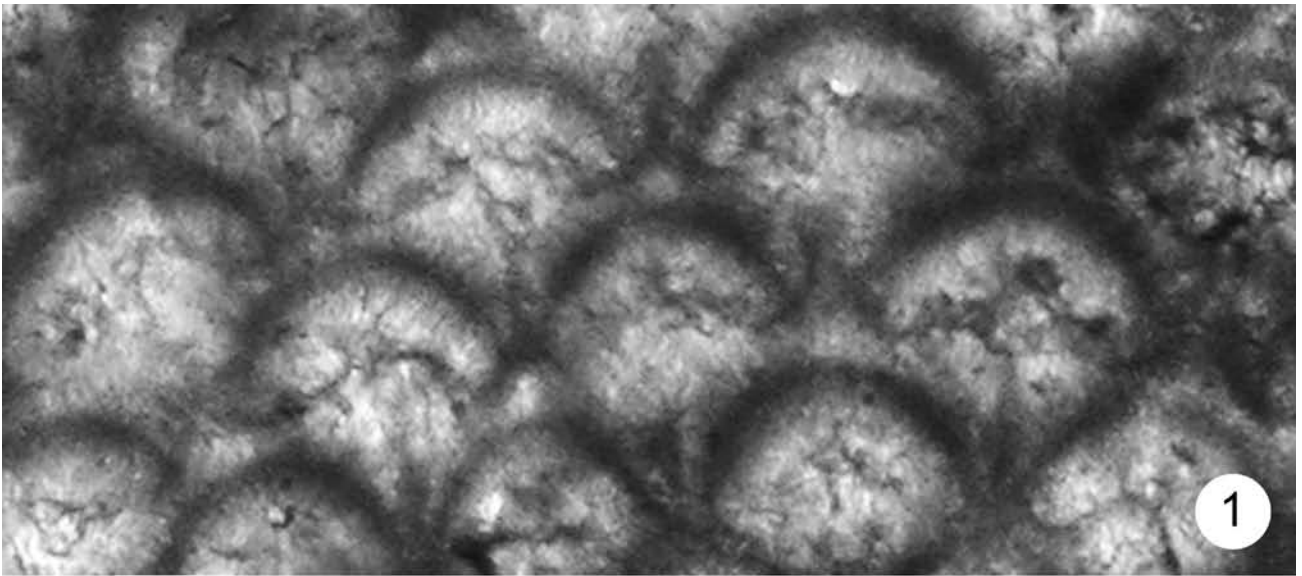
The scatter diagram FD5 - SI5 in Fig. 8 might be a significant representation of the trend that is defined as "Neanic Acceleration". The data of LND77 and LND88 are plotted keeping the high correlation between the mean values of the two variables. Even though LND77 and LND88 are in a sequence that is not in agreement with their stratigraphic position, there is a minimum distance (confirmed statistically) between them.

Although there is a very slight, statistically not significant decrease of the neanic mean values, going from LND77 to LND88, the data may be referred to two coeval populations at the same evolutionary degree. It is also of particular interest that the mean values of FD5 and SI5 of LND77 and LND88 are closer to the mean values regarding the T1 population, still showing a wide gap of values between the Lonedo populations and the TLS 76, AC5 populations.

Very significant statistic differences have been recorded in the comparisons of the neanic mean values with all the populations studied previously; only in the comparison with the population T1 significant differences

EXPLANATION OF PLATE 1

- Fig. 1 - First annuli of primitive neanic equatorial chambers. The whole shape is arcuate, with low values of Factors FD and SI. Specimen LND77-27, x 600.
- Fig. 2 - First annuli of intermediate neanic chambers. The whole shape is ogival, with intermediate values of Factors FD and SI. Specimen LND77-37, x 300.
- Fig. 3 - First annuli of advanced neanic chambers. The whole shape is sub-exagonal, with high values of Factors FD and SI. Specimen LND88-48, x 300.
- Fig. 4 - First annuli of advanced neanic chambers. The whole shape is sub-exagonal, with low degree of curvature of the front wall. Higher values of Factors FD and SI. Specimen LND88-62, x 150.



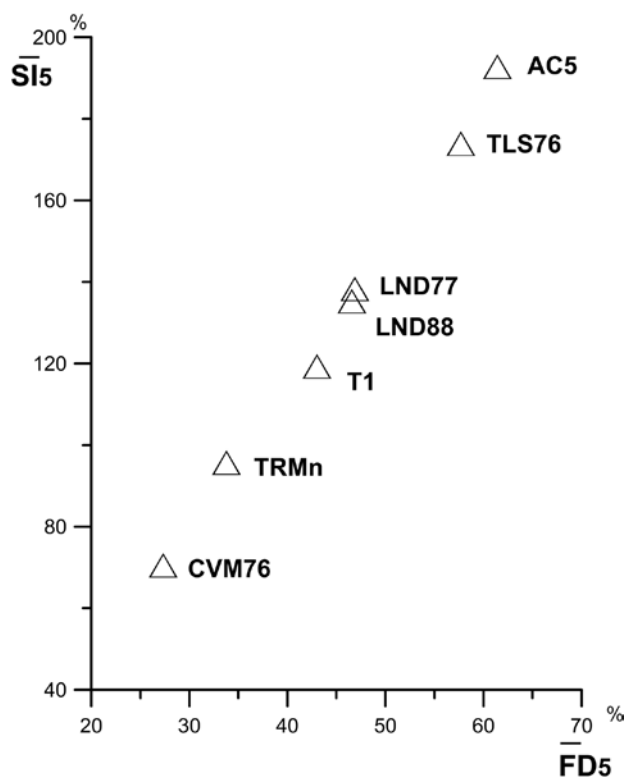


Fig. 8 - $\bar{F}D5$ - $\bar{S}I5$ scatter diagram for the *Nephrolepidina* populations studied to date. Mean values after Schiavinotto (1992, 1993, 1994).

were not recorded for the Ea5 mean values, both of LND77 and LND88. These results evidence that the LND77 and LND88 *Nephrolepidina* populations can be differentiated both from the more primitive and from the more evolved stages of *Nephrolepidina*, at the level of the ontogenetic stage studied (5th annulus), on the basis of the “Degree of Stolonial Distalization” and of the “Shape Index”.

That discrimination is much more marked than those obtained between populations of *N. tournoueri*, as reported by Schiavinotto (1992), and between populations of *N. praemarginata*, as reported by Schiavinotto (1994).

Therefore, the variations of the parameters/factors, as a whole, are evidence of the following tendencies in the changes of the morphology of neanic equatorial chambers in *Nephrolepidina*:

- increase of the degree of elongation;
- increase of the lateral length “c” of the common wall between contiguous chambers;
- consequent increase of the “Degree of Stolonial Distalization”;
- increase of the “Shape Index”, tending to more elongated chambers with smaller degree of curvature of the frontal wall.

So, the data obtained on the “Degree of Stolonial Distalization” in *Nephrolepidina* from Lonedo provide another clear quantitative definition of the ontogenetic development already described qualitatively by Grimsdale (1959), Eames et al. (1962), Sirotti (1982a, b) and Adams (1987) for *Nephrolepidina*, and by Van Gorsel (1975, 1978) for *Orbitoides* and *Lepidorbitoides*. In fact, the

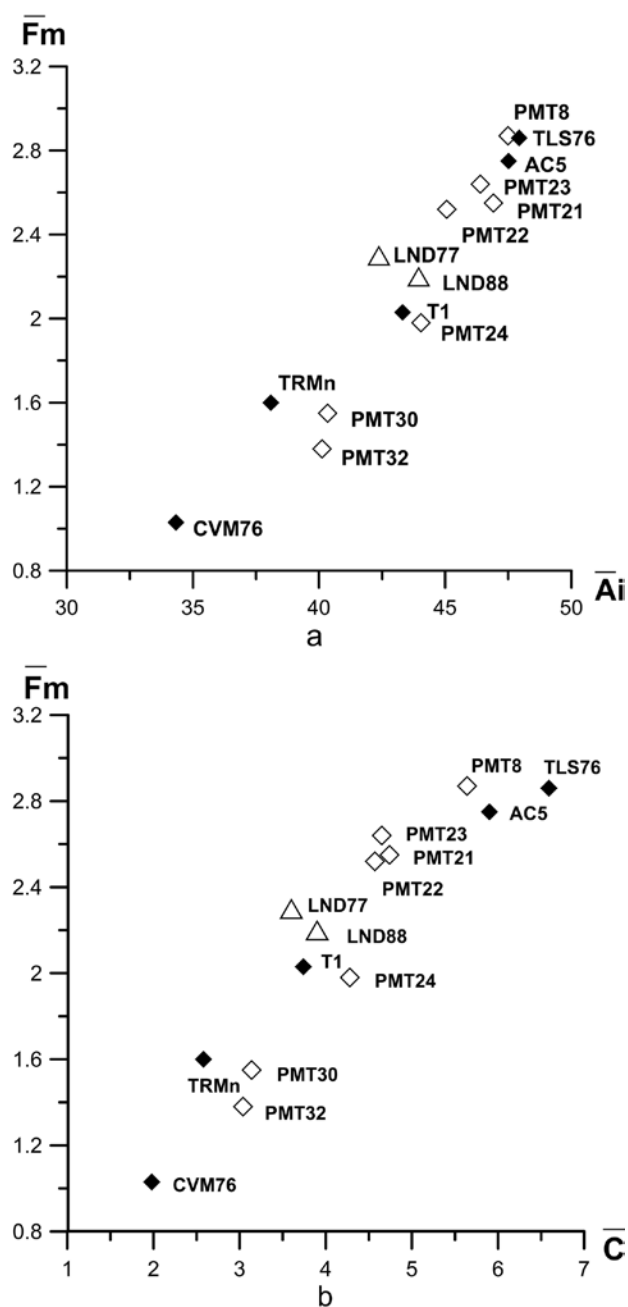


Fig. 9 - a) $\bar{A}i$ - $\bar{F}m$ scatter diagram; b) $\bar{C}$ - $\bar{F}m$ scatter diagram.

distal end of the common wall between contiguous chambers fits with the position of the radial (intercyclic) stolons; the more this wall is developed, the greater also is the distancing of the annular (conccyclic) stolons from the proximal end of the common walls (Eames et al., 1962; Adams, 1987). The Factor SI5 confirms the progressive weakening of the initially pointed-arcuated characteristic of the front wall, which can be connected with a more distal position and a less radial trend of the intercyclic radial stolons; consequently, the morphological differences between chambers of successive annuli are emphasized.

Modification of the neanic equatorial chambers arrangement

The mean values of $\bar{F}_m$ in LND77 and LND88 have statistically significant differences in almost all the comparisons with the populations studied previously. Some higher populations of the sequence of M. Torretta (Giovagnoli & Schiavinotto, 1995) are an exception (PMT22 and PMT21, when compared with LND88, and PMT23, PMT22 and PMT21, when compared with LND77), in a range of values between $\bar{F}_m=2.52-2.64$.

This is evident also inserting the values of LND77 and LND88 in the $\bar{A}_i - \bar{F}_m$ and $\bar{C} - \bar{F}_m$ scatter diagrams in Fig. 9, with the data obtained from the populations studied by Schiavinotto (1987) and Giovagnoli & Schiavinotto (1990). The following indications are obtained:

1) According to $\bar{F}_m$, LND77 and LND88 are not in accordance with the trend towards increasing values: however, they have the same stratigraphic position.

2) The deviation from the trend is much more important at more advanced evolutionary levels, with a withdrawal of the mean values of all the embryo-nepionic parameters/factors and of $\bar{F}_m$.

3) The $\bar{F}_m$ values of LND77 and LND88 allow to discriminate a group of populations at an intermediate evolutionary level; however, $\bar{A}_i$ and $\bar{C}$ are also effectual in this distinction, both in the graph and on the basis of the statistical comparisons.

Embryo-Nepionic Trends

From Tab. 5, the means of all the embryo-nepionic parameters and factors follow the expected trends according to the principle of the “embryonic acceleration” (Drooger & Freudenthal, 1964) and of the “nepionic acceleration” (Tan Sin Hok, 1936a, b, 1937a, b). In particular, $\bar{A}_i$ and $\bar{C}$, the features that as yet have been considered the most significant from the taxonomic, phylogenetic and stratigraphic viewpoint, have a statistically significant increase, going from LND77 population to the stratigraphically higher LND88 population.

An extensive comparison with most of the data concerning the populations of *Nephrolepidina* in the literature is allowed by inserting the data of LND77 and LND88 in the $\bar{A}_i - \bar{C}$ scatter diagram in Fig. 10. Both

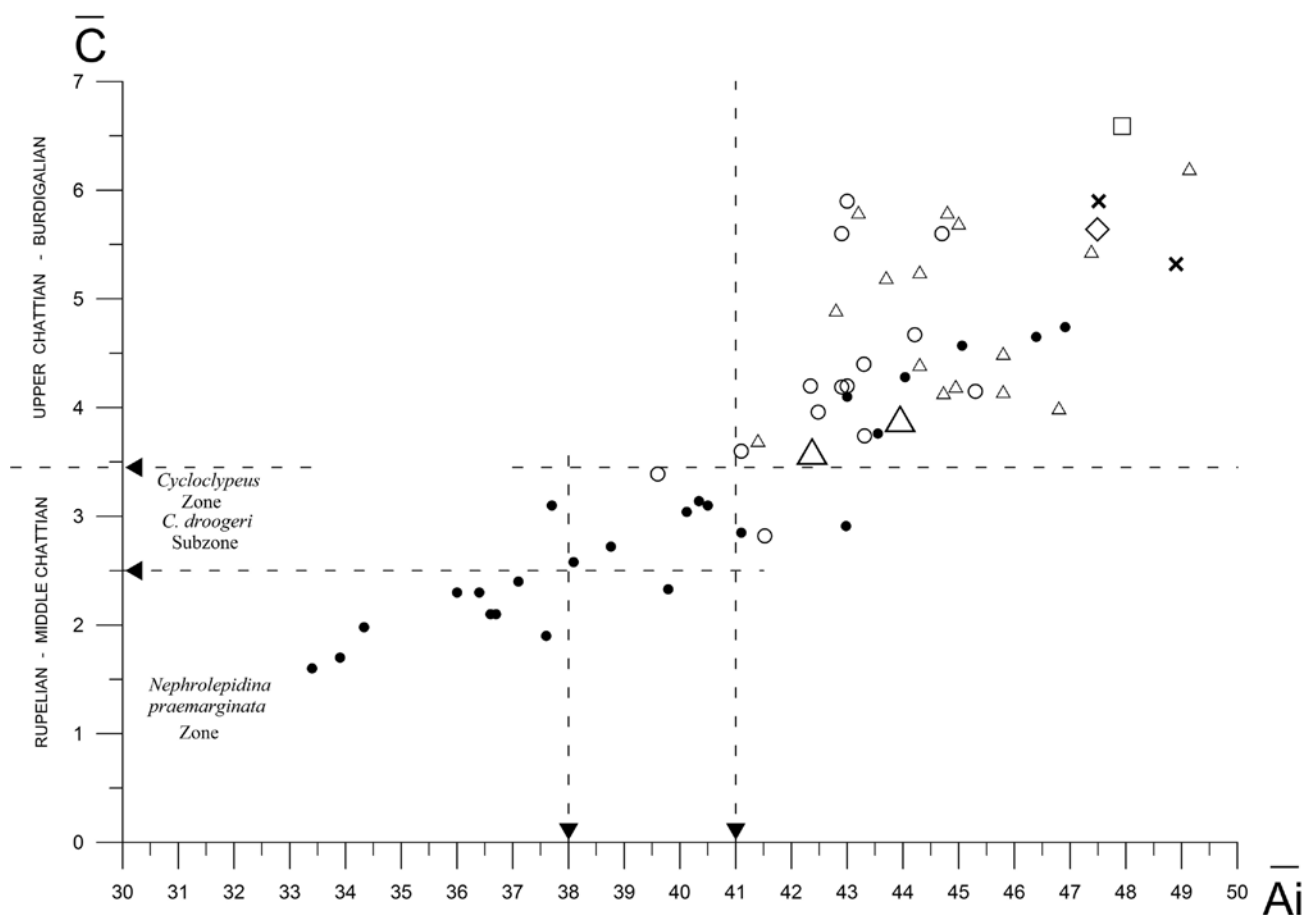


Fig. 10 - $\bar{A}_i - \bar{C}$ scatter diagram for a significant part of the available data on the Mediterranean *Nephrolepidina* populations (Pieroni, 1965; Serpagli & Sirotti, 1966, 1967; Matsumaru, 1971; Meulenkamp & Amato, 1972; De Mulder, 1975; Matteucci & Schiavinotto, 1977; Schiavinotto, 1978, 1979; Drooger & Laagland, 1986; Giovagnoli & Schiavinotto, 1990, 1995; Wildenborg, 1991; Schiavinotto & Verrubbi, 1994b; Giannini et al., 2007; Schiavinotto, present paper). • = absence of *Miogypsina* s.l. (Middle-Upper Oligocene); o = association with *Miogypsina* (*Miogypsina*) *complanatus-formosensis* and/or *M. (Miogypsina) basraensis*; Δ = association with *M. (Miogypsina) bantamensis* - *M. (M.) gunteri*; ◇ = association with *M. (M.) tani*; □ = association with *M. (M.) globulina*; X = association with *M. (M.) intermedia*; Δ = LND populations (this paper).

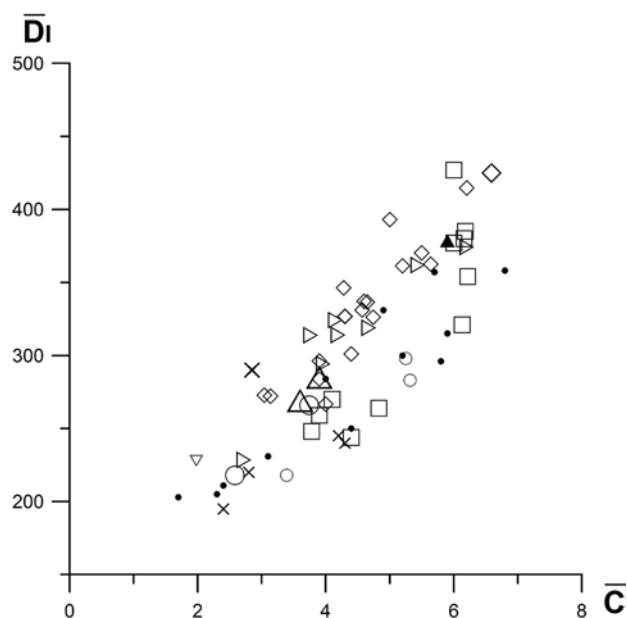


Fig. 11 - $\bar{C}$ - $\bar{D}_I$ scatter diagram with mean values from the literature. •) De Mulder (1975); $\diamond$) PMT - Giannini et al. (2007); $\circ$) T1, TRMn - Matteucci & Schiavinotto (1977); ∇) CVM76 - Schiavinotto (1978); $\diamond$) TLS76 - Schiavinotto (1987); $\square$) Drooger & Freudenthal (1964); $\blacktriangle$) AC5 - Giovagnoli & Schiavinotto (1990); X) Mollere - Meulenkamp & Amato (1972); $\circ$) Wildenborg (1991); x) Vervloet (1966); $\triangleright$) Gran Sasso - Schiavinotto & Verrubbi (1994a, b); $\triangle$) LND (this paper).

populations can be plotted in the field of intermediate values at an intermediate stage of the embryo-nepionic evolutionary development. In this field, many statistic comparisons with the populations already studied in the literature are possible without significant differences.

Embryo-size

The mean values of the absolute dimensions of the embryonic apparatus also have a statistically significant increase, and they are among the lowest mean values of those relating to the same embryo-nepionic evolutionary degree. The insertion of the LND77 and LND88 data in the $\bar{C}$ - $\bar{D}_I$ and $\bar{D}_I$ - $\bar{D}_{II}$ scatter diagrams (Fig. 11 and Fig.

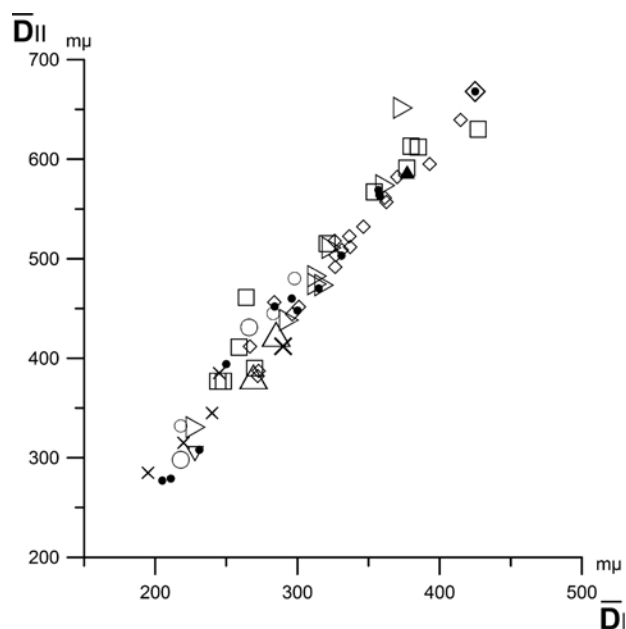


Fig. 12 - $\bar{D}_I$ - $\bar{D}_{II}$ scatter diagram with mean values from the literature. Symbols as in Fig. 11.

12) (see also De Mulder, 1975, p. 118, fig. 45; Van Heck & Drooger, 1984, p. 315, fig. 12) gives an immediate comparison with the embryo sizes of a great part of the Mediterranean material.

Combined Trends

In the $\bar{A}_i$ - $\bar{D}_5$ and $\bar{C}$ - $\bar{D}_5$ scatter diagrams in Fig. 13 and Fig. 14, it is evidenced that LND77 and LND88 populations are in tune with the previously detected trends towards higher values. The intermediate position of LND77 and LND88 is confirmed.

TAXONOMY

According to the phylogenetic classification of Lepidocyclinidae proposed by Sirotti (1982a, b),

EXPLANATION OF PLATE 2

Variability of the neanic chambers arrangement in equatorial sections of *Nephrolepidina* from Lonedo. Samples LND77 and LND88.

Fig. 1 - Category 1, with intersecting curves ("engine turned") pattern. Specimen LND77-43, x 25.

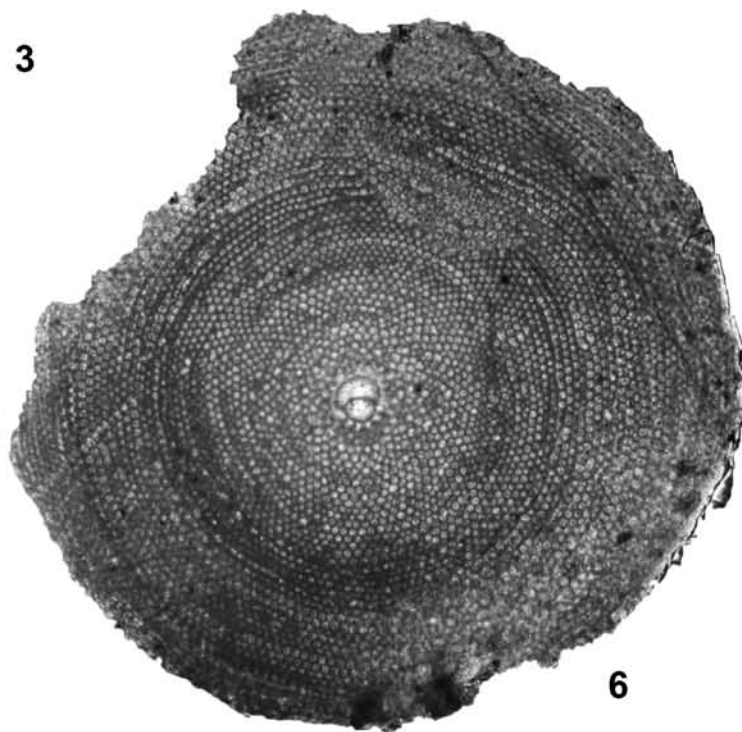
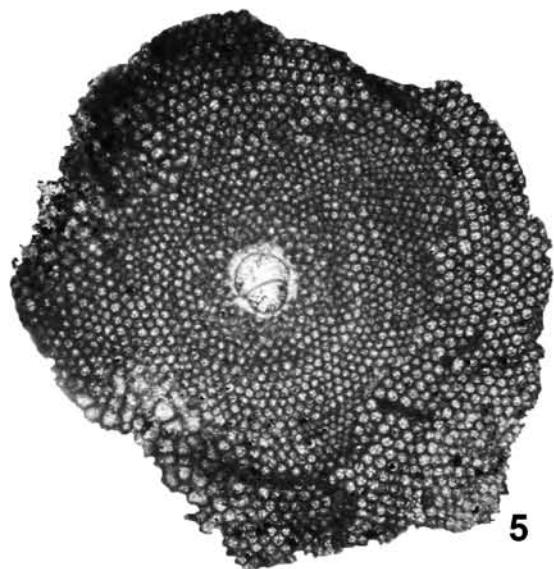
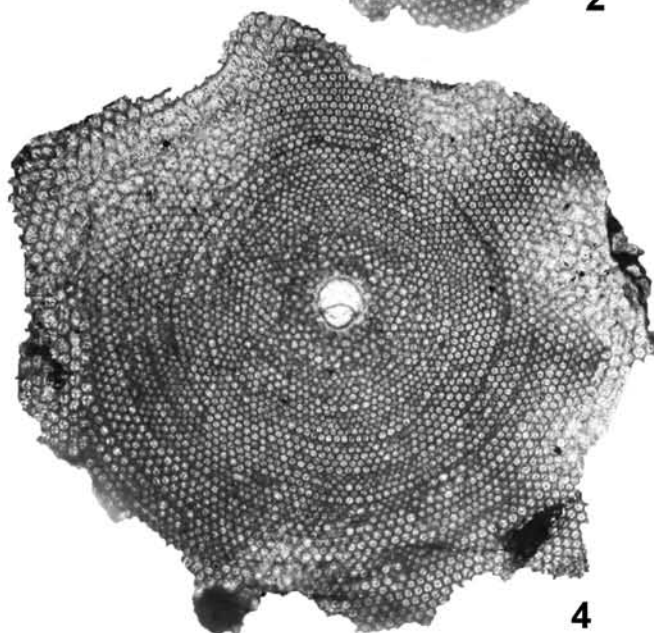
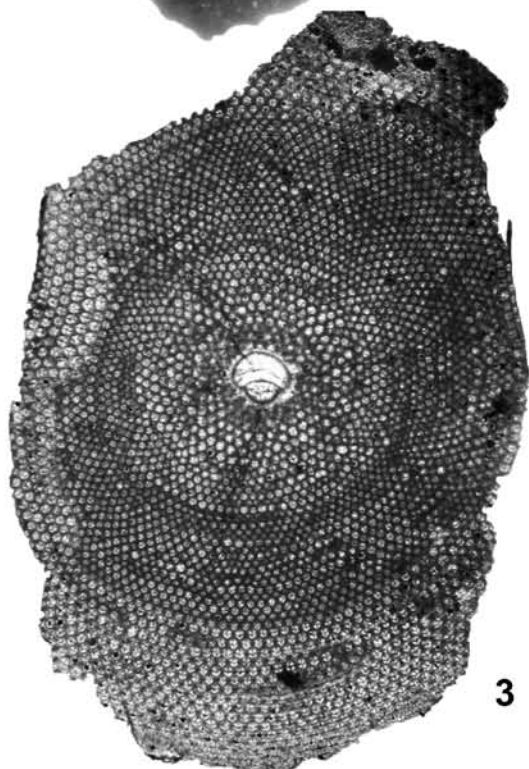
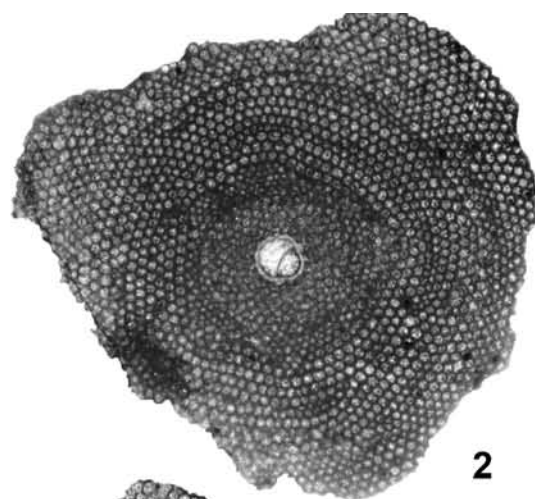
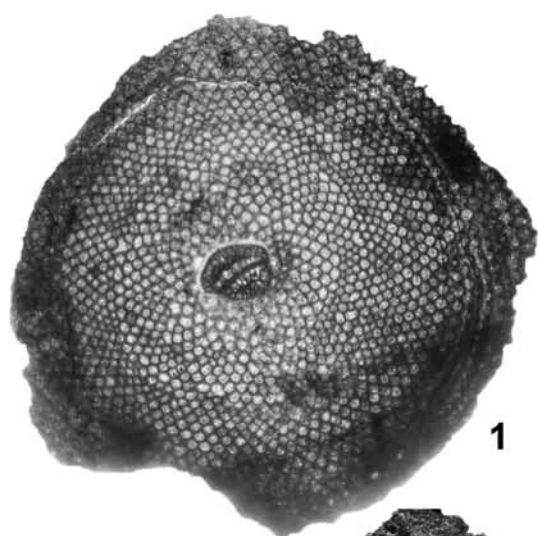
Fig. 2 - Category 2, with annular pattern mixed with intersecting curves in the whole equatorial layer. Specimen LND88-8, x 15.

Fig. 3 - Category 3, with annular, concentric pattern. Specimen LND77-46, x 15.

Fig. 4 - Category 3, with annular, concentric pattern mixed with intersecting curves. Specimen LND88-37, x 15.

Fig. 5 - Category 3, with annular, concentric pattern. Specimen LND77-48, x 25.

Fig. 6 - Category 2, with a wide area of intersecting curves. Specimen LND88-50, x 15.



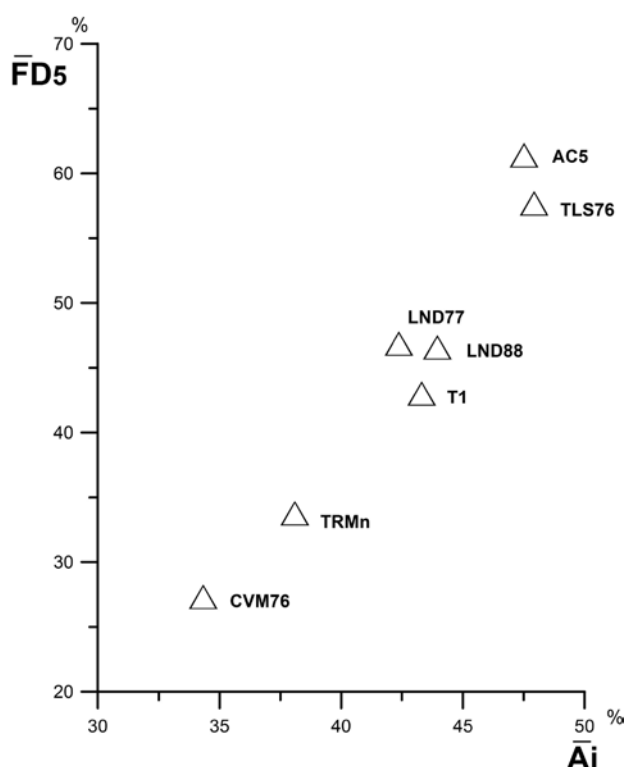


Fig. 13 - $\bar{A}i$ - $\bar{FD}5$ scatter diagram for the *Nephrolepidina* populations studied to date. Mean values after Schiavinotto (1992, 1993, 1994).

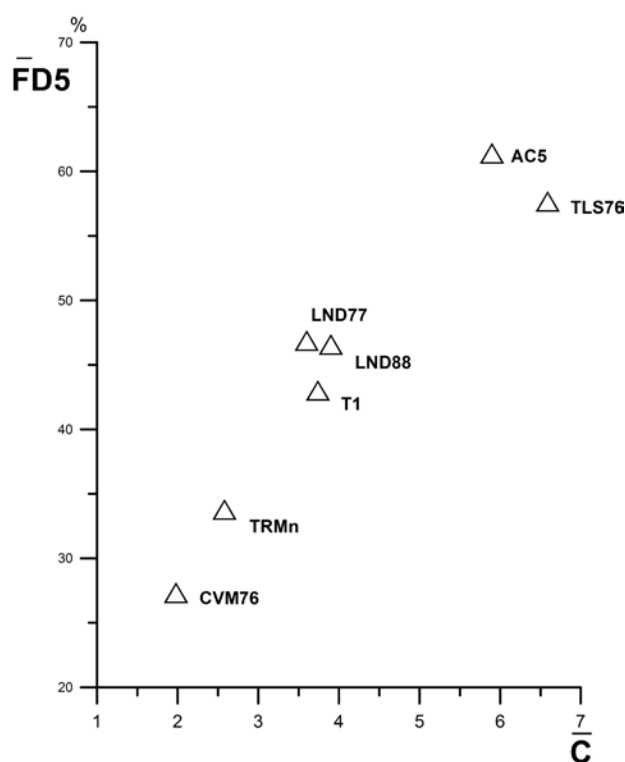


Fig. 14 - $\bar{C}$ - $\bar{FD}5$ scatter diagram for the *Nephrolepidina* populations studied to date. Mean values after Schiavinotto (1992, 1993, 1994).

Nephrolepidina is considered here at a generic level. As yet, the *Nephrolepidina* species have been defined on the basis of the average values of the Factor $\bar{A}i$ and the parameter $\bar{C}$. According to De Mulder (1975, p. 61) and Van Heck & Drooger (1984), the boundaries between the species are the following:

Nephrolepidina praemarginata

$35 < \bar{A}i \leq 40\%$ and $1 < \bar{C} \leq 3$

Nephrolepidina morgani

$40 < \bar{A}i \leq 45$ and $3 < \bar{C} \leq 5.25$

Nephrolepidina tournoueri

$45 < \bar{A}i$ and $\bar{C} > 5.25$

This classification has proved to be insufficient for solving the problems imposed by some cases with

marked deviations of the mean values, that appear to be not correlated with the stratigraphic sequence of the populations and might be produced by a dependence of the embryo-nepionic features on numerous interacting environmental and/or reworking factors (Schiavinotto & Verrubbi, 1994a, b; Giannini et al., 2007). Consequently, Schiavinotto (1996b) suggested modified species boundaries (Fig. 10), as follows:

N. praemarginata

$\bar{A}i \leq 38.00$

$\bar{C} \leq 2.50$

N. morgani

$38.00 < \bar{A}i \leq 41.00$

$2.50 < \bar{C} \leq 3.45$

N. tournoueri

$\bar{A}i > 41.00$

$\bar{C} > 3.45$

EXPLANATION OF PLATE 3

Variability of the embryonic-nepionic chambers in equatorial sections of *Nephrolepidina* from Lonedo. Samples LND77 and LND88.

Fig. 1 - Very low values of $\bar{A}i$ and $\bar{C}$. Specimen LND77-34, x 75.

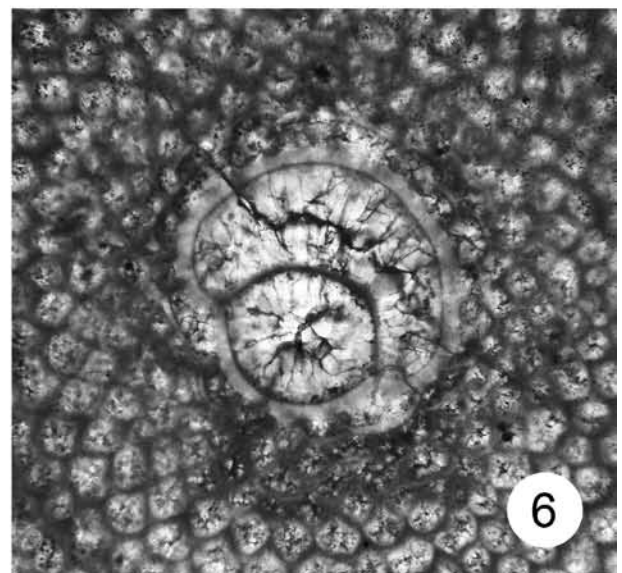
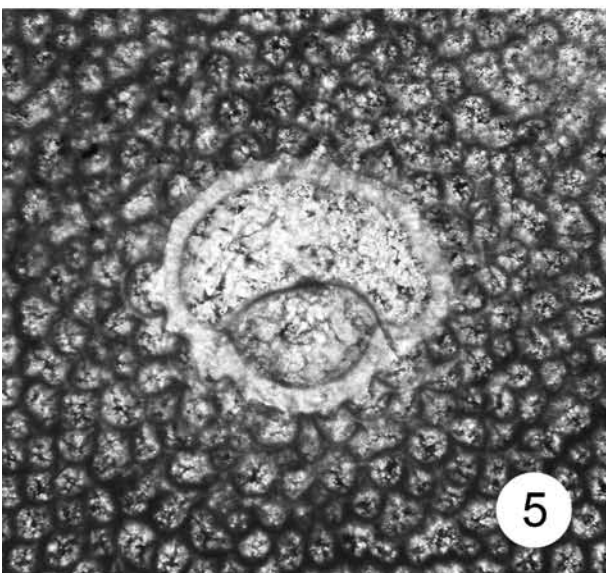
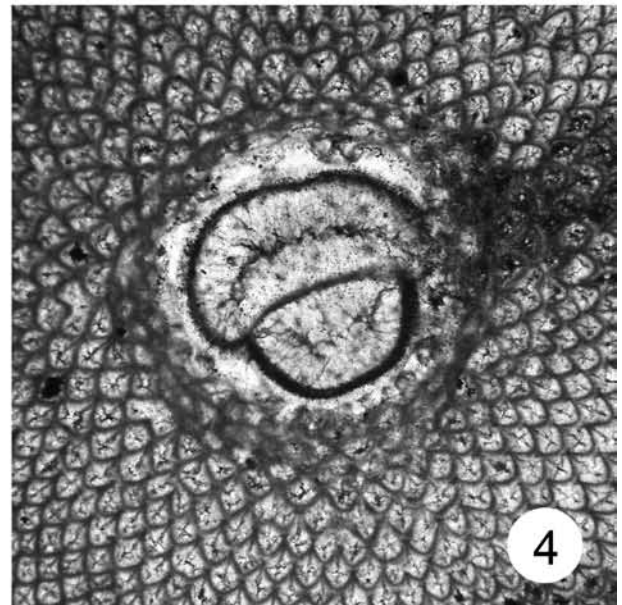
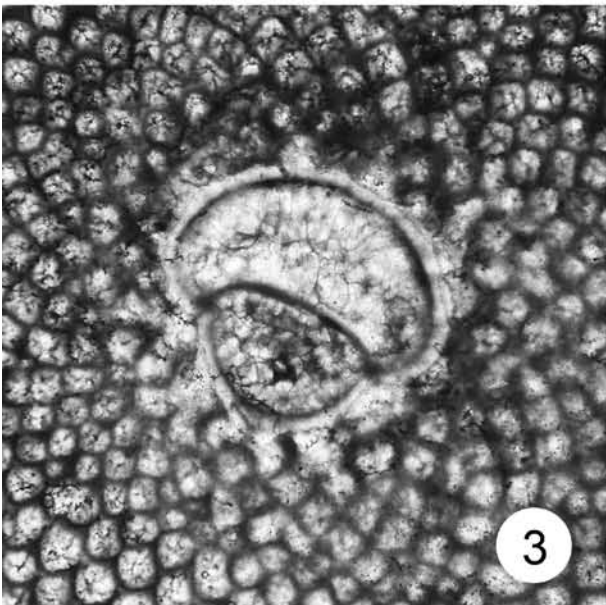
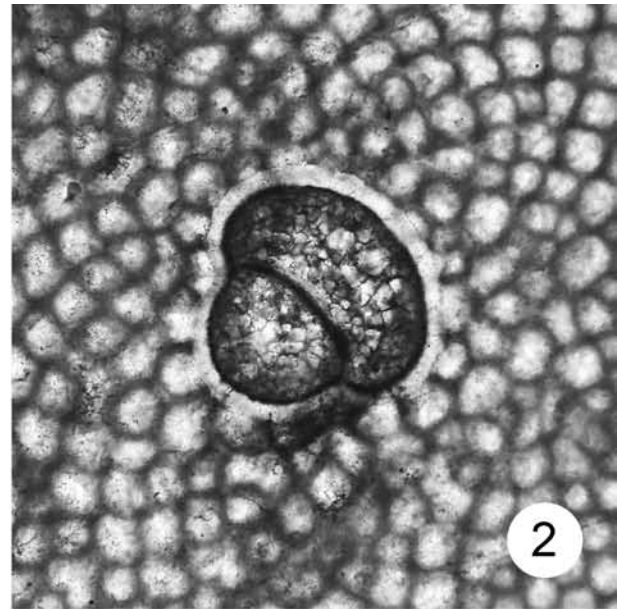
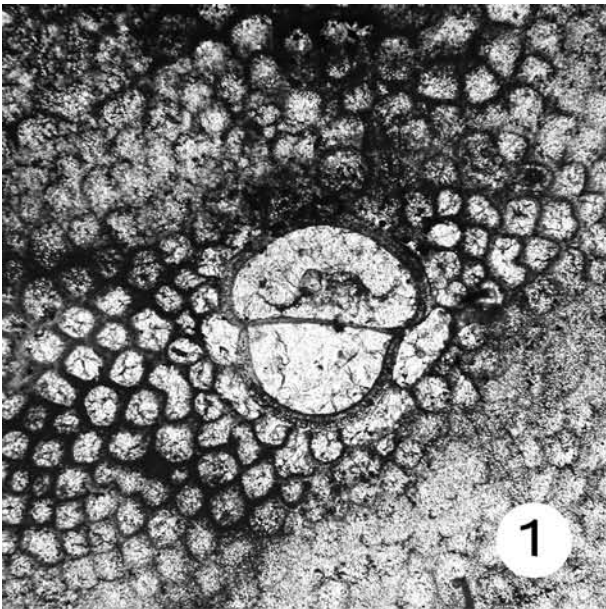
Fig. 2 - Low values of $\bar{A}i$ and $\bar{C}$. Specimen LND77-18, x 90.

Fig. 3 - Intermediate values of $\bar{A}i$ and $\bar{C}$. Specimen LND77-33, x 75.

Fig. 4 - Intermediate values of $\bar{A}i$ and $\bar{C}$. Specimen LND88-48, x 75.

Fig. 5 - High values of $\bar{A}i$ and $\bar{C}$. Specimen LND88-70, x 75.

Fig. 6 - Very high values of $\bar{A}i$ and $\bar{C}$. Specimen LND88-11, x 75.



These boundaries should allow to attenuate the deviations of $\bar{A}i$ and $\bar{C}$, including them all within the most advanced evolutionary stage of *Nephrolepidina*, and thus obtaining less confusion not only at the taxonomic, but also at the biostratigraphic level.

According to De Mulder (1975), the embryonic and nepionic data shown in Tab. 3, put both populations in the range established for *N. morgani* (Lemoine & R. Douvillé), also considering the values of $M \pm Sm$. According to Schiavinotto (1996b), both the populations would be referable to *N. tournoueri* (Lemoine & R. Douvillé). In this way, LND77 has the embryo-nepionic mean values that comes very close to the lower limits still considered for *N. tournoueri*, if the values of $M - Sm$ are to be considered (Fig. 10).

Therefore, the modification proposed by Schiavinotto (1996b) seems to be consistent in this case, although it awaits further confirmations, because the data about the total range of the oscillations caused by the environment, and also by possible resedimentation/reworking processes, are not exhaustive as yet. The normality of a great part of the distributions of the data allows to consider the specimens of *Nephrolepidina* coming from the LND77 and LND88 samples as belonging to the same species; the definition of "population" would thus be justified both at the level of embryonic and nepionic chambers and at the level of neanic chambers.

The wide gap of values between the LND77 population and the TLS 76 and AC5 populations might be an indication of the potentialities offered by the neanic factors for their application to an integration of the embryo-nepionic classification. In fact, further discriminations within the ranges of *N. morgani* and *N. tournoueri* (sensu Schiavinotto, 1996b) might be possible.

Both the shape of the chambers and the type and position of the stolons are considered a feature of taxonomic value, at the specific level (Eames et al., 1962, p. 298; Adams, 1987). Consequently, the data obtained here confirm that in the *Nephrolepidina* populations, classified on the basis of the mean values of embryo-nepionic features, a further distinction can be made on the basis of the mean values of neanic features, as hypothesized in Schiavinotto (1993, p. 304, tab. 4). The insertion of the neanic variables in the taxonomic thematic appears to be very promising.

BIOSTRATIGRAPHIC INDICATIONS

The previous Chattian age of the "Calcar di Lonredo" formation can be better specified on the basis of the data obtained here. The first biostratigraphic indications for LND populations can be obtained at embryo-nepionic level, on the basis of some statistic comparisons made with other populations that are accompanied by a significant biostratigraphic reference. It is necessary to consider the detected statistic comparability of the characteristics of LND77 and LND88, with Sample T1 (Matteucci & Schiavinotto, 1977, 1985), because of its biostratigraphic significance. Sample T1 was collected from the type level of *Cycloclypeus mediterraneus* in the top part of the Oligocene sequence outcropping on Mt. La Rocca, in the locality of Tornimparte (L'Aquila - Central Apennines)

(Renz, 1936, 1951; Accordi, 1963, 1966; Parotto & Pratulon, 1975; Matteucci & Schiavinotto, 1985).

The new *Cycloclypeus* species allowed Drooger & Laagland (1986) to propose a larger foraminifera zonation of the European - Mediterranean Oligocene; their sequence of Zones is the following:

Nummulites fichteli Zone - *Nephrolepidina praemarginata* Zone - *Cycloclypeus* Zone (*C. droogeri* Subzone - *C. mediterraneus* Subzone) - *Miogypsinoides* Zone (*M. complanatus* Subzone - *M. formosensis* Subzone).

Planktonic foraminifera in the same sample were referred to the N3 Zone (Sartoni, 1974); the very rare miogypsinids (with $\bar{X}=22.60$) were determined as *M. (Miogypsinoides) complanatus* by Laagland (1990), with an age assignment on the basis of the *Miogypsinoides* Zone of Drooger & Laagland (1986).

LND77 and LND88 do not contain *Cycloclypeus*, probably because of lack of preservation or due to paleoenvironmental conditions; *Nummulites vascus* and *N. fichteli* are absent. On the contrary, the absence of *Miogypsinoides* might be in analogy with the rarity of this taxon in sample T1. In their tentative correlation scheme, Drooger & Laagland (1986, p. 145, fig. 2) adopted planktonic zonations from Hardenbol & Berggren (1978) and Berggren et al. (1985). The zonal scheme of Drooger & Laagland was revised later by Laagland (1990, p. 22, fig. 4; p. 118, fig. 60), with the planktonic zonations and numerical time-scale that are largely adopted from Berggren et al. (1985). A subsequent tentative biozonation of the Mediterranean Oligo-Miocene, based on larger foraminifera, is due to Cahuzac & Poignant (1997). The planktonic foraminifera zonation had tentative refinements (Iaccarino, 1985; Iaccarino et al., 1996; Mancin & Pirini, 2001; Bicchi et al., 2006). Additional indications can be obtained by means of the comparisons of LND88 with the populations of De Mulder: non-significant difference both for $\bar{A}i$ and for $\bar{C}$ have been obtained for populations with a different stratigraphic significance. In fact, only A116 and A111 populations can clearly indicate a reference to the Upper Oligocene (Zone N3/P22; De Mulder, 1975, p. 121, fig. 46).

For the A109 and A104 populations, a clear position in the sequence of Aphales has not been ascertained, and in any case they are associated with Miogypsinids indicative of the Oligo-Miocene boundary (De Mulder, 1975, p. 56, 64). For the DM363 and DM331 populations, hypotheses of reworking have been put forward on the basis of bimodal distributions and association with Lower Miocene Miogypsinids (De Mulder, 1975, p. 78, fig. 33; p. 95, figs. 35-36). On the basis of the present knowledge, it could not be excluded that these populations also are the result of shiftings from the trends caused by environmental factors.

Also the comparison with the populations from the Gran Sasso cannot give satisfactory results in the biostratigraphic field. In fact, there are some non-significant comparisons with populations that confirm an Upper Oligocene age, but there are equally non-significant comparisons with some "shifting" and "environment/reworking-controlled" populations associated with Aquitanian Miogypsinids (Schiavinotto & Verrubbi, 1994a, b).

The populations of Mt. Torretta that are comparable with the LND88 population (PMT 24 - PMT 22) are very close to the Oligocene/Miocene boundary

(*Globorotalia kugleri* Zone) (Baumann, 1970; Giovagnoli & Schiavinotto, 1995; Giannini et al., 2007). LND88 does not have significant differences with $\bar{A}_i$ of the JT7313/4/5 population of Wildenborg (1991) referred to an Aquitanian age (Zone N4). Consequently, according to the biostratigraphic scheme of Drooger & Laagland (1986, p. 145, fig. 2) revised by Laagland (1990), sample T1 and samples LND77 and LND88 are related to the *Miogypsinoides complanatus* Subzone, with a possible correlation with the middle part of the *G. ciperoensis* Zone (P22/N3) (middle-upper Chattian).

A correlation with the larger Foraminifera SB 23 Biozone of Chauzac & Poignant (1997, p. 162) and the lower part of *Miogypsinoides* spp./*Nephrolepidina morgani* Zone of Bicchi et al. (2006) is possible (planktonic Foraminifera P22, NP25, lower N4 Zones of Blow, 1969; IFP22 Zone of Mancin et al., 2003). References are made to the biostratigraphic zonal scheme in Bicchi et al. (2006, p. 183, fig. 8).

LND88 has the $\bar{A}_i$ and $\bar{C}$ values that are higher than those of T1, even though they are statistically comparable, so that its position stratigraphically higher than T1 could be hypothesized. According to all the collected data, it seems useful to focus the attention on the neanic features, in order to be able to identify a new basis for a possible implementation of *Nephrolepidina* in the biostratigraphic field. In that way, it seems that the resolving power in the biostratigraphic application of *Nephrolepidina* could be implemented.

CONCLUSIONS

The neanic data obtained on the *Nephrolepidina* populations from Lonedo confirmed that the most significant of the obtained parameters and factors are: 1) the “Degree of Stolonization” (Factor FD5), which expresses the variation of the length of the common walls between contiguous chambers, connected with the position of the intercytic radial stolons; 2) the “Curvature Index” of the front wall of the chambers (Factor Re); the “Shape Index” (Factor SI5), obtained from the percentage ratio between the above mentioned factors, which is therefore an expression of the whole morphology of the chambers. The overall tendency to modify the shape of the equatorial chambers, connected with a gradually more distal position of the intercytic, radial stolons, appears to be confirmed.

Factors FD5 and SI5 have a slight decrease in time of their mean values in the 5th annulus, not in accordance with the vertical position of the populations. However, this decrease has a not statistical significance and it can be related to the lower number of data analysed in the underlying population. Consequently, the “Neanic Acceleration” seems to have only a stasis in populations without stratigraphical difference.

The analysis of the arrangement of the equatorial chambers shows the same stasis of the relative frequency of specimens with neanic equatorial chambers arranged in concentric rings; the mixed arrangement is dominant. Also the quantitative expression of the arrangement of the equatorial chambers (Parameter Fm) shows a feeble stasis of the mean values.

The embryo-nepionic features confirm an evolutionary trend according to the embryonic and nepionic acceleration, allowing to refer the two population from Lonedo to an evolutionary stage very near to the *N. morgani* - *N. tournoueri* transition.

The mean values of Factors FD5 and SI5 appear useful for taxonomic purposes: the data obtained here confirm that in the *Nephrolepidina* populations, classified on the basis of the mean values of embryo-nepionic features, a further distinction can be made on the basis of the mean values of neanic feature, mainly at the level of the intermediate species *N. morgani*.

In that way, it seems that the present specific/biostratigraphic definition of the Mediterranean *Nephrolepidina* lineage could be improved by supplementing the embryonic and nepionic data with the neanic morphometric data, in order to be able to detect especially the Oligocene/Miocene boundary.

Consequently, further researches on the “Neanic Acceleration” process in the evolution of *Nephrolepidina* are encouraged.

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REFERENCES

- Accordi B. (1963). Lineamenti strutturali del Lazio e dell'Abruzzo meridionali. *Memorie della Società Geologica Italiana*, 4 (1): 595-633.
- Accordi B. (1966). La componente traslativa nella tettonica dell'Appennino laziale-abruzzese. *Geologica Romana*, 5: 355-406.
- Accordi G., Carbone F., Civitelli G., Corda L., De Rita D., Esu D., Funicello R., Kotsakis T., Mariotti G. & Sposato A. (1988). Note illustrative alla Carta delle litofacies del Lazio-Abruzzo ed aree limitrofe. *Quaderni della Ricerca Scientifica*, 114 (5): 1-22.
- Adams C.G. (1987). On the classification of the Lepidocyclinidae (Foraminifera) with redescription of the unrelated Paleocene genera *Actinosiphon* and *Orbitosiphon*. *Micropaleontology*, 33 (4): 289-317.
- Antonelli R., Barbieri G., Dal Piaz G.V., Dal Prà A., De Zanche V., Grandesso P., Mietto P., Sedeo R. & Zanferri A. (1990). *Note illustrative della Carta Geologica del Veneto 1:250,000, Regione Veneto*. Dipartimento di Geologia, Paleontologia e Geofisica, Università di Padova: 1-30.
- Bassi D., Hottinger L. & Nebelsick J.H. (2007). Larger foraminifera from the upper Oligocene of the Venetian area, north-east Italy. *Palaeontology*, 50 (4): 845-868.
- Baumann P. (1970). Mikropalaontologische und stratigraphische Untersuchungen der obereozänen-oligozänen Scaglia im zentralen Apennin (Italien). *Eclogae Geologicae Helvetiae*, 63 (3): 1133-1211.
- Berggren W.A., Kent D.V. & Flynn J.J. (1985). Paleogene geochronology and chronostratigraphy. In Snelling N.J. (ed.), *The chronology of the geological record. Memories of the Geological Society*, 10: 211-260.

- Bicchi E., Dela Pierre F., Ferrero E., Maia F., Negri A., Pirini Radrizzani C., Radrizzani S. & Valleri G. (2006). Evolution of the Miocene Carbonate Shelf of Monferrato (north-western Italy). *Bollettino della Società Paleontologica Italiana*, 45 (2-3): 171-194.
- Blow W.H. (1969). Late-Middle Eocene to Recent planktonic foraminiferal biostratigraphy. *Proceedings First International Conference on Planktonic Microfossils, Geneva, 1967*, 1: 199-422.
- Boccaletti M. & Guazzone G. (1974). Il microcontinente sardo come un arco residuo di un sistema arco-fossa miocenico. In *Paleogeografia del Terziario sardo nell'ambito del Mediterraneo occidentale* (1973). *Rendiconti Semestrali Facoltà di Scienze Università di Cagliari*, 43, suppl.: 57-68.
- Bosellini A. (1964). Nuovi affioramenti miocenici nei Lessini orientali. *Servizio Geologico d'Italia*, 85: 35-40.
- Bosellini A. (1967). Arenarie e Calcari di S. Urbano. In Bosellini A., Carraro F., Corsi M., De Vecchi G.P., Gatto G.O., Malaroda R., Sturani C., Ungaro S. & Zanettin B. (eds.). *Note illustrative della Carta Geologica d'Italia alla scala 1:100.000, Foglio 49, Verona. Servizio Geologico d'Italia, Roma*: 1-61.
- Bosellini A., Russo A., Arush M.A. & Cabdulquadir M.M. (1987). The Oligo-Miocene of Eil (NE Somalia): a prograding coral - *Lepidocyclus* system. *Journal of African Science*, 6 (4): 583-593.
- Bosellini F.R. & Russo A. (1992). Stratigraphy and Facies of an Oligocene Fringing Reef (Castro Limestone, Salento Peninsula, Southern Italy). *Facies*, 26:145-166.
- Braga G., Gatto G.O., Gatto P., Gregnanin A., Massari F., Medizza F., Nardin M., Perna G., Rossi D., Sacerdoti M., Semenza E., Sommariva E., Zirpoli G. & Zulian T. (1971). Note illustrative della Carta Geologica d'Italia, Foglio 22 "Feltre", 1:100,000. Servizio Geologico d'Italia.
- Cahuzac B. & Poignant A. (1997). Essai de biozonation de l'Oligo-Miocène dans les bassins européens à l'aide des grands foraminifères néritiques. *Bulletin de la Société Géologique de France*, 168: 155-169.
- Castellarin A. & Gatto G.O. (1968). "Calcarea di Lonardo". In Castellarin A., Corsi M., De Vecchi G., Gatto G.O., Largaioli T., Mozzi G., Piccoli G., Sassi F.P., Zanettin B. & Zirpoli G. (eds.). *Note illustrative della Carta Geologica d'Italia alla scala 1:100.000, Foglio 36, Schio. Servizio Geologico d'Italia, Roma*: 1-94.
- Chaproniere G.C.H. (1975). Palaeoecology of Oligo-Miocene larger Foraminifera, Australia. *Alcheringa*, 1: 37-58.
- Chaproniere G.C.H. (1980). Biometrical studies of Early Neogene larger Foraminifera from Australia and New Zealand. *Alcheringa*, 4: 155-181.
- Chaproniere G.C.H. (1984). Oligocene and Miocene larger Foraminifera from Australia and New Zealand. *Bureau of Mineral Resources, Geology and Geophysics Bulletin*, 188: 1-98.
- Cherchi M.A. & Montadert I. (1982a). Oligo-Miocene rift of Sardinia and the early history of the Western Mediterranean Basin. *Nature*, 298 (5876): 736-739.
- Cherchi M.A. & Montadert I. (1982b). Il sistema di rifting oligo-miocenico del Mediterraneo occidentale e sue conseguenze paleogeografiche sul Terziario sardo. *Memorie della Società Geologica Italiana*, 24 (2): 387-400.
- De Mulder E.F.J. (1975). Microfauna and sedimentary-tectonic history of the Oligo-Miocene of the Ionian Islands and western Epirus (Greece). *Utrecht Micropaleontological Bulletins*, 13: 1-140.
- Drooger C.W. (1984). Evolutionary patterns in lineages of orbitoidal foraminifera. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B, Palaeontology, Geology, Physics and Chemistry*, 87 (1): 103-130.
- Drooger C.W. (1993). Radial Foraminifera: Morphometrics and Evolution. *Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen, Afd. Natuurkunde, Eerste Reeks*, 41: 1-242.
- Drooger C.W. & Freudenthal T. (1964). Association of *Miogyxina* and *Lepidocyclus* at some European localities. *Eclogae Geologicae Helvetiae*, 57 (2): 509-528.
- Drooger C.W. & Laagland H. (1986). Larger foraminiferal zonation of the European-Mediterranean Oligocene. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B, Palaeontology, Geology, Physics and Chemistry*, 89: 135-148.
- Drooger C.W., Meulenkamp J.E., Schmidt R.R. & Zachariasse W.J. (1976). The Paleogene-Neogene boundary. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B, Palaeontology, Geology, Physics and Chemistry*, 19 (5): 317-329.
- Eames F.E., Banner F.T., Blow W.H., Clarke W.J. & Smout A.H. (1962). Morphology, taxonomy and stratigraphic occurrence of the *Lepidocyclus* group. *Micropaleontology*, 8 (3): 289-322.
- Fabiani R. (1905). Studio geopaleontologico dei Colli Berici. Nota preventiva. *Atti Regio Istituto Veneto di Scienze, Lettere ed Arti*, 64: 1797-1839.
- Fabiani R. (1915). Il Paleogene del Veneto. *Memorie dell'Istituto di Geologia della R. Università di Padova*, 3: 1-336.
- Fabiani R. (1922). Il Terziario del Trentino. *Memorie dell'Istituto di Geologia della R. Università di Padova*, 6: 3-60.
- Giannini E., Schiavinotto F. & Verrubbi V. (2007). Ecology versus evolution in *Nephrolepidina* from the Oligocene-Miocene of Monte Torretta (L'Aquila - Central Apennines). *Geologica Romana*, 40: 97-118.
- Giovagnoli M.C. & Schiavinotto F. (1990). *Nephrolepidina tournoueri* (Lemoine & R. Douvillé) from the Lower Miocene of Ales (Sardinia). *Bollettino della Società Paleontologica Italiana*, 29 (2): 233-244.
- Giovagnoli M.C. & Schiavinotto F. (1995). Evolutionary trends in *Nephrolepidina* in the Upper Oligocene-Lower Miocene sequence of Monte Torretta (Central Apennines - Italy). *Bollettino del Servizio Geologico d'Italia*, 92: 59-102.
- Grimsdale T.F. (1959). Evolution in American *Lepidocyclus* (Cainozoic foraminifera): An interim review. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B, Palaeontology, Geology, Physics and Chemistry*, 62 (1): 1-7.
- Hardenbol J. & Berggren W.A. (1978). A new Paleogene numerical time scale. *American Association of Petroleum Geologists Publications, Studies in Geology*, 6: 213-234.
- Iaccarino S. (1985). Mediterranean Miocene and Pliocene Planktonic Foraminifera. In Bolli H.M., Saunders J.B. & Perch-Nielsen K. (eds.), *Plankton Stratigraphy*: 283-314, Cambridge University Press, Cambridge.
- Iaccarino S., Borsetti A.M. & Rögl F. (1996). Planktonic foraminifera of the Neogene Lemme-Carrosio GSSP Section (Piedmont, Northern Italy). In Steininger F.F., Iaccarino S. & Cati F. (eds.), *In search of the Paleogene/Neogene boundary. Part III: The Global stratotype section and point the GSSP for the base of the Neogene (The Paleogene/Neogene boundary)*. *Giornale di Geologia*, 58 (1-2): 35-49.
- Iaccarino S., D'Onofrio S. & Murru M. (1985). Miocene foraminifera of several sections of the Marmilla area (central-western Sardinia). *Bollettino della Società Paleontologica Italiana*, 23 (2) (1984): 395-412.
- Laagland H. (1990). *Cycloclypeus* in the Mediterranean Oligocene. *Utrecht Micropaleontological Bulletins*, 39: 1-171.
- Less G.Y. (1987). Paleontology and stratigraphy of the European Orthophragminae. *Geologica Hungarica, series Palaeontologica*, 51: 1-373.
- Mancin N. & Pirini C. (2001). Middle Eocene to early Miocene foraminiferal Biostratigraphy in the epiligurian succession (Northern Apennines, Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 107 (3): 371-393.
- Mancin N., Pirini C., Bicchi E., Ferrero E. & Valleri G. (2003). Middle Eocene to middle Miocene planktonic foraminiferal biostratigraphy for internal basins (Monferrato and Northern Apennines, Italy). *Micropaleontology*, 49: 341-358.
- Matsumaru K. (1971). Studies on the genus *Nephrolepidina* in Japan. *The Science Reports of the Tohoku University, Sendai, Japan, Second Series (Geology)*, 42 (2): 97-185.
- Matteucci R. & Schiavinotto F. (1977). Studio biometrico di *Nephrolepidina*, *Eulepidina* e *Cycloclypeus* in due campioni dell'Oligocene di Monte La Rocca, L'Aquila (Italia centrale). *Geologica Romana*, 16: 141-171.

- Matteucci R. & Schiavinotto F. (1985). Two new species for the Mediterranean inornate *Cyclocypeus* lineage. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B, Palaeontology, Geology, Physics and Chemistry*, 88 (1): 123-130.
- Meulenkamp J.E. & Amato V. (1972). *Cyclocypeus* and *Nephrolepidina* from the Oligocene of Mollere (N. Italy). *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B, Palaeontology, Geology, Physics and Chemistry*, 75 (1): 34-47.
- Parotto M. & Praturlo A. (1975). Geological summary of the Central Apennines. *Quaderni della Ricerca Scientifica*, 90: 257-312.
- Piccoli G. (1966). Studio geologico del vulcanismo paleogenico Veneto. *Memorie degli Istituti di Geologia e Mineralogia dell'Università di Padova*, 26: 1-100.
- Piccoli G. (1967). Illustrazione della carta geologica del Marosticano occidentale fra Thiene e la valle del torrente Laverda nel Vicentino. *Memorie degli Istituti di Geologia e Mineralogia dell'Università di Padova*, 26: 1-14.
- Pieroni P.G. (1965). *Lepidocyclina* and *Miogypsina* from Opi, Sangro Valley. *Geologica Romana*, 4: 161-180.
- Reiss Z. & Hottinger L. (1984). The Gulf of Aqaba. *Ecological Micropaleontology*: 1-354.
- Renz O. (1936). Stratigraphische und mikropalaeontologische Untersuchung der Scaglia (Obere Kreide-Tertiar) im Zentralen Apennin. *Eclogae Geologicae Helveticae*, 29 (1): 1-149.
- Renz O. (1951). Ricerche stratigrafiche e micropaleontologiche nella Scaglia (Cretaceo superiore-Terziario) dell'Appennino centrale. *Memorie descrittive Carta Geologica d'Italia*, 29: 1-173.
- Sartoni S. (1974). Nota preliminare sui foraminiferi planctonici di un livello a *Lepidocyclina* dell'Oligocene superiore. *Atti della Società Italiana di Scienze naturali. Museo civico di Storia naturale, Milano*, 11 (2): 204-212.
- Schiavinotto F. (1978). *Nephrolepidina* nella Valle del Maso (Borgo Valsugana - Italia settentrionale). *Rivista Italiana di Paleontologia e Stratigrafia*, 84 (3): 729-750.
- Schiavinotto F. (1979). *Miogypsina* e *Lepidocyclina* del Miocene di Monte La Serra (L'Aquila - Appennino centrale). *Geologica Romana*, 18: 253-293.
- Schiavinotto F. (1985). Different evolutionary stages in the *Miogypsinidae* from Sardinia. *Bollettino della Società Paleontologica Italiana*, 23 (2) (1984): 381-393.
- Schiavinotto F. (1987). Remarks on the taxonomic and biostratigraphic value of the equatorial chambers arrangement in some populations of the Mediterranean *Nephrolepidina* lineage. *Bollettino della Società Geologica Italiana*, 106 (4): 723-735.
- Schiavinotto F. (1992). The neanic stage of *Nephrolepidina tournoueri*: biometry and biostratigraphic implications. *Bollettino della Società Paleontologica Italiana*, 31 (2): 189-206.
- Schiavinotto F. (1993). Biometry of the neanic stage of Upper Chattian *Nephrolepidina morgani* (Lemoine & R. Douvillé). *Geologica Romana*, 29: 291-306.
- Schiavinotto F. (1994). Neanic stage biometry in *Nephrolepidina praemarginata* (R. Douvillé, 1908). *Bollettino della Società Geologica Italiana*, 112 (1993): 805-824.
- Schiavinotto F. (1995). Environmental influence on the neanic acceleration in Oligo-Miocene *Nephrolepidina*. *Geologica Romana*, 31: 273-283.
- Schiavinotto F. (1996a). Neanic acceleration in Oligo-Miocene *Nephrolepidina*: a check-point in the refinement of its biometric definition. *Bollettino della Società Geologica Italiana*, 115 (1): 47-53.
- Schiavinotto F. (1996b). Modification of the biometric definition of the species belonging to the Mediterranean *Nephrolepidina* lineage. *Bollettino della Società Geologica Italiana*, 115 (3): 561-567.
- Schiavinotto F., Corradini D., D'Onofrio S., Iaccarino S., Martini E., Murru M. & Russo A. (1985). Site H.3 - Lower Miocene of Ales. 19th European Micropaleontological Colloquium, Sardinia October 1985 - Guidebook: 252-261.
- Schiavinotto F. & Verrubbi V. (1994a). Ecology versus evolution in Oligo-Miocene *Nephrolepidina*. In Matteucci R., Carboni M.G. & Pignatti J. (eds.), *Studies on ecology and paleoecology of Benthic Communities. Proceedings 5th Symposium Roma 1992. Bollettino della Società Paleontologica Italiana, Spec. Vol. 2*: 305-312.
- Schiavinotto F. & Verrubbi V. (1994b). *Nephrolepidina* in the Oligo-Miocene section of the Gran Sasso (Central Apennines): environment-evolution relations. *Bollettino della Società Paleontologica Italiana*, 33 (3): 375-406.
- Serpagli E. & Sirotti A. (1966). Gli strati a *Lepidocyclina* e *Miogypsina* ai Sassi di Rocca Malatina e a Montegibbio (Appennino settentrionale modenese). *Bollettino della Società Paleontologica Italiana*, 5 (1): 79-91.
- Serpagli E. & Sirotti A. (1967). Età aquitaniana delle breccie a *lepidocyclina* e *miogypsina* delle "Arenarie del Monte Cervarola" (Appennino settentrionale). *Bollettino della Società Paleontologica Italiana*, 6 (1): 18-29.
- Sirotti A. (1982a). A tentative phylogenetic interpretation of the *Lepidocyclinidae*. In Montanaro Gallitelli E. (ed.), *Paleontology, essential of Historical geology. Proceedings International Meeting, Venice 1981*: 467-480.
- Sirotti A. (1982b). Phylogenetic classification of *Lepidocyclinidae*: a proposal. *Bollettino della Società Paleontologica Italiana*, 21 (1): 99-112.
- Stefanini G. (1915). Il Neogene del Veneto. *Memorie dell'Istituto di Geologia della R. Università di Padova*, 3: 337-624.
- Tan Sin Hok (1936a). Zur Kenntnis der *Miogypsiniden*. *De Ingenieur in Nederlandsch-Indië IV, Mijnbouw en Geologie*, 3 (3): 45-61.
- Tan Sin Hok (1936b). Zur Kenntnis der *Miogypsiniden* (1. Fortsetzung). *De Ingenieur in Nederlandsch-Indië IV, Mijnbouw en Geologie. De Mijningenieur*, 3 (5): 84-98.
- Tan Sin Hok (1937a). Weitere Untersuchungen über die *Miogypsiniden* I. *De Ingenieur in Nederlandsch-Indië IV, Mijnbouw en Geologie. De Mijningenieur*, 4 (3): 35-45.
- Tan Sin Hok (1937b). Weitere Untersuchungen über die *Miogypsiniden* II. *De Ingenieur in Nederlandsch-Indië IV, Mijnbouw en Geologie. De Mijningenieur*, 4 (6): 87-111.
- Ungaro S. (1978). L'Oligocene dei Colli Berici. *Rivista Italiana di Paleontologia e Stratigrafia*, 84: 199-278.
- Van der Vlerk I.M. (1959). Modifications de l'ontogénèse pendant l'évolution des *Lépidocyclines* (Foraminifères). *Bulletin de la Société Géologique de France, Notes et Mémoires*, ser. 7, 1: 669-673.
- Van der Vlerk I.M. (1963). Biometric research on *Lepidocyclina*. *Micropaleontology*, 9 (4): 425-426.
- Van der Vlerk I.M. (1964). Biometric research on European *Lepidocyclinas*. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B, Palaeontology, Geology, Physics and Chemistry*, 67 (5): 1-10.
- Van der Vlerk I.M. (1968). Two methods of worldwide correlation. *Micropaleontology*, 14 (3): 334-338.
- Van der Vlerk I.M., de Bock J.F. & Sirotti A. (1973). Biometrical investigations on *Operculina* and *Lepidocyclina*. A test on their degree of objectivity and reliability for geological age determinations. *Bollettino della Società Paleontologica Italiana*, 11 (1): 86-99.
- Van Gorsel J.T. (1975). Evolutionary trends and stratigraphic significance of the Late Cretaceous *Helicorbitoides-Lepidorbitoides* lineage. *Utrecht Micropaleontological Bulletins*, 12: 1-100.
- Van Gorsel J.T. (1978). Late Cretaceous Orbitoidal Foraminifera. *Foraminifera*, 3: 1-120.
- Van Heck S.E. & Drooger C.W. (1984). Primitive *Lepidocyclina* from San Vicente de la Barquera (N. Spain). *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B, Palaeontology, Geology, Physics and Chemistry*, 87 (3): 301-318.
- Van Vesseem E.J. (1978). Study of *Lepidocyclinidae* from south-east Asia, particularly from Java and Borneo. *Utrecht Micropaleontological Bulletins*, 19: 1-163.

- Venzo S. (1934). Il Neogene del Trentino, Veronese e Bresciano. *Memorie del Museo di Storia Naturale della Venezia Tridentina*, 2 (2): 111-207.
- Vervloet C.C. (1966). Stratigraphical and micropaleontological data on the Tertiary of Southern Piemont (Northern Italy). Schotanus & Jens, Utrecht NV: 1-88.
- Wildenborg A.F.B. (1991). Evolutionary aspects of the miogypsinids in the Oligo-Miocene carbonates near Mineo (Sicily). *Utrecht Micropaleontological Bulletins*, 40: 1-139.
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