STRATIGRAPHICAL AND MICROPALEONTOLOGICAL DATA ON THE TERTIARY OF SOUTHERN PIEMONT

(NORTHERN ITALY)

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C. C. VERVLOET

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CONTENTS

ILLUSTRATIONS

INDEX OF GENERA AND SPECIES AMONG THE PLANKTONIC AND LARGER FORAMINIFERA STUDIED

ABSTRACT

During the years 1959—1963 stratigraphical investigations were carried out in Southern Piemont (Northern Italy) along five traverses, taken at right angles to the strike of the strata, which range in age from Eocene to Pliocene.

These sections are important in that they include the type sections of some Neogene stages (Langhian, Serravallian and Tortonian) and some classical localities, such as Mollere and Costa Lupara.

The sequences of these sections (numbered I—V) show large discrepancies in lithology as well as in the thickness between the corresponding units. To avoid confusion a number of formations and members are introduced for each of the sections.

Parts of the sections are barren but in most portions numerous planktonic foraminifera were found. They could be used to establish ten biozones, successively I: the *semi-involuta* Zone, II: the *cerro-azulensis* Zone, III: the *Globigerina* Zone, IV: the *Globigerinoides-Globoquadrina* Zone, V: the *Globorotalia* Zone, VI: the *bisphericus* Zone, VII: the *Orbulina* Zone, VIII: the *menardii* Zone, IX: the *nepenthes* Zone, and X: the *obliquus* Zone.

In addition some of the larger Foraminifera were investigated in more detail, in particular the *Nephrolepidina* and *Miogypsina* species. The embryonic-nepionic apparatus of *Lepidocyclina praemarginata* and *Lepidocyclina morgani* were compared on a biometric basis. Only a part of the phylogenetic series of the Miogypsinidae was encountered, namely from *M. gunteri* to *M. intermedia.*

Correlation by means of the zonation with these larger and planktonic Foraminifera leads to interesting stratigraphic results.

1. In the correlation of the sections II, III and IV only slight differences with the Italian Geological Map have been met with, but in the sections I and V there are large deviations from this map.
2. The type Langhian appears to begin closely above the *Orbulina* surface. For the assumed chronological interval between Helvetian and Tortonian the author suggests to use the term Serravallian rather than Langhian, because the latter has commonly been erroneously considered to be the equivalent of the Burdigalian. The limits between the successive stages Burdigalian, Helvetian, Serravallian and Tortonian can be correlated with biozones of planktonic Foraminifera.
3. Furthermore it was found that the beginnings of the genera *Globigerinoides* and *Globoquadrina* do not coincide with the Oligocene-Miocene boundary. Both genera start their range in the Late Oligocene already.
4. Among the general conclusions of a paleogeographic nature we may note, that the transgression over the metamorphic basement of the Massif of Voltri and Ligurian Alps advanced in westward direction during Rupelian and probably Chattian times.
5. In the most eastern section (Tortona-Garbagna area) the Miocene sequence is not complete, as sediments, corresponding to at least two of the biozones are lacking here.

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The Maps, Tables and Textfigures have been ably drawn by Mr. A. VAN DOORN, whereas Mr. J. J. VERMAAT illustrated the specimens of the foraminifera.

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Chapter I

INTRODUCTION

The area of Southern Piemont (text fig. 1), to which this paper refers, has attracted the interest of geologists from the early 19th century onwards, and it derives its importance from the fact, that a number of authors have based several stratigraphical units (stages) of the Upper Paleogene and the Neogene on the formations exposed here, and on their fossil content.

In the course of time the interpretation of these stages has frequently been changed, but some of the names (Langhian, Tortonian) are still widely used.

In the attempt to contribute to the solution of the correlation difficulties that have arisen, the present paper will deal in detail with five selected sections, some of them including these type sections, and generally at right angles to the strike of the strata in the hilly country of Le Langhe.

The sections are numbered I—V from West to East, and have been named after the villages or towns of: Ceva, Spigno Monferrato, Acqui-Molare, Serravalle Scrivia and Tortona-Garbagna respectively. Some of the other names in text fig. 1 refer to classical, fossiliferous localities,

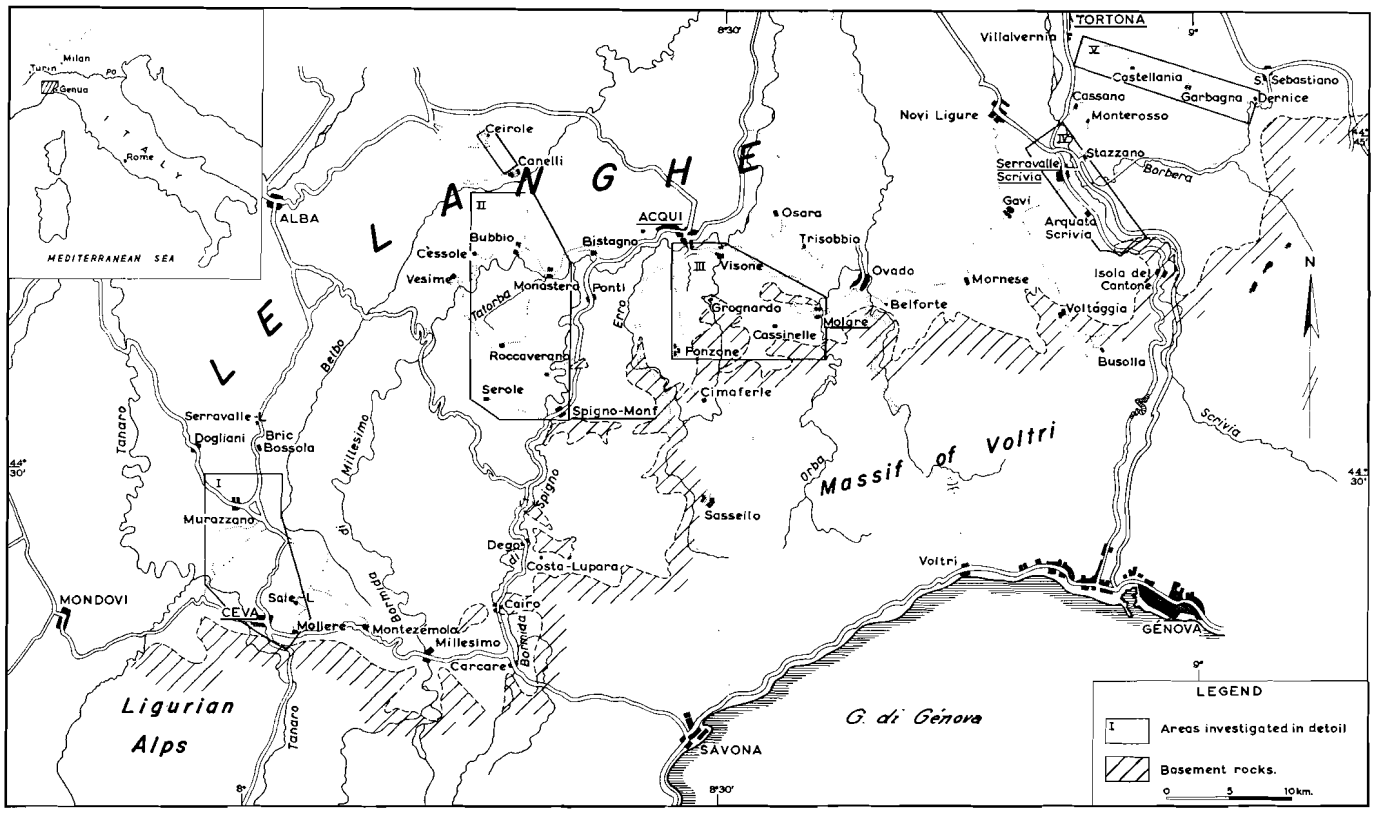


Figure 1
Outline Map of Southern Piemont, with the areas studied in detail.

such as Mollere (near Ceva) and Costa Lupara (near Dego).

The area is approximately limited by the upper course of the river Tanaro in the West, the rivers Borbera and Castellania in the East, the Massif of Voltri and the Ligurian Alps in the South, and the line along the villages of Dogliani, Canelli and Villalvernia in the North. It covers parts of the following sheets (1 : 100.000) of the Geological Map of Italy:

69: Asti, 70: Alessandria, 71: Voghera, 80: Cuneo, 81: Ceva and 82: Genova.

In the East West direction the area is about 90 km and about 40 km in the North South direction.

The choice of this area by previous authors for defining stages is probably due to favourable geographic circumstances:

1. The proximity to centers of civilization, education and population, such as Genoa, Milan and Turin.
2. The abundance of major and minor roads, which facilitate its accessibility.
3. The excellent outcrops along streams, in roadcuts, as well as on slopes.
4. The high content of fossils in several localities.
5. The constant, if slight, dip of the strata, seldom exceeding 10°, thus enabling the geologist to study the succession of strata over distances of several kilometers, even though the hills in Le Langhe are relatively low.
6. The easy recognition of lithostratigraphic units, because of the alternation of soft (marly) and hard (sandy) layers on the one hand, and their differential erosion on the other, which have given rise to a series of cuestas.

The general strike of the strata is decided by the topography of the basement of the Ligurian Alps and the Northwestern Apennines. It is about East-West near Ceva. Some kilometers eastwards it bends to the North East and the strata can be traced in this direction as far as Spigno Monferrato, turning gradually to the East again near Acqui. Then their strike curves to the South East, around the Massif of Voltri. Between Ovada and Serravalle Scrivia it is nearly East and follows the course of the river Borbera. About 10 km East of the village of Stazzano it bends sharply to the North North East.

The strata are cut by rivers, running South-North, for instance the upper courses of the Tanaro, Belbo and Bormida. These streams bend to the North East and East, following the strike of the strata. Other rivers, however, run to the North entirely, such as the Orba and Scrivia. Ultimately all rivers are gathered in the Tanaro and Scrivia, which debouch in the river Po.

The most important villages are situated along the valleys and are connected by main roads, which are in good condition notwithstanding the high frequency of heavy, motorized traffic. Minor roads lead to the smaller villages, often lying on the crests of the hills. Apart from these there are numerous gravel roads and unpaved footpaths.

From the geologists point of view the working conditions in Piemont are usually optimal from the spring till the second half of October.

Chapter II

HISTORICAL REVIEW

An exhaustive review would be beyond the scope of this paper. We confined ourselves to the main line in the development of the stratigraphic terminology and to the most important micropaleontological papers.

The first important stratigraphical record on Southern Piemont is from PARETO (1852). He tried to establish a correlation on lithological grounds between the exposures along the rivers Bormida di Spigno and Scrivia. In 1855 he published four North-South traverses through the Apennines and its sedimentary cover, approximately along the villages of Serravalle Scrivia, Voltaggio, Cassinelle and Acqui.

Although MAYER already established the Tortonian in 1857, it is PARETO, who should be considered the founder of the stratigraphy in Piemont. In 1865 he introduced four "Etages" in the "Miocene", the extension of which he traced throughout Northern Italy.

PARETO's lowest unit of the "Miocene" is the "Etage Bormidien" (Bormidiano, SACCO). PARETO indicated as type region the valley of the river Bormida di Spigno, where conglomerates and marls are exposed. The conglomerates of Costa Lupara and sandstones of Spigno Monferrato, as well as the overlying marls with conglomeratic intercalations belong in this stage (our Bormida Formation, section IIA, table II). The Miocene age of the Bormidian PARETO based on the occurence of 130 Miocene against 52 Eocene fossils, on which no further details are given here.

PARETO's second "Miocene" stage is the "Etage Langhien" (Langhiano, SACCO), which he considered to be Middle Miocene. The typical development is found in the hills of Le Langhe, where it consists of sandy marls with intercalated sandstones. These are well exposed between the rivers Belbo and Bormida di Millesimo, and extend in the direction of Bistagno, Acqui and Ponti. Originally the Langhian was said to be distinguishable from the Bormidian by being more fine-grained and its paucity of fossils. In PARETO's opinion it represented the apex of a transgressive sedimentary cycle (1865, p. 229).

PARETO's Langhian could be subdivided into a lower sandy, and an upper marly part. MAYER (1868) restricted the Langhian to the marls (Marnes à Ptéropodes), using for the lower part the term Aquitanian. SACCO (1887) followed this subdivision. Mainly because of that author's influence this distinction has survived in Italy until today, though it is not in accordance with the original concept of 1865.

PARETO's third stage, the Upper Miocene, is the "Etage Serravallien".

In this case it is interesting to cite PARETO (1865, p. 232):

"... Vers la partie supérieure de l'étage Langhien on voit commencer l'alternance de marnes grisâtres, avec des couches plus sableuses jaunâtres, qui commencent à prendre l'aspect de dépôts, qui se sont formés dans une mer moins profonde et moins loin des côtes.

C'est au commencement de ces alternances de marnes sableuses grisâtres et de sables jaunes que je place la limite inférieure de la troisième subdivision du terrain miocène, qui est celle du miocène supérieur que j'appellerai l'étage Serravallien, ..."

PARETO indicated as type the sandstones and marls of the hilly range, on which the village of Serravalle Scrivia has been built. He considered this stage to represent the regressive phase of a sedimentary cycle.

PARETO thought that his fourth stage or "Etage Tortonien" (Tortoniano, SACCO) already belonged in the Pliocene. Its name is derived from the town of Tortona. PARETO was of the opinion that the Tortonian and the Plaisancian should together form one stage. Characteristic for the Tortonian are the marls exposed near the villages of Stazzano, Sardigliano and S. Aloysio, South of Tortona, while PARETO also included the marls of Sant' Agata Fóssili.

Some twenty years later SACCO (1887) introduced a

more refined subdivision of the Oligo-Miocene in Italy. He mainly followed the terminology of MAYER (1857—'58), but he retained some of PARETO's terms as well (Langhiano).

He subdivided the Bormidian in Tongriano and Stampiano, placing both in the Oligocene. The overlying strata of the Miocene he divided into Aquitaniano, Langhiano, Elveziano and Tortoniano. The Bormidian was thus suppressed and the Serravallian was substituted by the Elveziano, because of the great similarity in lithology of the Serravallian with the Swiss Helvetian. In this fashion SACCO introduced a number of aprioristic correlations, which frequently recur even in the more recent literature.

The opinion, that part of the Langhian would be equivalent in time with the Burdigalian, was expressed, amongst others, by DEPÉRET (1905), founder of the latter stage. This idea of the near-identity of both stages is still prevailing in the literature.

In 1905 SACCO gave an excellent survey of MAYER's and PARETO's stages in Piemont, without adding new points of view. In the same year and in the course of terminating his work on the Geological Map of Piemont, he published a paper, in which he concluded, that the Oligo-Miocene strata wedge out near Ceva and Mondovi. On this ground he based his opinion that the rim of the basin should be looked for here.

In the meantime TRABUCCO (1893) had discussed the stratigraphical position of the so-called "Calcaire d'Acqui", placing it at the base of the Langhian, but DI ALESSANDRI (1900) assigned an Aquitanian age to it. On the recent geological maps it has several stratigraphical positions. Whereas in the Bric Albarella (Map II) it lies several tens of meters above the base of the "Aquitaniano", it occurs near Acqui (Map III) at the limit between the "Aquitaniano" and "Langhiano" and South of the village of Visone (Map III) it forms the base of the "Aquitaniano". In 1962 LORENZ attributed a Middle Aquitanian age to this limestone bed near Acqui, Ponzone and Visone, because of its content of *Miogypsina* s.s.

Larger Foraminifera from Southern Piemont had attracted the attention already of several authors.

In 1861 MICHELOTTI had reported from the localities Belforte, Dego and Millesimo: *Orbitoides marginata,* which he had originally described as *Nummulites marginata* from the Turin area (1841).

From exposures in Southern Piemont he recorded: *Nummulites perforata* d'Orbigny (Dego), *Nummulites striata* d'Orbigny (Belforte, Grognardo and Mornese), *Nummulites biaritzensis* d'Archiac and *Nummulites intermedia* d'Archiac (Grognardo). MICHELOTTI placed all these localities with larger Foraminifera in his "Lower Miocene", including the locality of Mollere, the type locality of his *Orbitoides dilatata.*

Nowadays many of MICHELOTTI's specific names are out of use and the afore-mentioned *Nummulites* are mostly referred to as belonging to two groups, that of *Nummulites vascus-bouillei* and of *Nummulites intermedius-fichteli.*

LEMOINE & R. DOUVILLÉ revised the genus *Lepidocyclina* GÜMBEL in 1904, including in their paper a clearer description of *Lepidocyclina dilatata* (Michelotti).

Using, among other things, many observations in Piemont R. DOUVILLÉ & PRÉVER (1905) proposed a zonation of the Oligo-Miocene, based on the occurrences of *Nummulites* and the relative decrease in frequency of *Lepidocyclina* and increase of *Miogypsina.*

SACCO (1905) placed the conglomerates of Costa Lupara in the Tongriano. R. DOUVILLÉ (1908) described a new species, *Lepidocyclina praemarginata* from the outcrops here.

ROVERETO (1910), basing himself on the distribution of *Lepidocyclina,* subdivided SACCO's "Stampiano" into two parts. The upper part, being devoid of *Lepidocyclina,* he thought to be of Aquitanian age.

The thesis of VAN DER HEIDE (1941) dealt with the stratigraphy of the area between the rivers Scrivia and Staffora, but mainly with the intention to arrive at a tectonical interpretation.

GINO, DI NAPOLI, RUSCELLI and GIANOTTI (1953) designated the type section of the Tortonian. The section lies in the Rio Castellania, South East of the village of Sant' Agata Fóssili. GINO mapped the surroundings, GIANOTTI described the Foraminifera of the Tortoniano, RUSCELLI those of the underlying Elveziano, while DI NAPOLI gave an account of the microfauna of the Aquitaniano, which is unconformably overlain by the Elveziano.

The association from these "Aquitaniano" clays contains, amongst other things, *Globigerinita dissimilis* and *Globigerinoides trilobus.* The "Elveziano" is characterized

by a fauna with *Orbulina suturalis* and *O. universa,* which led RUSCELLI and DI NAPOLI to conclude, that the "Langhiano" is lacking at the disconformity.

Anticipating other publications, it may be mentioned that, after the description of the type Langhian in Le Langhe (CITA & PREMOLI SILVA, 1960), PIZZOCHERO (1962, second hand information; BONI, 1962) assumed no unconformity, and according to this author the Oligo-Miocene succession is fully represented here.

In the meantime DROOGER (1954), in a paper on *Miogypsina* s.l. in the Turin area, showed that the evolutionary series of the Miogypsinids in this area may be used for comparison with the Aquitaine Basin. He concluded that:

1. The base of the Italian "Aquitaniano" is placed lower than that of the type Aquitanian.
2. The upper part of the „Aquitaniano", together with the "Langhiano" of the Turin hills are of Aquitanian age.

Furthermore DROOGER (1956) and DROOGER et al. (1957) suggested that the age Helvetian begins at the level of extinction of *Miogypsina intermedia* and the Tortonian at the first appearance of *Orbulina.* The rock unit "Elveziano" which underlies the type Tortonian, already contains *Orbulina* (GINO et al. 1953). This is in accordance with the common use in the Mediterranean stratigraphy to place the beginning of *Orbulina* at the base of the Helvetian or still lower. The type Helvetian, however, contains no planktonic Foraminifera (RUTSCH, 1958), but from correlation with the Vienna Basin, based on the molluscan fauna, it may be concluded, that the type Helvetian is older than the Tortonian. During the Congress on the Mediterranean Neogene in Berne (1964) it was placed just below the *Orbulina* Zone.

At the same meeting the subdivision of the Miocene was recommended to stay: Aquitanian, Burdigalian, Helvetian, Tortonian and Messinian.

The planktonic foraminiferal zonation from the Langhian type locality near the village of Cèssole in the hilly country of Le Langhe (Southern Piemont) was described by CITA & PREMOLI SILVA (1960). The type section is said to range from the disappearance of *Globigerinita dissimilis* up to, but excluding the *Globigerina mayeri* Zone, thus incorporating, amongst other things, a part of the evolutionary series from *Globigerinoides bisphericus* to *Orbulina.*

CITA & ELTER (1960) correlated the type Langhian with the Aquitaniano, Langhiano and Elveziano in the Turin area, where these strata contain *Miogypsina* s.l. This led to the conclusion that the Langhian of Le Langhe and the Langhiano of the Turin area are of different age.

LORENZ (1962) is of the opinion that the first transgression over the metamorphic basement in Southern Piemont took place during the Late Oligocene, but he maintained his earlier suggestion (1960), that in the area West of the village of Montezémolo it occurred in the Early Miocene. The latter statement was based on the presence of *Lepidocyclina* and *Miogypsina.*

Finally, TEDESCHI & COCCOCETTA (1962) described Late Eocene and Early-Middle Oligocene foraminiferal faunas from the Ranzano sandstones and marls near Costa-Merlassino, a village, some km South of San Sebastiano (text fig. 1).

Chapter III

LITHOSTRATIGRAPHY

1. Introduction

The sediments in the Southern Piemont Basin are almost entirely clastic, varying from coarse boulders and conglomerates to fine pelitic marls and pure clays. There is a certain regularity in the alternation of these deposits, which was interpreted by earlier authors (e.g. PARETO, 1865) as transgressive and regressive phases in the sedimentation.

The passage between coarse and fine-grained beds is usually quite rapid, both vertically and horizontally.

Locally the succession is interrupted by the occurrence of slumped masses (in the hilly ridge of the Catena Montada, Serravalle Scrivia area) or by detritic limestone beds (e.g. the Limestone of Acqui in the Acqui-Molare area).

Due to the rapid lateral change in facies the lithologic correlation of the outcrops in a small area may be doubted, that of the successive lithological units from one composite section to the other appears to be very difficult. In order to avoid any aprioristic correlation between them, it was felt necessary to establish formations and members with their own names in each area. Although an embarrassing quantity of local names thus had to be introduced, we preferred not to omit them after our faunistic correlations.

In the description of the sediments we have used a number of short descriptive terms without dwelling in detail on the various possibilities of composition. No analysis have been carried out. Thus, in using the term "conglomerate", this means that a major part of the components in the bed have a grain size between 2 mm and 4 cm in diameter, including the types of pebble and grit conglomerate. "Boulders" are larger and "sandstone" is smaller. The latter may mean anything from a pure quartzite to a graywacke type of sandstone. The term marl is applied to all pelitic sediments, containing a quantity of shell material and/or calcareous matter, whereas the term clay is used when no reaction was found on the application of hydrochloric acid (10%).

The only limestones identified as such in the field, are the calcarenites (limestones) of Acqui and the Bric Albarella, which do not offer difficulties in terminology.

This terminology is based on field observations only.

2. Description of the sections

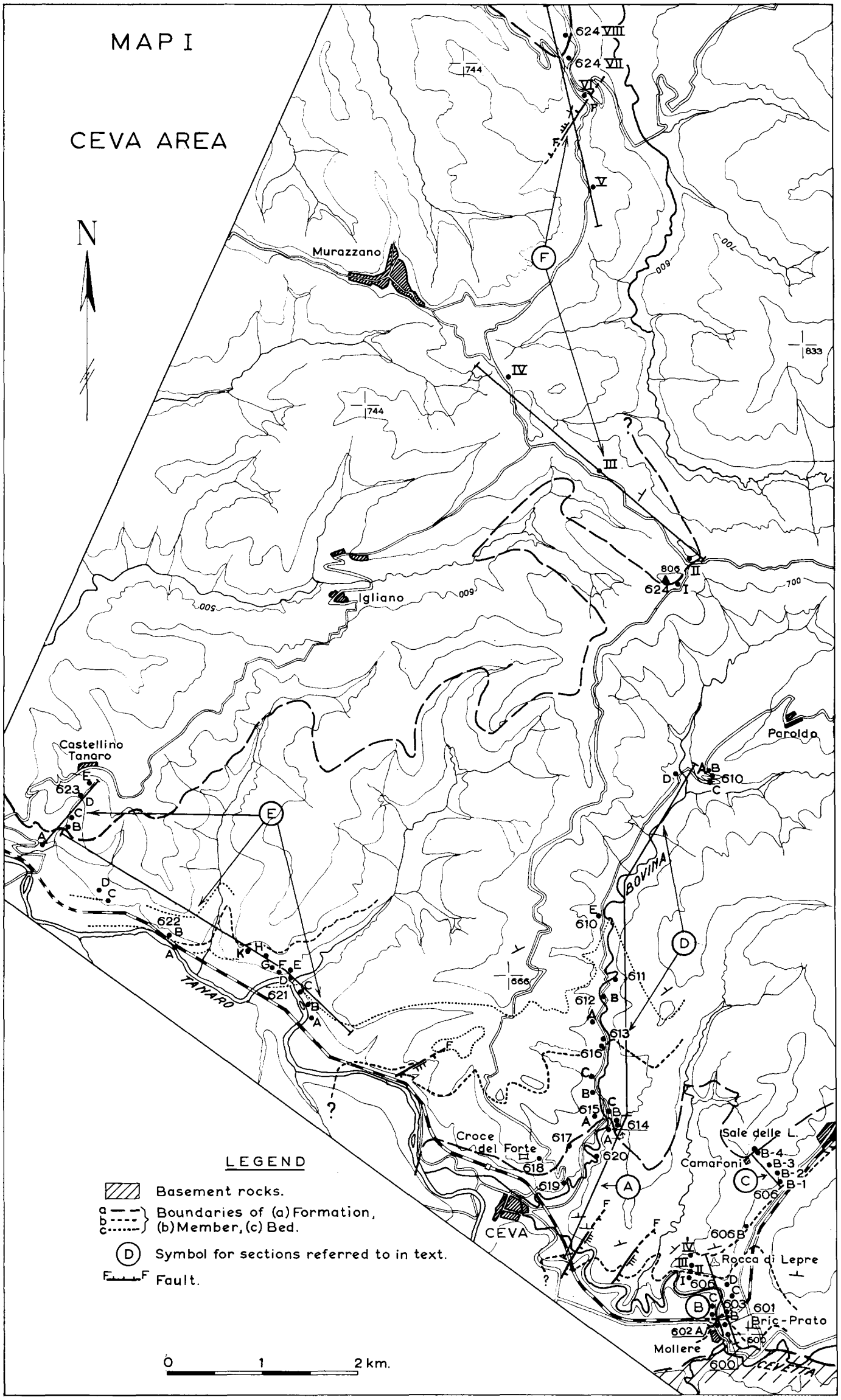
The following five areas with their stratigraphic sequences are described in detail. Their geographic position is shown in text fig. 1.

Section I: **Ceva area,**
Section II: **Spigno Monferrato area,**
Section III: **Acqui-Molare area,**
Section IV: **Serravalle Scrivia area,**
Section V: **Tortona-Garbagna area.**

The location of the stratigraphical columns (Tables I—V) can be found on the corresponding Maps (I—V).

The lithological column in every area is subdivided into formations and members. Their boundaries are primarily lithologic, and generally agree with the limits between the units on the maps of the Italian Geological Survey. Sometimes our subdivision is more detailed.

The sample numbers are placed alongside each column as well as on the map. The intervals between the samples may vary between 1 and 50 m, depending on the outcrops, the importance of formational or faunistic boundaries and on the suitability of the material for extraction of a microfauna.


MAP I
CEVA AREA
N
Murazzano
Igliano
Castellino Tanaro
Paroldo
Croce del Forte
Sale delle L.
Camaroni
Rocca di Lepre
Bric-Prato
Mollere
CEVA
TANARO
BOVINA
CEVETTA
LEGEND
Basement rocks.
Boundaries of (a) Formation, (b) Member, (c) Bed.
Symbol for sections referred to in text.
Fault.
0
1
2 km.

A. **Section I: Ceva area.**

Appendices: Lithostratigraphical columns Table IA—F; Map I.

Introduction.

The thickness of the sequence, in the hills of "Le Langhe", near the village of Ceva, is only 1300 m. This might in the first place be due to the wedging out of the strata near the Southwestern rim of the Piemont Basin (SACCO, 1905b) and secondly it is a consequence of the absence of continuous exposures in the upper portion of the Miocene succession.

Lithologically the stratigraphical column can be subdivided into four units corresponding to sedimentary cycles. The lower two cycles (?) have been united in one formation because of their heterogeneous character and because the upper cycle is indistinct.

In this way the three following formations were recognized: the Ceva, the Tanaro and the Murazzano Formations.

CEVA FORMATION

This formation comprises from bottom to top: the Mollere, Prato, Lepre and Sale Members.

The formation derives its name from the town of Ceva. Thickness: about 250 m. Type section: I B—C.

The lower part is composed of conglomeratic sandstones and of marls, whereas sandstones, clays and very sandy marls form the upper portion. This sequence is rather heterogeneous and the thicknesses of the individual layers differ from place to place, indicating a rapid change of the facies.

The formation overlies the basement. The contact is nicely exposed in the Torrente Cevetta near the village of Mollere (section I B). The surface of the dolomitic underground is very irregular; it shows solution cavities, which are filled with unfossiliferous, layered sandstones. No basal gravel marks the unconformity.

Mollere Member (type section I B).

Indistinctly graded, conglomeratic sandstone beds of approximately 1 meter thickness each, are exposed along the river Cevetta, North of the village of Mollere. The thickness of the member amounts to 40 m. Its most obvious feature is the uniformity of conglomeratic sandstones, between which only scarce marls are intercalated. Locally, the beds contain algal balls and polygenetic pebbles and grit, such as badly rounded grains of serpentine and quartz.

Towards the top of the member the beds contain larger Foraminifera in increasing quantities. LEMOINE & R. DOUVILLÉ (1904) supposed that MICHELOTTI (1861) described *Orbitoides* (= *Lepidocyclina,* subgenus *Eulepidina*) *dilatata* from the uppermost bed. MICHELOTTI's locality is situated about 50 m North of the village of Mollere, where, on the left-hand side of the river, a path branches off from the main road of Ceva and leads towards the railway viaduct over the stream. In fact, many lepidocyclinids occur at this locality.

LORENZ (1959) was the first to study in detail the Mollere Member, on the other, right-hand side of the stream. Among the larger Foraminifera he recorded *Heterostegina* sp. and *Cycloclypeus communis.* He furthermore determined the *Lepidocyclina* (*Eulepidina*) specimens as: *L. dilatata* and *L. roberti.* The *Nephrolepidina* types he described as *L. tournoueri* and a single *L. morgani.*

No specimens of the Miogypsinidae have been found at Mollere, neither by LORENZ, nor by the present author.

On the right-hand side of the valley of the river Cevetta the Mollere Member is conformably overlain by the Prato Member.

Prato Member (type section I B).

Named after the Bric Prato, a hill on the eastern side of the valley and opposite the village of Mollere.

In the outcrops on the northern slope of this hill and in the stream towards the North, about 110 m of sandy to clayey blue-grey marls with rare thin sandstone beds are exposed. At about 50 m above the base occurs a sandy, conglomeratic wedge, from which LORENZ (1960) reported a single specimen of *Miogypsinoides* cf. *complanatus.*

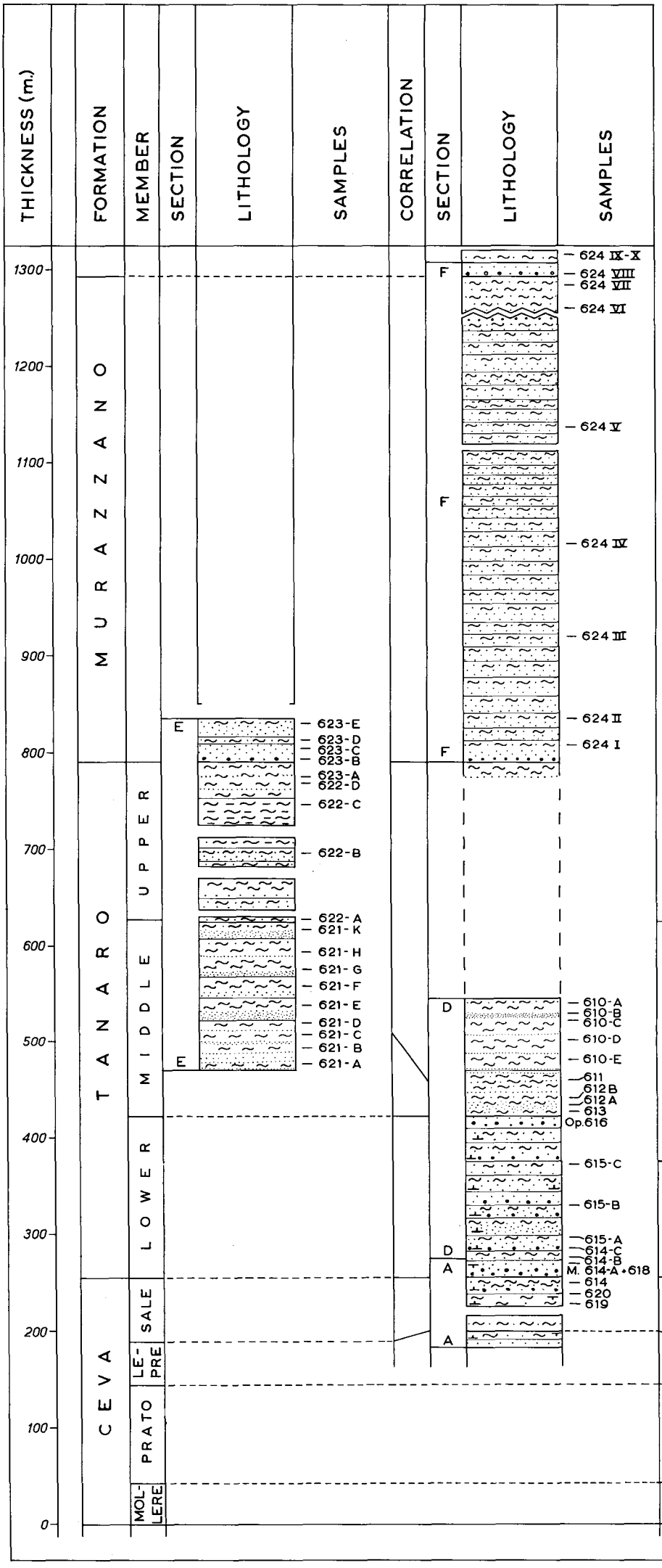
In the same exposure it can be observed that the marls are conformably overlain by the beds of the Lepre Member.

Lepre Member (sections I A and B).

Type section I B.

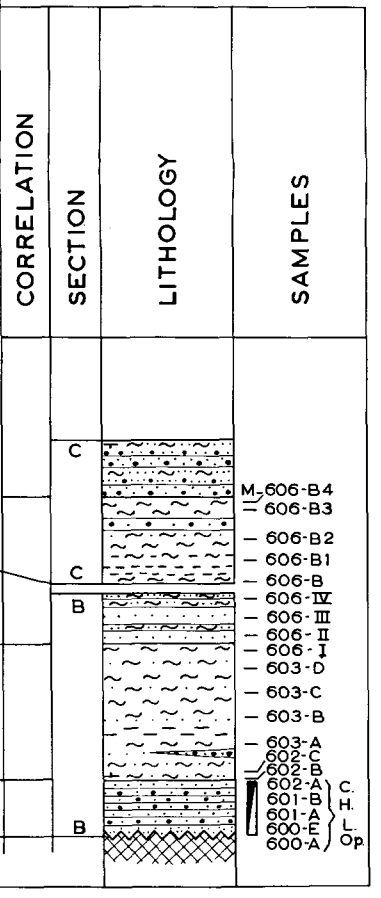
The name of this member is derived from the Rocca di Lepre, in the southern escarpment of which about 40 m of indurated fine sandstones and some very sandy marls are exposed. Whereas the upper boundary of the member in section I B is not clearly distinguishable owing to the

TABLE I: Lithological columns of area I: Ceva.



LEGEND TABLES I - V

- gypsum
- detritic limestone
- calcareous: sand, marl
- marl: pure, slightly sandy, very sandy
- clay: pure, silty-slightly sandy, sandy-very sandy
- sand(stone): fine, coarse
- conglomerate: fine, coarse (boulder)
- etc.: crystalline boulders, algal ball, marl ball
- C=Cycloclypeus
- M=Miogypsina
- H=Heterostegina
- N=Nummulites
- L=Lepidocyclina
- Op=Operculina
- fault
- unconformity
- not exposed, not known
- indurated
- section indicated on the map



vegetation, it can easily be found along the road to the village of Sale delle Langhe, North East of Mollere (section I C). At this exposure, however, coarser-grained sandstones are intercalated in the Lepre Member.

This feature might justify the assumption of LORENZ (1960) that these sandstones correspond to the sandstones of Montezémolo further East, in which he found *Miogypsina gunteri-socini.*

Along the road to Sale delle Langhe one observes on top of the Lepre Member the beds of the Sale Member.

Sale Member (sections I A and C).

Type section I C.

The name of the member is derived from the village of Sale delle Langhe. In section I C about 70 m of rather sandy, greyey marls intercalate with plastic, greenish clays. At about 20 m below the top a sandy layer is found, which becomes thicker and conglomeratic further towards the East. Here, as well as in section I A the contact with the overlying formation is clearly distinguishable.

TANARO FORMATION (sections I D and E).

The name of the formation is derived from the river Tanaro, along which a part of the type section (I E) has been placed.

The formation can roughly be devided into a lower conglomeratic, a middle sandy and an upper marly part, which were not given formal names.

The thickness of the formation amounts to about 520 m.

The lower boundary is clearly visible in the escarpment of the Croce delle Forte, North of Ceva, but it is better accessible along the Rio Bovina (I D). The upper limit can be traced from the neighbourhood of the village of Castellino Tanaro eastwards to about the middle of the investigated area, where outcrops occur along the road from Ceva to Murazzano.

Lower part of the Tanaro Formation (section I D).

Thickness: about 150 m.

The basal part of this unit consists predominantly of conglomerates and sandstones, each bed being about two meters thick. They alternate with beds of sandy marl of about 30 cm. All beds are graded. In the coarser layers some friable specimens of *Miogypsina* were collected (samples: 606 B4, 614 and 618), but they were too ill-preserved for specific identification. In one of the uppermost beds (sample 616) specimens of *Operculina complanata* occur.

Towards the top of the unit the conglomeratic character disappears gradually and the transition to the middle part of the formation is not sharp. The top of the uppermost conglomeratic bed is regarded as the boundary with the overlying part.

Middle part of the Tanaro Formation (sections I D and E).

This unit consists of coarse-grained sandstones, each bed gradually changing into marls. Conglomeratic layers occur sporadically, though they seem to be more frequent in section I E than in I D. The thickness of the individual beds varies from some cm to 1 m, while the thickness of the whole unit is about 200 m.

The upper part of this portion could not be studied in section I D, but it is nicely exposed along the river Tanaro (I E). Here too the contact with the overlying unit is visible and the transitional strata were sampled.

Upper part of the Tanaro Formation (section I E).

About 165 m of marls with some sandy beds are exposed along the river Tanaro, South of the village of Castellino Tanaro. The uniform character of this unit is in marked contrast with the overlying strata.

MURAZZANO FORMATION (sections I E and F).

The name of this formation was derived from the village of Murazzano. This unit consists of about 500 m of graded beds of fine- or coarse-grained sandstones and sandy marls. The yellow-brown weathered colour of the sandstone facilitates the distinction of this formation from the grey marls at the top of the Tanaro Formation. The intercalated marls are relatively thin at the base, whereas they increase in thickness towards the top of the formation, the uppermost 75 m of which consists entirely of uniform sandy marls.

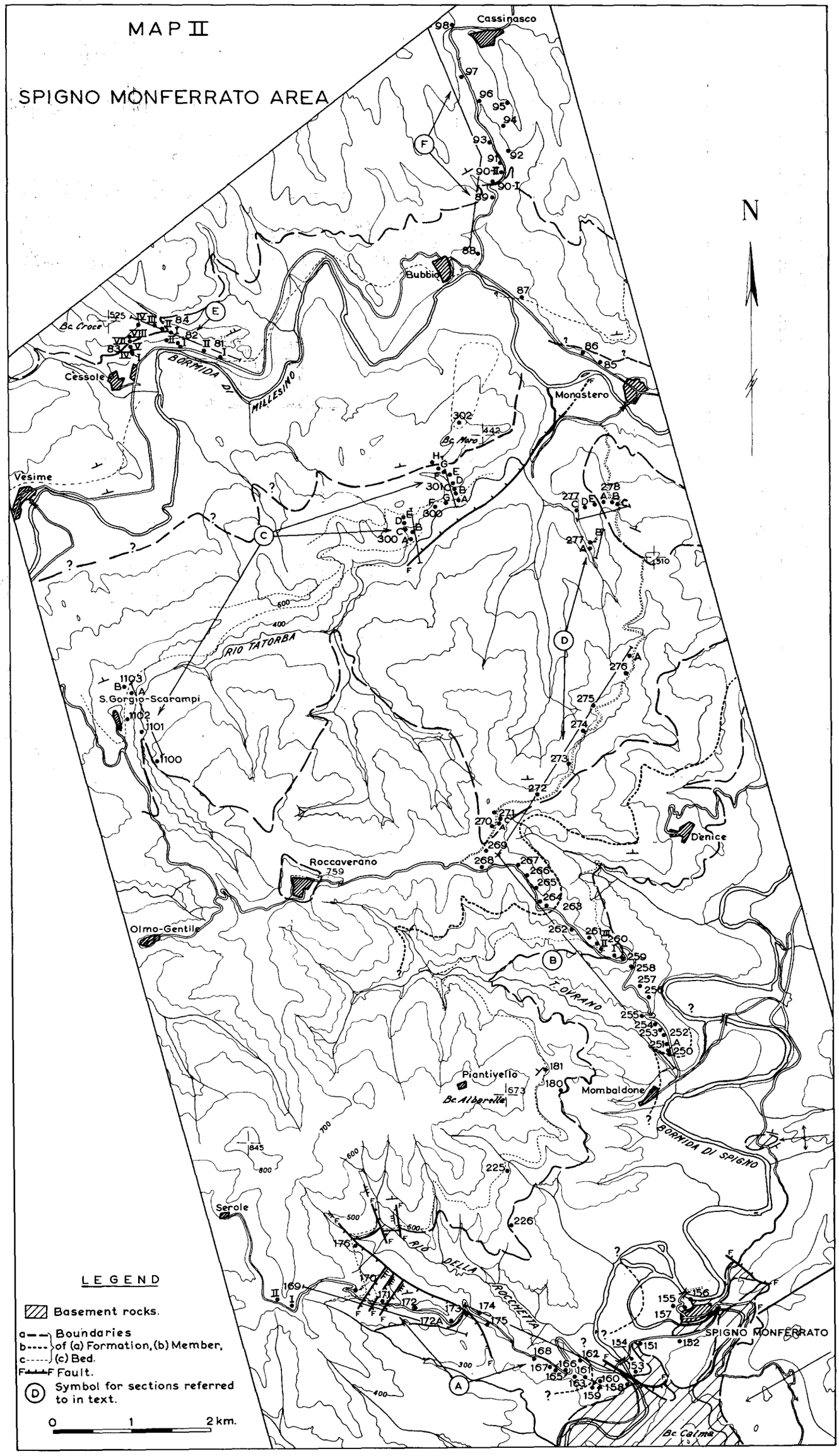
At the top of section I F a next (unnamed) formation again starts with coarse conglomeratic sandstones, which were not studied.

B. Section II: Spigno Monferrato area.

Appendices: Lithostratigraphical columns
Table II A—F, Map II.

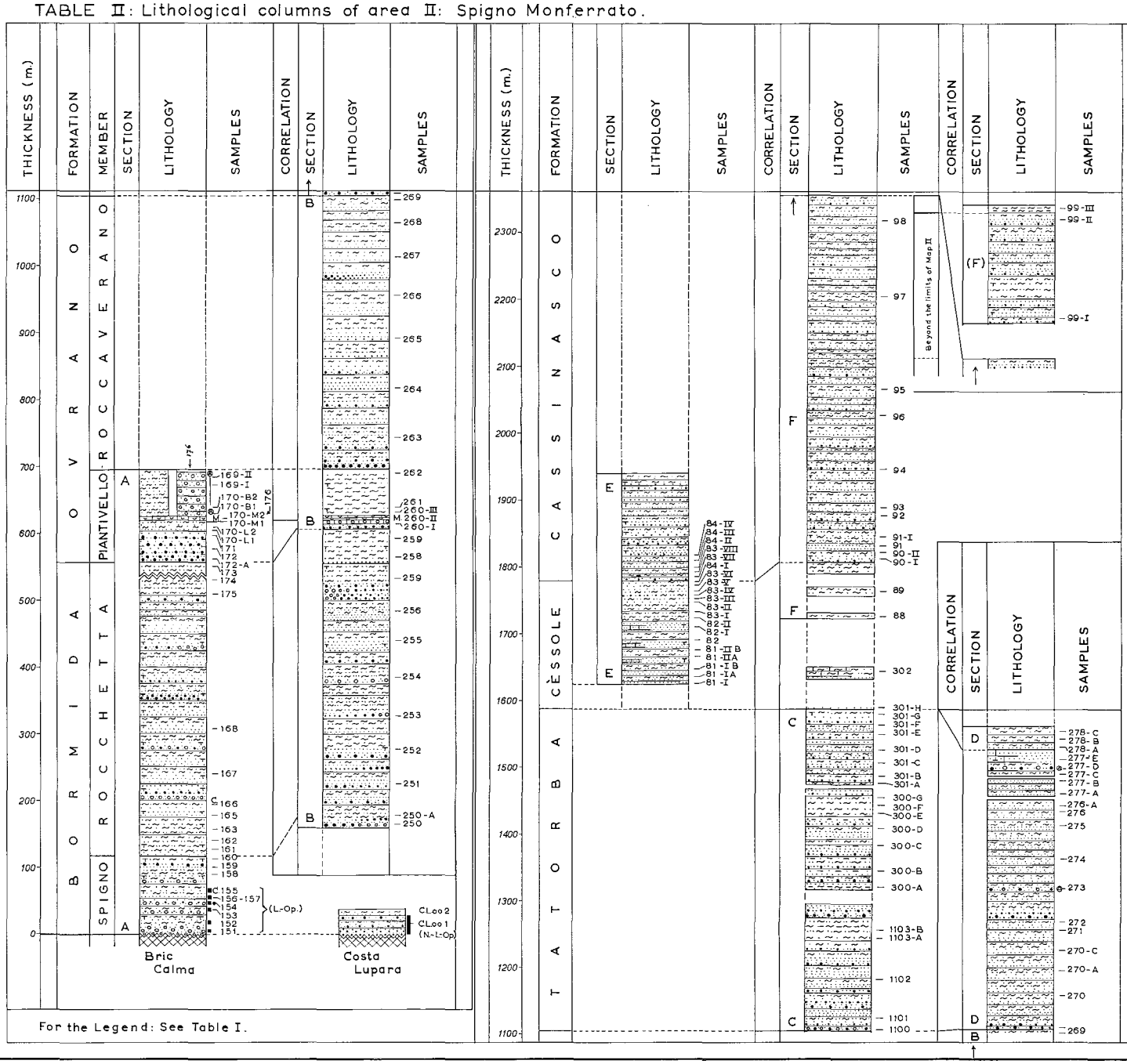
Introduction.

This area has been chosen, because the Langhian has


MAP II
SPIGNO MONFERRATO AREA
N
Cassinasco
Bubbio
Monastero
Cessole
Vesime
Bc. Croce
Bc. Muro
BORMIDA DI MILLESINO
RIO TATORBA
S. Gorgio-Scarampi
Roccaverano
Olmo-Gentile
Denice
Piantivello
Bc. Alberello
Mombaldone
BORMIDA DI SPIGNO
OVRANO
Serole
RIO DELLA ROCCHETTA
SPIGNO MONFERRATO
Bc. Calma
LEGEND
Basement rocks.
a Boundaries
b of (a) Formation, (b) Member,
c (c) Bed.
F Fault.
D Symbol for sections referred to in text.
0 1 2 km.

been defined here (PARETO, 1865). This stage is of particular interest, because CITA & PREMOLI SILVA studied its planktonic foraminiferal zonation recently (1960). Moreover, the locality of Costa Lupara, well known for its larger Foraminifera, can be connected and compared with this section. Finally, the limestone bed of the Bric Albarella (TRABUCCO, 1908) also occurs in this area.

TABLE II: Lithological columns of area II: Spigno Monferrato.



Six subsidiary and parallel sections, and a number of scattered outcrops were studied. Five formations, as shown on Map II, were recognized, from bottom to top respectively: the Bormida, Ovrano, Tatorba, Cèssole and Cassinasco Formations. In our opinion the Tatorba and Cèssole Formations form one unit, but we tried to distinguish between them in accordance with MAYER-EYMAR (1868) who distinguished "Aquitanian" and "Langhian" in this area.

BORMIDA FORMATION (sections II A and B).

Type section II A.

Named after the river Bormida di Spigno, this formation, as defined in section II A, is proposed as type of the Bormidian of PARETO (1865). PARETO did not indicate a stratotype for his stage. Thickness: about 600 m.

The lower contact of the formation is formed by an unconformity and the basal strata, overlying the metamorphic rocks, were studied at two localities: Costa Lupara and Spigno Monferrato. At both places conglomeratic sandstones and conglomerates (even boulders with a diameter of several meters) have been observed, which beds are intercalated locally with thin marls. Near Costa Lupara these beds are rich in pectinids and larger Foraminifera, but near Spigno Monferrato these fossils are poorly represented.

The Bormida Formation is subdivided into two distinct members, the Spigno Member and the Rocchetta Member.

Spigno Member (sections II A and B).

Named after the village of Spigno Monferrato. Thickness of the member: about 115 m.

This member is best exposed near the Bric Calma, 1 km South of the village, in type section I A. Between the hill and the railway station towards the North West, the member is found in a continuous section. Here one observes, on the basement, a layer of about 1 m thickness and composed of well-rounded crystalline boulders. In section II A it is followed by about 110 m of graded conglomeratic sandstones, which become intercalated with marls; the latter increase in quantity towards the top of the member.

The number of larger Foraminifera is disappointingly small. Especially at the base of the member, local accumulations of *Lepidocyclina* and *Operculina* specimens occur in between small reefal structures, but only a few specimens could be separated from the rock. Near the village of Costa Lupara (text fig. 1), however, many larger Foraminifera are found in the conglomerates, mainly *Nummulites* and *Lepidocyclina.* Of this locality R. DOUVILLÉ (1908) described *Lepidocyclina praemarginata* and H. DOUVILLÉ (1924) *Eulepidina eodilatata.*

The first species is studied in this paper.

Rocchetta Member (sections II A and B).

It is named after the Rio della Rocchetta and it consists of about 450 m of sandy marls, in which many graded, more or less conglomeratic sandstone layers occur at irregular intervals. The uppermost 50 m are devoid of sandstone beds. In the coarse layers miliolids are frequent and rare specimens of *Heterostegina* and *Lepidocyclina* occur.

In addition to the typical section along the road to the village of Serole (II A) a parallel section (II B) was sampled near the village of Mombaldone. This section appeared to contain a better microfauna.

The strata overlying the Bormida Formation are distinguished as the Ovrano Formation.

OVRANO FORMATION (sections II A and B).

As type we consider the part of section II B, that is situated on the spur of the hills, running towards the village of Roccaverano and along the road on top, North East of the Torrente Ovrano. The name of the formation was derived from this stream. The thickness is estimated at about 550 m. In section II B two members are distinguished: the Piantivello Member and the Roccaverano Member. Both units are characterized by the predominance of conglomeratic sandstones at the base and of marls near the top.

Piantivello Member (sections II A and B).

The name is derived from the hamlet of Piantivello. The thickness of the member varies from about 140 m in section II A to 90 m in II B, where the basal part is missing?

In section II A this basal part of the member consists of conglomeratic to pure sandstones. Each bed grades from conglomeratic to pure sandstone and has a primary, sedimentary inclination of 5° to 10° to the North West. The following 20 m of indurated sandy marls are intercalated by thin laminated sandstones. On top of these a purely detritic limestone is found, composed almost

entirely of the fragments of algal balls. The thickness of the bed is about 1 m, but it varies from one place to the other. Although its outcrop locally may be absent, the bed can be traced along the dotted line, indicated on Map II. This so-called "Albarella Limestone" of TRABUCCO (1908) is, however, gradually disappearing into northern direction.

Whereas the limestone in section II A is overlain by sandstones and marls, the same bed is superposed by coarse-grained, thick sandstones with algal balls near exposure 176.

In section II B the member is markedly different. Instead of the 90 m of conglomeratic sandstones at the base there are only 10 m of fine conglomeratic sandstones with plant-detritus. Then follows a layer composed of more or less complete algal balls and on top of this the limestone, comparable to that of the section II A. The upper part of the member consists of some 80 m of rather uniform sandy marls.

From these facts it may be clear that the correlation between the sections II A and B would have been very difficult without the use of the limestone.

Roccaverano Member (section II B).

Named after the village of Roccaverano and consisting of about 400 m of, sometimes conglomeratic, sandstones. Each bed grades into marls and varies in thickness from some cm to 1.50 m. South East of the village of Roccaverano and directly above the course of the Ovrano river the sandstone beds are thicker. One clearly observes here that towards the top of the member marls are intercalated in the sandstone in increasing quantities. The village itself, however, is already situated on the basal part of the sandstones of the overlying Tatorba Formation.

TATORBA FORMATION (sections II C and D).

Named after the river Tatorba, along which the composite type section (II C) is situated. The thickness of the formation is here about 475 m. The formation consists of mostly conglomeratic sandstones, each grading into marls (II C). In the section II D the formation differs from the typical in that the sandstones are finer-grained and somewhat reduced in thickness, so that the total thickness of the formation amounts here to 400 m.

The contact with the following formation is indistinct. At the top of the sections II C and D marls become increasingly important, but so gradually that placing a limit is highly arbitrary. According to the Italian Geological Map the boundary (Aquitaniano-Langhiano) is situated at the top of our section II C. In section II D, however, it is found several tens of meters below the top of the section. This boundary is of great importance, because it has been used as the limit between the so-called „Aquitaniano" and the lower portion of the type section of the Langhian, (Bric Moro, CITA & PREMOLI SILVA, 1960).

CÈSSOLE FORMATION (sections II D, E and F).

Thickness: about 200 m.

This formation (type section II E) is named after the village of Cèssole and it corresponds to the main body of the stratotype of the Langhian. It consists predominantly of sandy marls, which gradually replace the sandstones of the underlying formation.

At irregular intervals sandstones occur in the formation and will, towards the top of the formation, predominate over the marls.

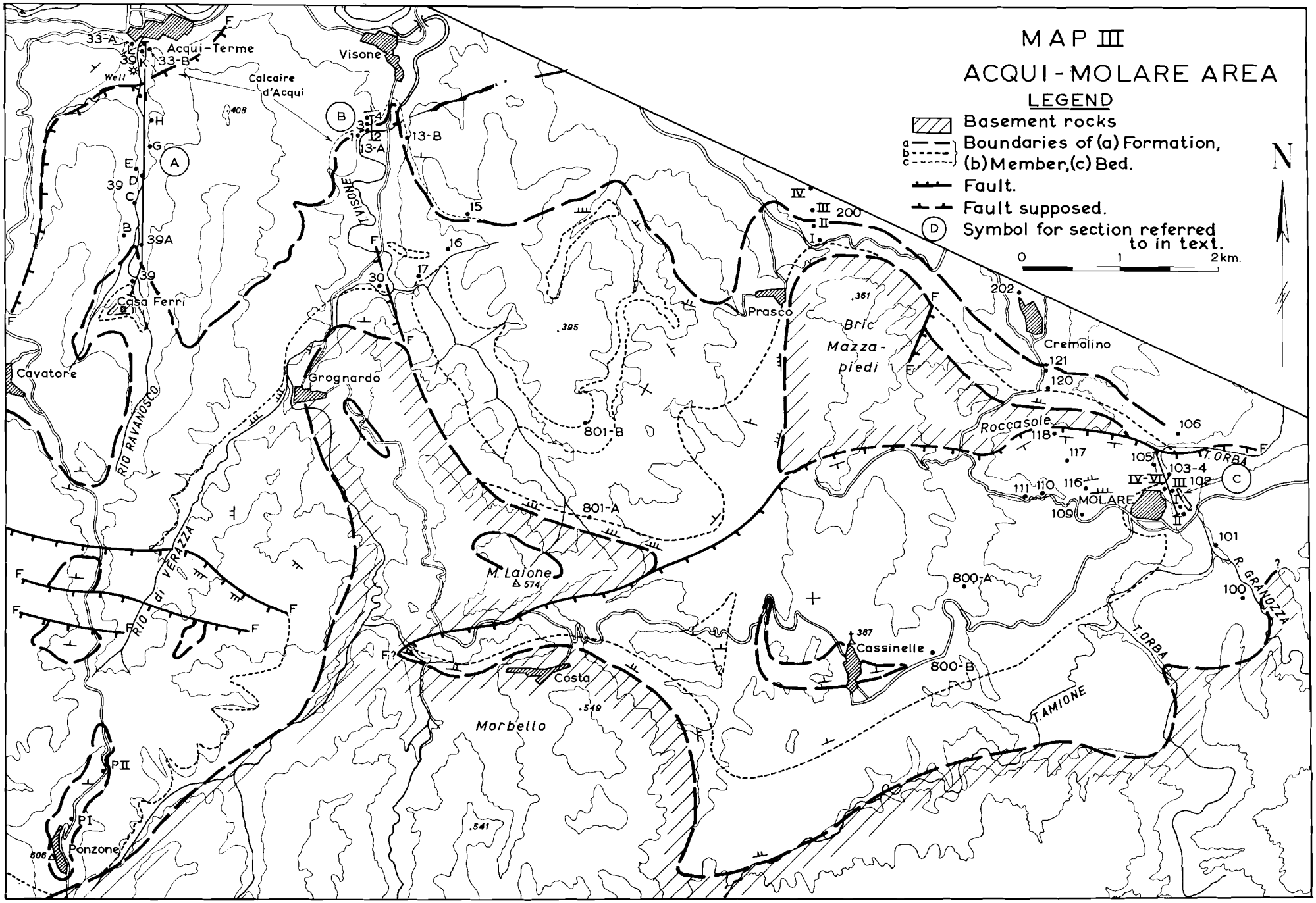
The formation is not completely exposed near the village of Cèssole. The basal part is partly exposed near the sections II D and E. As a consequence an unknown part of the lower end of the formation is lacking in our sections. The upper boundary of the formation was traced from the neighbourhood of Cèssole towards the road Bubbio-Cassinasco. It coincides approximately with the limit between the Langhiano and Elveziano on the Italian Geological Map.

CASSINASCO FORMATION (sections II E and F).

Named after the village of Cassinasco, which is situated along the road from Bubbio to Canelli and on the watershed between the rivers Bormida di Millesimo and Belbo.

The formation is sampled along the road here and that, North of the town of Canelli, towards the village of Ceirole (text fig. 1).

The thickness is estimated at about 700 m and the formation consists of coarse sandstones. Each bed grades into marls and the thickness of the layers varies from some centimeters to meters. Only a few samples were taken, because of the indurated character of the marls.


MAP III
ACQUI - MOLARE AREA
LEGEND
Basement rocks
Boundaries of (a) Formation, (b) Member, (c) Bed.
Fault.
Fault supposed.
Symbol for section referred to in text.
0 1 2km.
N
Acqui-Terme
Visone
Calcaire d'Acqui
Well
Casa Ferri
Cavatore
Grognardo
Prasco
Bric Mazza-piedi
Cremolino
Roccasole
MOLARE
M. Laione
Costa
Morbello
Cassinelle
Ponzone
RIO RAVANOSCO
RIO di VERAZZA
T. VISIONE
T. ORBA
R. GRANOZZA
T. AMIONE

C. **Section III: Acqui-Molare area.**

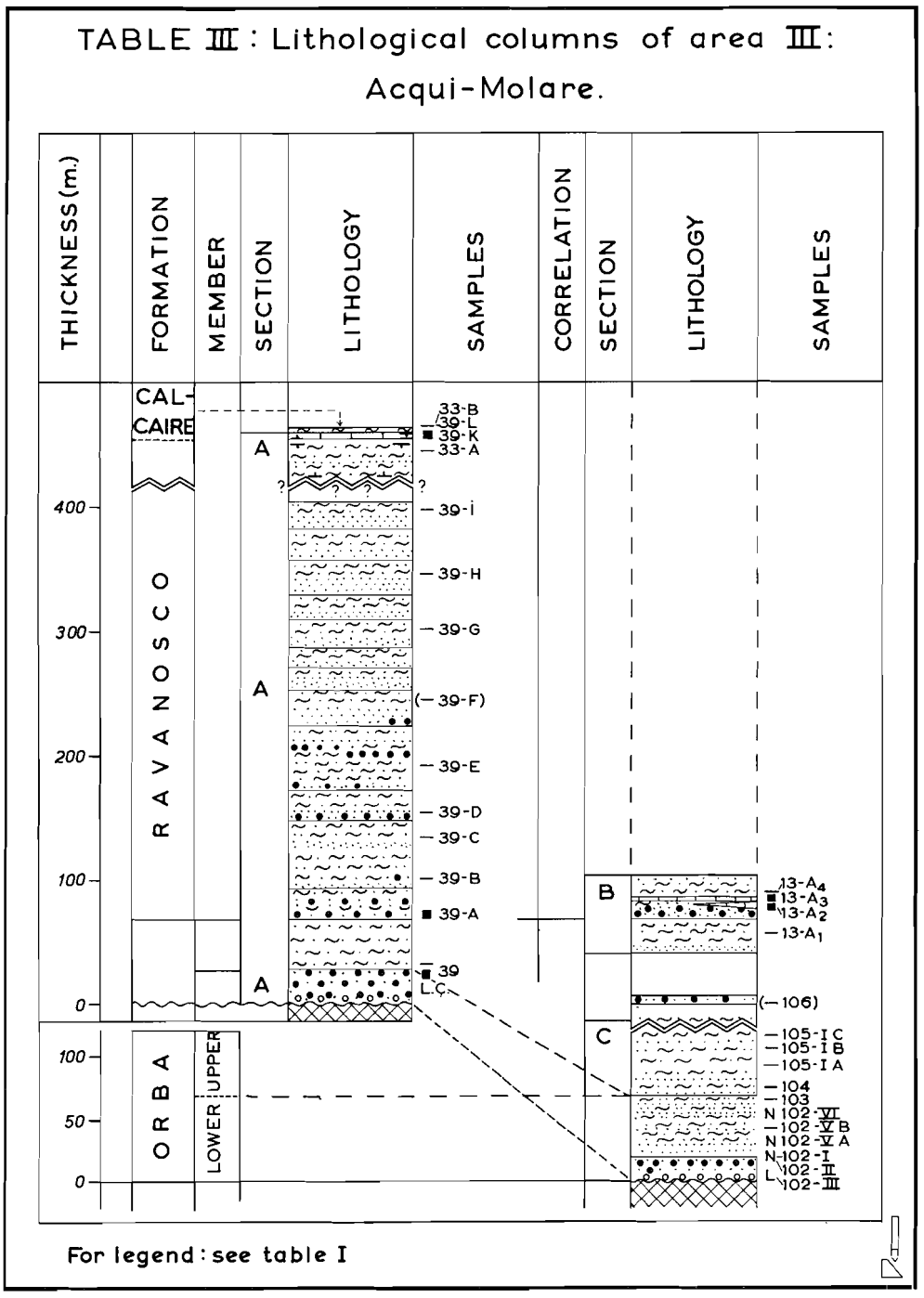
Appendices: Lithostratigraphical columns
Table III, A—C; Map III.

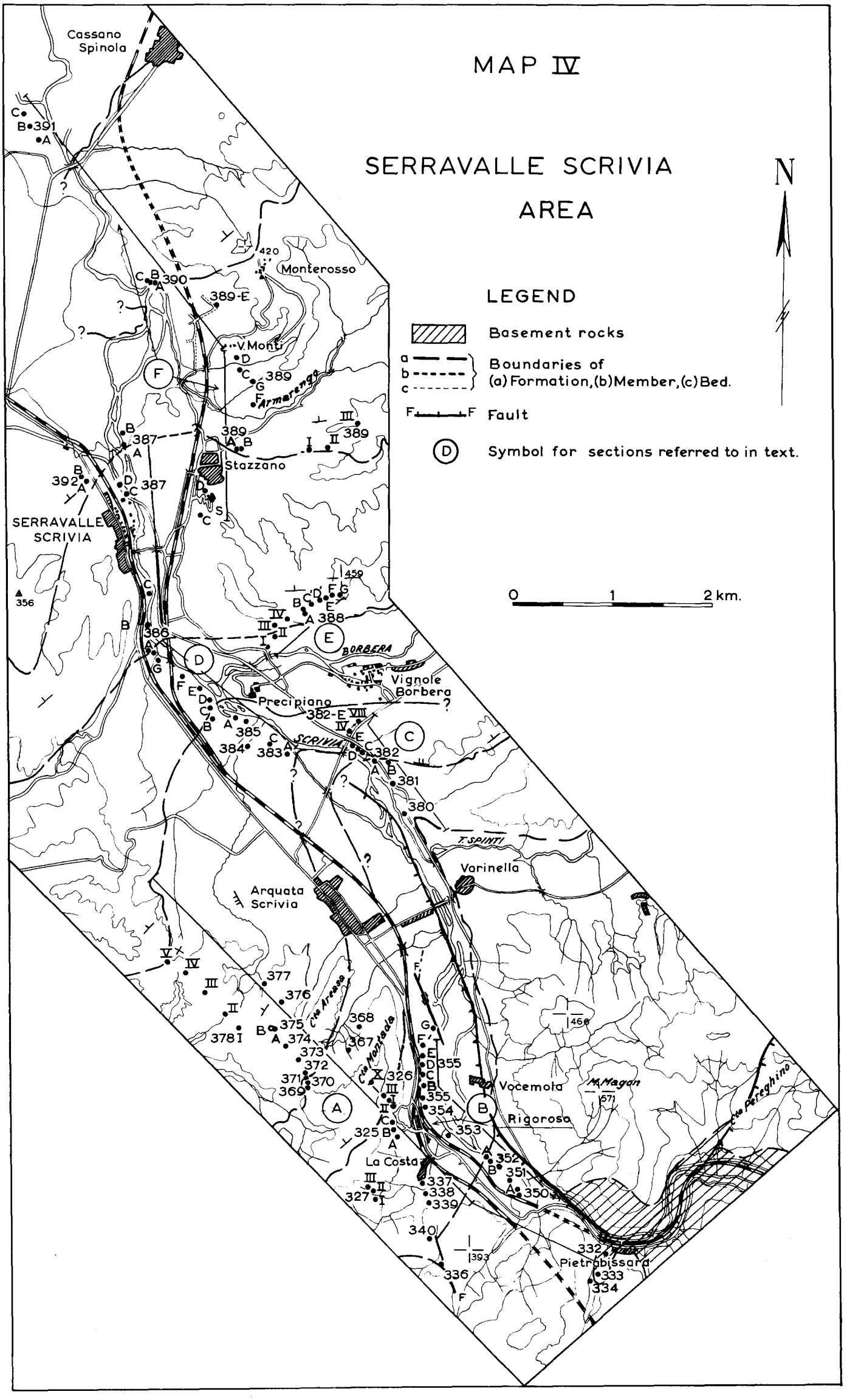
Introduction.

A generalized geologic map of this area was composed. The basement rocks evidently formed an irregular topography already during the sedimentation of the overlying units. As a consequence the lithological features and thicknesses of these units differ from place to place and to such a degree that the correlation between the sections is rather doubtful.

The basement, among other things composed of serpentinic, amphibolitic and gneissic rocks, crops out in the many hills; small exposures are found near Casa Ferri, in the Rio Ravanosco (section III A) and near the village of Molare in the river Orba (section III C).

We distinguished two formations in this region: the Orba Formation and the Ravanosco Formation.




MAP IV
SERRAVALLE SCRIVIA
AREA
N
LEGEND
Basement rocks
Boundaries of
(a) Formation, (b) Member, (c) Bed.
Fault
Symbol for sections referred to in text.
0
1
2 km.
Cassano Spinola
Monterosso
V. Monti
Armarenga
Stazzano
SERRAVALLE SCRIVIA
BORBERA
Vignole Borbera
Precipiano
SCRIVIA
T. SPINTI
Varinella
Arquata Scrivia
Vocemola
M. Magan
Rigoroso
La Costa
Pietrabissara

ORBA FORMATION (sections III A and C).

The type section III C has been studied for its microfauna, while some observations from scattered localities have been included.

Generally speaking, the formation can be subdivided into two parts; the limit between them is indicated as a member line on Map III.

Lower part of the Orba Formation (sections IIIA and C).

This unit consists of graded conglomerates and sandstones, which locally intercalate with marls towards the top. Out-side the typical section (III C) coal beds and plant remains have been found.

The thickness of this portion of the formation shows a great variation from place to place. In the Rio Granozza (South of the village of Molare) it amounts to a 100 m. Near the village only 40 m of boulders and conglomerates occur. The thickness is only a couple of meters near Casa Ferri in the Rio Ravanosco (basal part of section III A).

The association of the larger Foraminifera also differs markedly at these points. *Lepidocyclina* and *Nummulites* were observed in the Rio Orba and in the outcrop of Molare (III C); near Casa Ferri (III A) the conglomerates yielded *Lepidocyclina* and *Cycloclypeus,* whereas at several other points only *Nummulites* occur.

Upper part of the Orba Formation (sections III A, B and C).

This portion consists of uniform sandy marls. In the sections III A and C the thicknesses are 25 m and 35 m respectively. Only in section III C were the marls sampled. Because locally the conglomerates occur very frequently in these marls a distinction with the basal part of the formation is not possible.

On their top, however, a new series of conglomerates and sandstones has been deposited, which forms a distinct outcrop in the field and was used for mapping the area. These beds belong to the Ravanosco Formation.

RAVANOSCO FORMATION (sections III A and B).

Named after the Rio Ravanosco, South of Acqui. The formation consists of at least 300 m of greyey marls and sandstones, which contain especially at the base several meters of conglomeratic, polygenetic sandstones of local importance only. The latter wedge out rapidly, sandstones then forming the base of the formation. But they show up again locally, for instance in section III B, South of the village of Visone. Here a detritic limestone bed is intercalated. The limestone contains numerous fragments of algal balls, large pectinids and teeth of *Carcharodon.* It is known as the "Calcaire d'Acqui" (TRABUCCO, 1893, 1908; DI ALESSANDRI, 1900; SACCO, 1905 b; LORENZ, 1962 b). This limestone is also found in the Rio Ravanosco, South of Acqui, but there exists no direct connection between the outcrops near Acqui and that from Visone. At both localities *Miogypsina globulina* occurs. The relative position of the bed near Acqui can be explained by assuming a fault, the probable location of which is indicated on Map III by a dashed faultline.

The limestone bed at the top of section III A actually belongs at the base of the Ravanosco Formation and is thought to be the lateral equivalent of the conglomerates at its base, in which also *Miogypsina globulina* was observed.

D. Section IV: Serravalle Scrivia area.

Appendices: Lithostratigraphical columns, Table IV, A—F; Map IV.

Introduction.

The section starts where the conglomerates of the Pietrabissara Formation unconformably overlie calcarenites and siltstones of the so-called Albarese of probably Eocene age (many authors; e.g. BONI, 1962).

The subdivision of the stratigraphical column of this section is from bottom to top: Pietrabissara, Rigoroso, Montada, Areasa, Precipiano, Serravalle, Armarengo, Monterosso and Cassano Formations. The Montada and the Areasa Formations together form the "Aquitaniano" on Sh. 82 of the Map by the Italian Geological Survey.

PIETRABISSARA FORMATION (sections IV A and B).

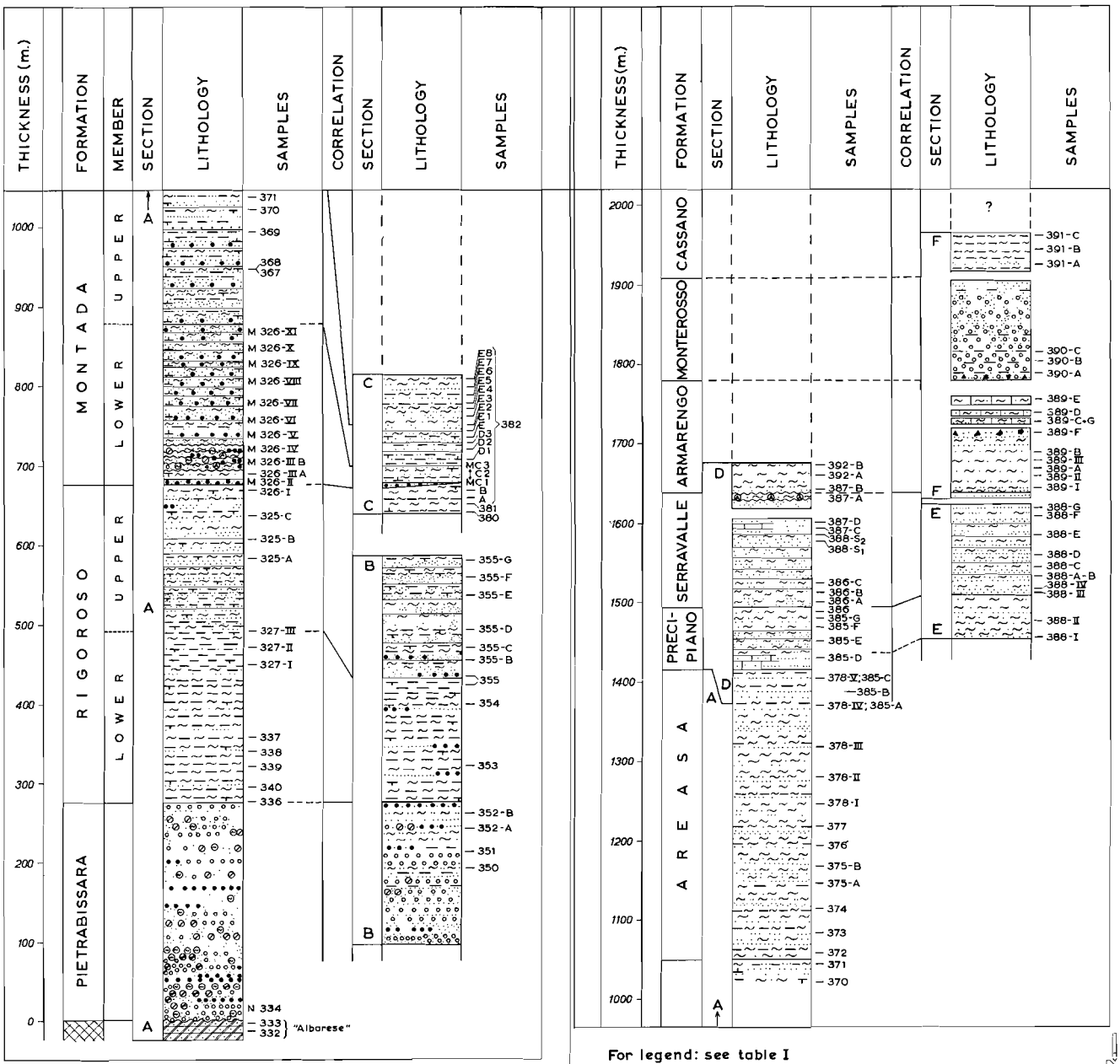
The formation, named after the village of Pietrabissara, consists of polygenetic boulders and gravel in a sandstone matrix which is locally calcareous. Large blocks (up to 0.5 m in diameter) of serpentine, amphibolite, calcarenite and indurated marls were observed in the basal part of the always graded layers.

The thickness of the formation in type section IV A

(near Pietrabissara) is 275 m, but it increases to about 4000 m in eastern direction along the river Borbera („Borbera" conglomerates of VAN DER HEIDE, 1941).

In section IV A the formation ends abruptly, to be succeeded by clayey marls of the Rigoroso Formation, while in section IV B (along the river Scrivia) sandy marls are intercalated near the top. The formation is conformably overlain by the Rigoroso Formation.

TABLE IV: Lithological columns of area IV: Serravalle Scrivia.



RIGOROSO FORMATION (sections IV A and B).

Type section IV A.

About 400 m of indurated, clayey marls are exposed, South and West of the village of Rigoroso, after which the formation is named. In the upper half of the formation sandstones frequently alternate with the marls. Some of these sandstones (near point 327) proved to wedge out in western direction. The separate layers are thicker in section IV B.

MONTADA FORMATION (section IV A).

Named after the hilly range Catena Montada. The formation consists of about 375 m of conglomerates, sandstones and rare marls. At the base about 20 m of indurated marls are included. This is a consequence of the placing of the boundary with the previous formation below the first conglomeratic bed. Above these lowermost 20 m of marls, four layers of conglomerates are exposed, each about 2.5 m thick and grading into marls. In each conglomeratic layer we found haphazardly distributed boulders of crystalline rock, algal and mud balls (several tens of centimeters in diameter) and more or less disconnected parts of layered marls. The latter frequently show convolute bedding, which may also be observed in the general matrix of finer material, which is mainly marl. These features suggest that we are dealing here with slumped masses. They were observed only in the escarpment near point 326-III, and their lateral extension is restricted to several tens of meters.

Towards the top of the formation the conglomeratic character disappears and graded sandstones remain, while silts and some indurated marls begin to alternate with the latter.

The conglomeratic lower 175 m of the formation in section IV A contain Miogypsinidae. The thickness of the corresponding part of the formation in section IV C amounts to only 2 m and some friable *Miogypsina* specimens were found in it too. Further East these beds totally disappear.

The formation is conformably overlain by the Areasa Formation.

AREASA FORMATION (sections IV A and C).

The name is derived from the Catena Areasa. The formation consists of 350 m of clayey marls with thin, graded beds of fine sandstone. The sandstone beds are uniformily distributed over the formation, but more frequent in section IV C than in the type IV A.

In section IV C and near the point where the conglomerates of the Montada Formation disappear (South of the village of Varinelle) a slight angle is observed (5—10°) between the slopes of the Montada and the overlying Areasa beds. An unconformity between the two formations may be assumed at this point.

Section IV A ends exactly at the top of the Areasa Formation. This top was traced towards the Scrivia valley, where the formation, in section IV D, is conformably overlain by the Precipiano Formation.

PRECIPIANO FORMATION (sections IV D and E).

This formation derives its name from the village of Precipiano. It is about 85 m thick and consists of 35 m of mainly indurated calcareous sandstones near the base and 50 m of more marly character at the top. In section IV D — along the Scrivia river — the microfauna is well preserved in the upper part only. The microfauna is still better preserved in the duplicate section IV E, but here the basal part of the formation is not exposed. In both sections this formation is seen to be overlain by the Serravalle Formation.

SERRAVALLE FORMATION (sections IV D and E).

Named after the village of Serravalle Scrivia, this formation corresponds to the Serravallian of PARETO (1865). The type section of the formation is situated in the Scrivia valley (IV D). The thickness of the formation is about 150 m. The best planktonic foraminiferal fauna was taken from the samples at the escarpment, East of the village of Serravalle Scrivia (section IV E).

The formation is composed of sandy marls, which contain sandstones in increasing quantity and thickness towards the top. In section IV D the sandstones are rather coarse and the beds about 2 m thick, whereas in the duplicate section they are somewhat thinner and more marly.

Foreset bedding was observed in the upper part of the formation. The inclination of the foresets is about 5° to the North East, both in the river Scrivia and East of the village of Stazzano.

About 300 m North West of this village a slump-

structure is found in an exposure on the right-hand side of the river Scrivia (point 387 A). An undulating surface is present between the beds, which for the greater part are composed of algal balls in an indurated calcareous matrix.* The slumped beds are included in the Serravalle Formation.

ARMARENGO FORMATION (sections IV D and F).

The formation derives its name from the river Armarengo. Its thickness is estimated at about 150 m. The type section lies on the East side of the river Scrivia, but there is no continuous exposure (section F).

On top of the slumped masses in IV D, sandstones have been deposited, which upwards become gradually replaced by marls. The same transition is present on the foresets at the top of the preceding formation, East of the village of Stazzano. The middle part of the formation consists of calcareous sandstones. These beds are rather concretionary. In some of them fragments of anhydrite occur.

Sandstones and marls occur in the upper part of the formation. The topmost 40 m of the formation are badly exposed because of the vegetation.

MONTEROSSO FORMATION (type section IV F).

The name of the village of Monterosso is used to indicate this formation.

About 150 m of sandy conglomerates with anhydrite blocks in local pockets form the main constituents of the formation. Near the base greenish-black clays rarely occur, alternating with the coarse beds. The formation forms a distinct morphological ridge on the right-hand side of the Scrivia river. Because of the paucity of well-preserved marine clays, only three samples were taken from this formation.

After an unexposed part, the gap of which is estimated at about 25 m, in the river near the bridge of Cassano Spinola, the following formation was distinguished: Cassano Formation.

* A comparable structure of larger scale and probably at the same stratigraphical level, is found near the village of Casteletto d'Orba, some kms to the West. It forms there a morphological ridge, on which the villages of Roccagrimalda, Montaldo, Orsara, Bormida and Strevi are located. The thickness of the slumped mass varies from 1 m near Orsara Bormida to maximally 50 m near Roccagrimalda, where a series of sandstones is involved.

CASSANO FORMATION (section IV F).

The name is derived from the village of Cassano Spinola. The continuous type section is exposed on the western bank of the Scrivia, North of the bridge.

The formation consists of 60 m of greenish-blue clays, which are slightly sandy at some levels. At 2 m above the base of the exposure two dark, glauconite-bearing, coarse sandstones are intercalated.

The top of the formation is not known.

E. Section V: Tortona-Garbagna area.

Appendices: Lithostratigraphical columns,
Table V A—G; Map V.

Introduction.

Below the studied succession of rocks in the Tortona-Garbagna area, a series occurs of about 1000 m of black and purple clays, which alternate with sandstone and limestone beds. This series scarcely contains Foraminifera and is probably of Eocene age (BONI, 1962).

Our investigations started in the region where marls begin to prevail over these "euxinic" clays. This level, near the village of Costa-Merlassino, is several hundreds of meters below the assumed equivalent of the basal conglomerates in the areas I—IV.

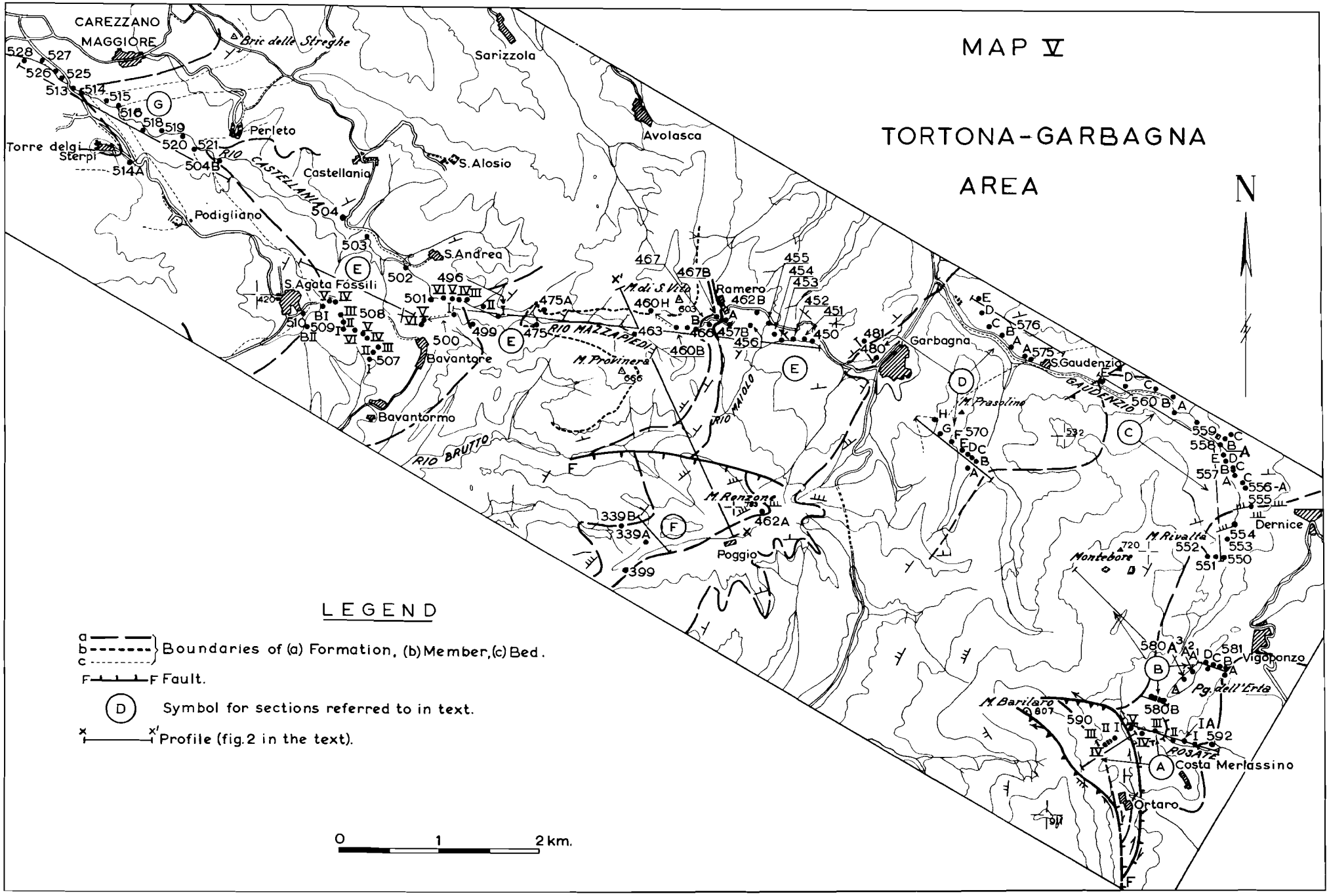
Nine formations were recognized, from bottom to top respectively: the Erta, Gaudenzio, Garbagna, Maiolo, Ronzone, Mazzapiedi, Castellania, Perleto and Carezzano Formations.

Our Mazzapiedi Formation includes the succession, described by GINO et al. (1953) as the „Elveziano" and the Castellania Formation corresponds to the type Tortonian, defined by the same authors. The Tortonian has recently been studied by CITA, PREMOLI SILVA and ROSSI (1964) on its planktonic Foraminifera.

ERTA FORMATION (section V A and B).

The name of the formation is derived from the hill Poggio dell'Erta, North East of the village of Costa-Merlassino. This formation incorporates at the base the Ortaro sandstones of VAN DER HEIDE (1941) and it is the equivalent of the Ranzano Formation of SEGNINI (1962).

TEDESCHI & COCCOCETTA (1962) in their study of the


MAP V
TORTONA-GARBAGNA
AREA
N
CAREZZANO
MAGGIORE
Bric delle Streghe
Sarizzola
Avolasca
Perleto
Torre delgi
Sterpi
RIO CASTELLANI
Castellania
S. Alosio
Podigliano
S. Andrea
S. Agata Fossili
Bavantore
Bavantormo
RIO BRUTTO
RIO MAZZAPIEDI
M. Provinera
M. di S. Vito
Ramero
RIO MALOLO
M. Ranzone
Poggio
Garbagna
S. Gaudenzio
GAUDENZIO
M. Prasolino
Dernice
M. Rivalta
Montebore
Vigoponzo
Pg. dell'Erta
M. Barilaro
ROSATE
Costa Merlassino
Ortaro
LEGEND
a
b
c
Boundaries of (a) Formation, (b) Member, (c) Bed.
F Fault.
D Symbol for sections referred to in text.
x x' Profile (fig. 2 in the text).
0 1 2 km.

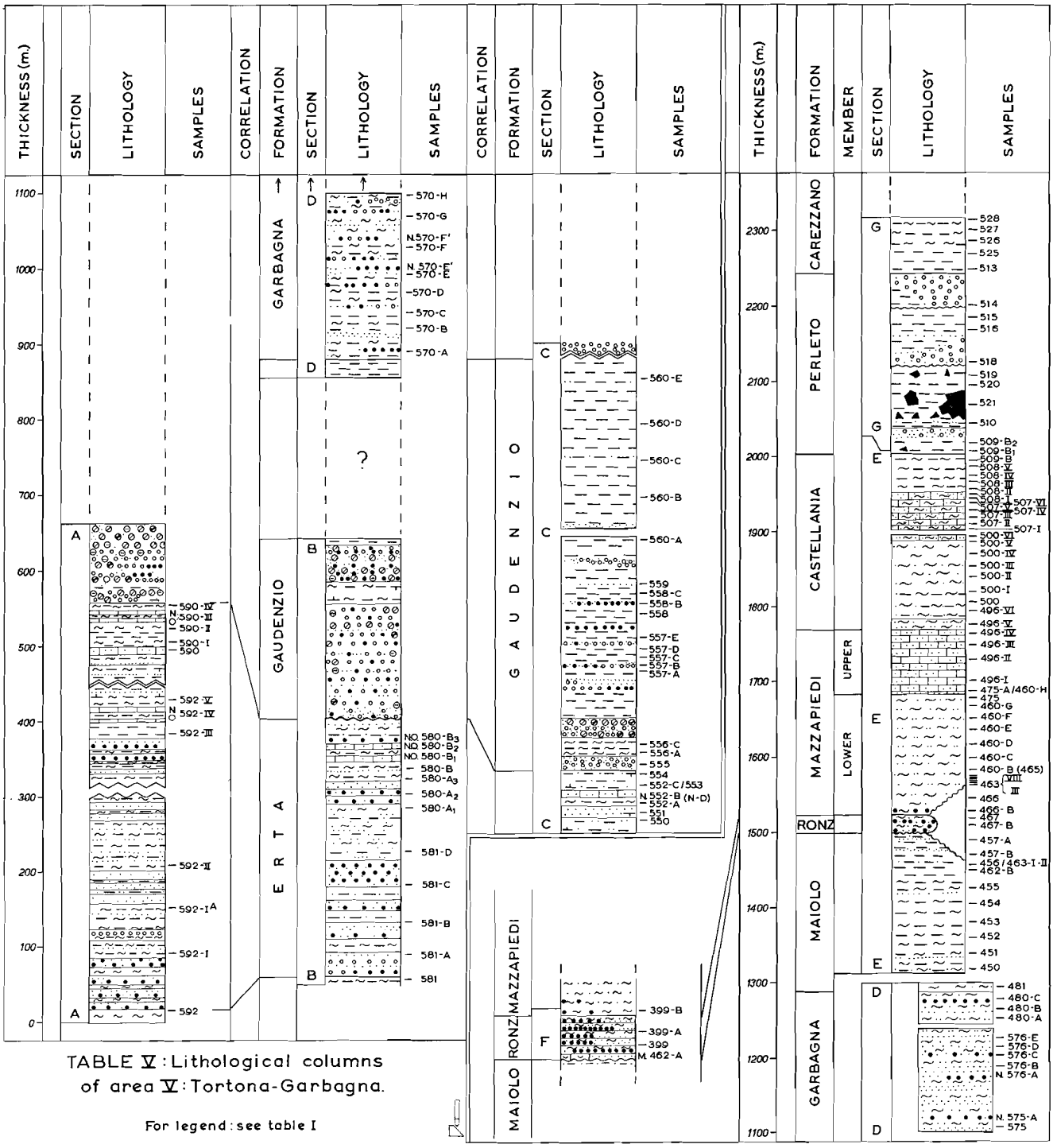


TABLE V: Lithological columns of area V: Tortona-Garbagna.

For legend: see table I

Foraminifera recorded, amongst other things, the planktonic species: *Globorotalia centralis* and *Hantkenina alabamensis*. Approximately at the top of the formation they found calcareous beds with *Nummulites* sp. and *Operculina complanata*.

The type section (V B) of our formation is not tectonically disturbed. The formation consists here of about 350 m of conglomeratic sandstones with intercalated marls of variable thickness. The uppermost 50 m are distinctly more clayey, and this sequence contains up to three calcareous beds, which are almost entirely composed of specimens of *Nummulites* and *Operculina*. At one point (551) some *Discocyclina* were found too.

The Erta Formation is overlain by the Gaudenzio Formation. The contact is locally unconformable.

GAUDENZIO FORMATION (sections V A, B and C).

In the Torrente Gaudenzio, after which this formation is named and where the type section (V C) is situated about 600 m of conglomerates, sandstones and black clays occur. To the North East the conglomerates in the lower part of the formation pass laterally into conglomeratic sandstones in several separate layers, which alternate then with marls and clays. Towards the South West, however, the conglomerates rapidly increase in thickness. At the Montebore hill the clays, overlying the conglomerates, are much diminished in thickness and are now entirely restricted to the upper part of the formation.

In section V C the top of the formation is missing owing to a fault. In section V D it is conformably overlain by the Garbagna Formation.

GARBAGNA FORMATION (section V D).

The formation derives its name of the village of Garbagna. It is exposed in three smaller sections, which form the type. The thickness of the formation amounts to about 400 m. The main constituent of the formation is clayey marl with intercalated beds and lenses of graded conglomeratic sandstones, which increase in thickness from South West to North East, and contain badly preserved reticulate *Nummulites* in several levels.

The upper boundary of the formation is placed on top of the last conglomeratic layer in section V D. The formation is conformably overlain by the Maiolo Formation.

MAIOLO FORMATION (sections V D and E).

The name is derived from the Rio Maiolo, along which the type section is situated (V E). The formation consists of about 200 m of clayey marls, the upper 50 m of which tend to become more clayey. Fine sandstones are intercalated at the top. In the sections V E and F, this formation is unconformably overlain by the Ronzone Formation (fig. 2).

RONZONE FORMATION (sections V E and F).

The name of this formation is derived from the Monte Ronzone (type section V F). Here the formation starts

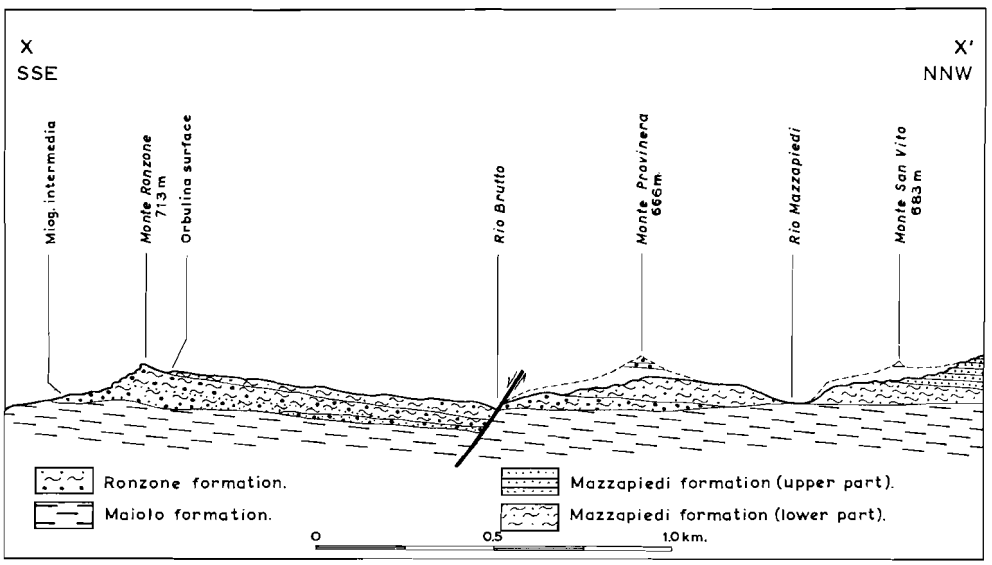


Figure 2
Profile between the Monte Ronzone and the Rio Mazzapiedi (Tortona-Garbagna area).

with 5 meters, composed nearly entirely of detritic limestone with sandy intercalations and containing *Miogypsina.* These beds are overlain by conglomerates with intercalated sandy marls, forming repeated microcycles of about 15 centimeters thickness. Pellets of indurated marl are frequent in the conglomerates. At the Monte Ronzone the entire thickness of the formation is about 50 m. In southwestern direction the separate beds become coarser and thicker, but towards the North East (V E) they tend to disappear. Locally the basal conglomerates suddenly increase to 10 m, filling depressions in the underlying marls and giving the lower contact of the formation a wavy appearance. On this ground an unconformity is assumed (text fig. 2).

In section V E the thickness of the formation is reduced to 15 m. The formation becomes thinner and wedges out in northern direction. At the unconformity (point 463), which is in fact a disconformity — in the Rio Mazzapiedi — the formation appeared to be absent (text fig. 2). Towards the West the formation is conformably overlain by the Mazzapiedi Formation.

MAZZAPIEDI FORMATION (sections V E and F).

The name of this formation is derived from the Rio Mazzapiedi. The type section is situated in the escarpment of the Monte San Vito and along the course of the river (V E).

In table V, the left-hand side of the lithological column represents the succession of the strata, found along the road from the village of Ramero towards the Monte San Vito. The right-hand side pictures the situation at point 463 in the Rio Mazzapiedi, where the formation unconformably overlies the Maiolo Formation. The thickness of the formation varies from about 250 m along the road section near Ramero towards the Monte San Vito, to about 225 m, starting at the point 463 in the Rio Mazzapiedi, where the lower part is absent.

Text fig. 2 shows the assumed development of the Ronzone Formation, it gives a possible explanation for the unconformity in the Rio Mazzapiedi.

The formation consists of 150 m of uniform sandy marls at the base and about 100 m of calcareous sandstones at the top. These sandstones show foresetbedding with an inclination in northwestern direction. The formation is conformably overlain by the Castellania Formation.

CASTELLANIA FORMATION (type section V E).

Named after the Rio Castellania, the formation consists of a sequence of 30 m of marls and clayey sand at the base, followed by about 85 m of sandy marls, 60 m of calcareous sandstones and marls, and 60 m of clayey marls. This succession of strata has partly been sampled in the Rio Castellania and partly on the crest of the hills between the villages of Bavantore and Sant' Ágata Fóssili.

The formation is conformably overlain by the Perleto Formation.

PERLETO FORMATION (sections V E and G).

The name is derived from the village of Perleto. The formation (type section V G) consists of about 225 m of dark clays with large anhydrite masses (quarried at some places) and three layers of conglomerates and sandstones. On the conglomerates we find the villages of Sant' Ágata Fóssili, Podigliano and Torre degli Sterpi. The conglomerates are thicker in the Rio Castellania than along the road between the villages. The top of the formation is placed on top of the highest conglomerate in succession where the formation conformably is overlain by the Carezzano Formation.

CAREZZANO FORMATION (type section V G).

The formation, which derives its name from the village of Carezzano Maggiore, consists of only 75 m of dark, marine clays, which are exposed in the stream. No upper limit of this formation could be established.

3. The types of earlier described stages

In text figure 3 all the formations and members, studied in the different sections, have been compiled and placed in the relative position where they should belong according to the Geological Maps of Southern Piemont.

For convenience, the stages described from Southern Piemont by Mayer Eymar (1857) and Pareto (1865) are brought in memory here below. These are the:

1. *Bormidian* (Pareto, 1865) = Tongriano and Stampiano of Sacco (1888) = Sannoisian, Stampian and Aquitanian of Rovereto (1914) = Stampian and Aquitanian of Lorenz (1962).
2. *Langhian* (Pareto, 1865), emended Mayer Eymar (1868) as follows : basal part = Aquitanian; upper

Age	Units It. Geol. map	Section I	Section II	Section III	Section IV	Section V
Plioc.	PIACENZIANO				CASSANO Form.	CAREZZANO F.
Miocene	MESSINIANO				MONTEROSSO F.	PERLETO F
	TORTONIANO				ARMARENGO F.	CASTELLANIA F.
	ELVEZIANO	MURAZZANO F. TANARO F.	CASSINASCO F.		SERRAVALLE F.	MAZZAPIEDI: Upper part
	LANGHIANO	CEVA FORMATION: SALE M.	CÈSSOLE F.		PRECIPIANO F.	MAZZAPIEDI: Lower part
	AQUITANIANO	CEVA FORMATION: LEPRE M.	TATORBA F. OVRANO F.	RAVANOSCO F.	AREASA Form. MONTADA Form.	RONZONE F.
Oligocene	STAMPIANO	CEVA FORMATION: PRATO M.	BORMIDA F.: ROCCHETTA Member	ORBA F.: Upper part	RIGOROSO F.	MAIOLO Form.
	TONGRIANO	CEVA FORMATION: MOLLERE M.	BORMIDA F.: SPIGNO Member	ORBA F.: Lower part	PIETRABISSARA	GARBAGNA F. GAUDENZIO F.
Eoc.						ERTA Form.

Figure 3
Formations and Members of the sections I—V, and their arrangement, according to the Italian Geological Maps.

part = Langhian s.s.; emended by SACCO (1888) : Langhian s.s. including the transitional strata at the top. In the last sense, its zonation is described by CITA and PREMOLI SILVA (1960) from the strata near the village of Cèssole, = our Cèssole Formation (Spigno Monferrato area).

3. *Serravallian* (PARETO, 1865) = Elveziano of SACCO (1888). The type section is that of our Serravalle Formation (Serravalle Scrivia area) designated in this paper.
4. *Tortonian* (MAYER, 1857). Type section, designated by GINO et al. (1953) in the Rio Castellania, = our Castellania Formation (Tortona-Garbagna area).

Chapter IV

BIOSTRATIGRAPHY

1. Introduction

Of each section an idealized column is formed (Tables VI—X), in which the formations are represented by correct thicknesses of their types.

The symbols in the sample columns have the following meaning:

- ○ sample devoid of planktonic Foraminifera;
- ● sample with planktonic Foraminifera;
- □ sample with larger Foraminifera (field observations only);
- ■ sample with determined larger Foraminifera.

In the distribution columns a similar use of symbols is applied to indicate the relative frequency of the species in comparison to one another and in comparable quantities of washresidue:

• very rare; ○ rare; ◐ common; ● abundant.

On the basis of the distribution of the planktonic Foraminifera in all sections a number of 10 biozones has been recognized. These zones are from the basis to the top respectively: the *semiinvoluta, cerro-azulensis, Globigerina, Globigerinoides-Globoquadrina, Globorotalia, bisphericus, Orbulina, menardii, nepenthes* and *obliquus* Zones. With the exception of the *semiinvoluta* and *cerro-azulensis* Zones, all are based on the first appearance of the selected genera or species, from which the zones derive their names.

Not all zones are present in every section; because of the unconformity at the base of the sections I—IV the *semiinvoluta* and *cerro-azulensis* Zones are lacking there. In some of them even the *Globigerina Zone* is lacking, the equivalent of which, however, could be found by way of the investigation of some larger Foraminifera at some localities.

The recognition of zonal boundaries within the sections is in many cases hampered by the absence of planktonic Foraminifera. If, after a gap in the record new zonal markers make their appearance the lower boundary of the zone is uncertain, for instance that of the *Globorotalia* Zone on table IX (section IV).

2. A. Planktonic foraminiferal zonation

I. *Semiinvoluta* Zone.

This zone is only present in the Tortona area. It is characterized by the range of *Globigerapsis semiinvoluta.* Throughout this zone *Globorotalia centralis* occurs and questionable *Globigerina ampliapertura* is present. Not restricted to this zone are: *Globorotalia cerro-azulensis, Globigerina increbescens, Globigerina tripartita, Globigerina globularis* and *Globigerinita dissimilis.*

The lower boundary of this zone was not investigated. In contrast with the record of Tedeschi & Coccocetta (1962) we did not find *Hantkenina alabamensis.*

At the top of the zone abundant *Nummulites* sp. 1 and *Operculina* sp. occur in several layers but only at one locality did we find *Discocyclina.*

II. *Cerro-azulensis* Zone.

Again only present in the Tortona area. The zone ranges between the disappearance of *Globigerapsis semiinvoluta* and that of *Globorotalia cerro-azulensis.*

Towards the top of the zone *Globigerina bulloides* and *Globigerina opima nana* make their appearance. As this zone contains poor faunas the base of the following zone can not be placed accurately. *Nummulites* sp. 2 is present in several layers near the top of the zone.*

III. *Globigerina* Zone.

This zone starts after the disappearance of *Globorotalia cerro-azulensis* and reaches as far as the appearance of *Globigerinoides* and/or *Globoquadrina* species. Only in

* Here we also found some *Pseudohastigerina micra* and doubtful *Globigerina gortanii* (not in the table).

section V (Table X) can the basis of this zone be given approximately. In this section *Globigerina bulloides* comes to full development, together with *Globigerina* cf. *regularis, Globigerina tripartita* (*tripartita, venezuelana, rohri, sellii*) and *Globigerina ampliapertura.* In the upper part of this zone *Globigerina angustiumbilicata* appears, but this species is recognized only in section V (Table X).

The following larger Foraminifera were observed: *Cycloclypeus* sp., *Heterostegina* sp., *Operculina* sp., *Lepidocyclina* (*Eulepidina*) *dilatata* and *Lepidocyclina praemarginata.* This association is known, more or less complete, from the localities of Mollere, Spigno Monferrato (without *Nummulites*), and of Costa Lupara and Molare (with *Nummulites*).

These associations with *Lepidocyclina praemarginata* are probably of the same age as the *Globigerina* Zone here.

IV. *Globigerinoides-Globoquadrina* Zone.

This zone ranges from the onsets of *Globigerinoides* or *Globoquadrina* to that of *Globorotalia scitula.*

The onsets of the former genera approximately coincide in the sections I—IV. In section V this level is less distinct.

If discernible the following additional species can be found in this zone: *Globigerina angustiumbilicata, G. obesa, G. concinna, G. mayeri, G. bulloides, G. globularis* and *Hastigerina siphonifera.* Also *Globigerina tripartita* and *Globigerinita dissimilis* are fairly frequently observed.

All localities with *Miogypsina* belong in this zone. *Miogypsina gunteri* lies above the base of this zone. From one locality LORENZ (1959) reported *Miogypsinoides* cf. *complanatus,* which occurrence also belongs to this zone (section I, Prato Member).

V. *Globorotalia* Zone.

This zone ranges from the onset of *Globorotalia scitula* to the appearance of *Globigerinoides bisphericus.* It contains, moreover, representatives of the *Globoquadrina altispira* group. *Globigerinoides trilobus* is abundant in this zone, as are locally: *Globoquadrina dehiscens* and *Globigerina mayeri. Globigerina tripartita* and *Globigerinita dissimilis* are rare and do not range beyond the lower $\frac{3}{4}$ of the zone. No larger Foraminifera are found. The zone is absent in section V E, at the disconformity in the Rio Mazzapiedi (point 463).

VI. *Bisphericus* Zone.

This zone ranges from the first record of *Globigerinoides bisphericus* to that of *Orbulina glomerosa,* both species belonging to the evolutionary series from *Globigerinoides trilobus* to *Orbulina universa* (BLOW, 1956).

The accompanying fauna is atypical and differs from the preceding one in that *Globigerinita dissimilis* and *Globigerina tripartita* are absent. The zone was recognized in all sections with the exception of the Tortona area, where it is lacking at the disconformity in section V E (point 463).

VII. *Orbulina* Zone.

The zone ranges from the beginning of *Orbulina gloglomerosa* to that of *Globorotalia menardii* s.l. Its base represents the *Orbulina* surface.

A further subdivision of this zone was omitted, because of the bad preservation of the specimens of *Orbulina.* The successive appearance of *O. glomerosa, O. suturalis* and *O. universa* could occasionally be traced.

The *Orbulina* Zone is present in all sections. The upper boundary of this zone, however, has not been encountered in every section.

In this zone all species present in the preceding one, are recorded in it too; in addition some *Globorotalia barissanensis* are present.

VIII. *Menardii* Zone.

This zone is based on the first appearance of keeled *Globorotalia* in our sections. In the sections II, IV and V the first keeled specimens resemble *Globorotalia menardii miotumida;* in section IV F they are true *G. menardii* in the marls. But the record in the sections is too scarce, probably due to facial circumstances, to be more definite about the influence of the environment on the variations of this species. The accompanying fauna is identical to that of the preceding zone.

IX. *Nepenthes* Zone.

The appearance of *Globigerina nepenthes* in the sections is not very distinct due to the scarcity in the record. The zone ranges from the appearance of this species to that of *Globigerinoides obliquus.* The accompanying fauna is not distinct: *Globigerina bulloides, G. globularis, G. obesa, G. concinna, G. angustiumbilicata, G. mayeri, Globorotalia scitula, Globigerinoides trilobus, G. bisphe-*

ricus, Globoquadrina dehiscens, G. altispira, Hastigerina siphonifera, Orbulina suturalis and *O. universa.*

The first though scarce record of *Globigerina nepenthes* in the Tortona area (Table X) is somewhat lower than that of CITA, PREMOLI SILVA & ROSSI (1964).

X. *Obliquus* Zone.

Compared with the areas outside the Mediterranean *Globigerinoides obliquus* appears much later (COLOM, 1955; REISS & GVIRTZMAN, 1964). Also in Southern Piemont a datum plane might be based on the appearance of this species, which is frequently observed, whereas *Globigerinoides ruber pyramidalis* is scarcely known in the zone. Also *Globoquadrina* specimens and *Globigerina mayeri* were rarely encountered.

Globigerinoides obliquus obliquus seems to evolve into *G. obliquus elongatus* within a short interval.

The accompanying fauna is not typically different from that of the preceding zone. The entire assemblage tends to disappear towards the top of the Tortonian, according as benthonic Foraminifera become increasingly important. Aberrant forms were observed, as did DI NAPOLI (1952).

The base of the zone is recorded from the sections II, IV and V.

Only the sections IV and V do reach into the base of the Pliocene. No other characteristic species were observed at the top of these sections, by which the zonation could have been extended (cf. MARTINIS, 1954; CITA, PREMOLI SILVA and ROSSI, 1964).

2. B. ZONATION BY MEANS OF LARGER FORAMINIFERA.

In the preceding part some associations of larger Foraminifera were recorded in the *semiinvoluta, cerro-azulensis, Globigerina* and *Globigerinoides-Globoquadrina* Zones.

PRÉVER and R. DOUVILLÉ (1905) proposed a zonation of the Oligocene-Miocene in Piemont by means of the occurrence of *Nummulites,* the relative decrease in frequency of *Lepidocyclina* and increase of *Miogypsina* in successive levels.

In 1908 R. DOUVILLÉ described *Lepidocyclina praemarginata* from Costa Lupara, and he supposed it to be more primitive than *Lepidocyclina marginata* in the Turin hills.

H. DOUVILLÉ (1925) described *Eulepidina eodilatata* from the same locality and considered this species to be more primitive than *Eulepidina dilatata* from Mollere.

The present biozonation is partly based on associations, and partly on the lineages in the nephrolepidinids and miogypsinids.

1. An association of *Nummulites* and *Discocyclina* was found at about the top of the *semiinvoluta* Zone, together with a planktonic foraminiferal fauna, characterized by *Globigerapsis semiinvoluta, Globorotalia centralis* and *G. cerro-azulensis.*

2. An association of reticulate *Nummulites* was found at the top of the *cerro-azulensis* Zone. The accompanying planktonic fauna consists of *Globorotalia cerro-azulensis, Globigerina bulloides* and *Globigerina opima nana.*

3. The associations, characterized by the presence of *Lepidocyclina praemarginata* and the absence of miogypsinids, are approximately equivalent to the *Globigerina* Zone. The accompanying fauna consists of *Eulepidina, Cycloclypeus* and *Heterostegina;* reticulate *Nummulites* may be present. This association was observed at the localities: Mollere, Costa Lupara, Spigno Monferrato and Molare.

4. An association of *Lepidocyclina morgani* with *Miogysinoides complanatus,* but without *Eulepidina* or *Nummulites,* is lacking in Southern Piemont, but it is known from the Turin hills (DROOGER & SOCIN, 1959). *Miogypsinoides* is known to occur in association with *Globigerinoides trilobus* (DROOGER, 1956; DROOGER & MAGNÉ, 1959). A single *Miogypsinoides* cf. *complanatus* has been found in the Prato Member (LORENZ, 1960; Ceva area) in the *Globigerinoides-Globoquadrina* Zone above the association, mentioned under point 3.

5. In the latter planktonic zone we furthermore found in successive levels: *Miogypsina gunteri* (together with indeterminable *Miogypsinoides*), *Miogypsina socini* and *Miogypsina globulina* (Scrivia area). *Miogypsina globulina* and *Miogypsina intermedia* were found in some of the other sections. All miogypsinids occur above the *Globigerinoides* surface and below the *Orbulina* surface. The beds with *Miogypsina* species can be correlated with the type Aquitanian and Burdigalian.

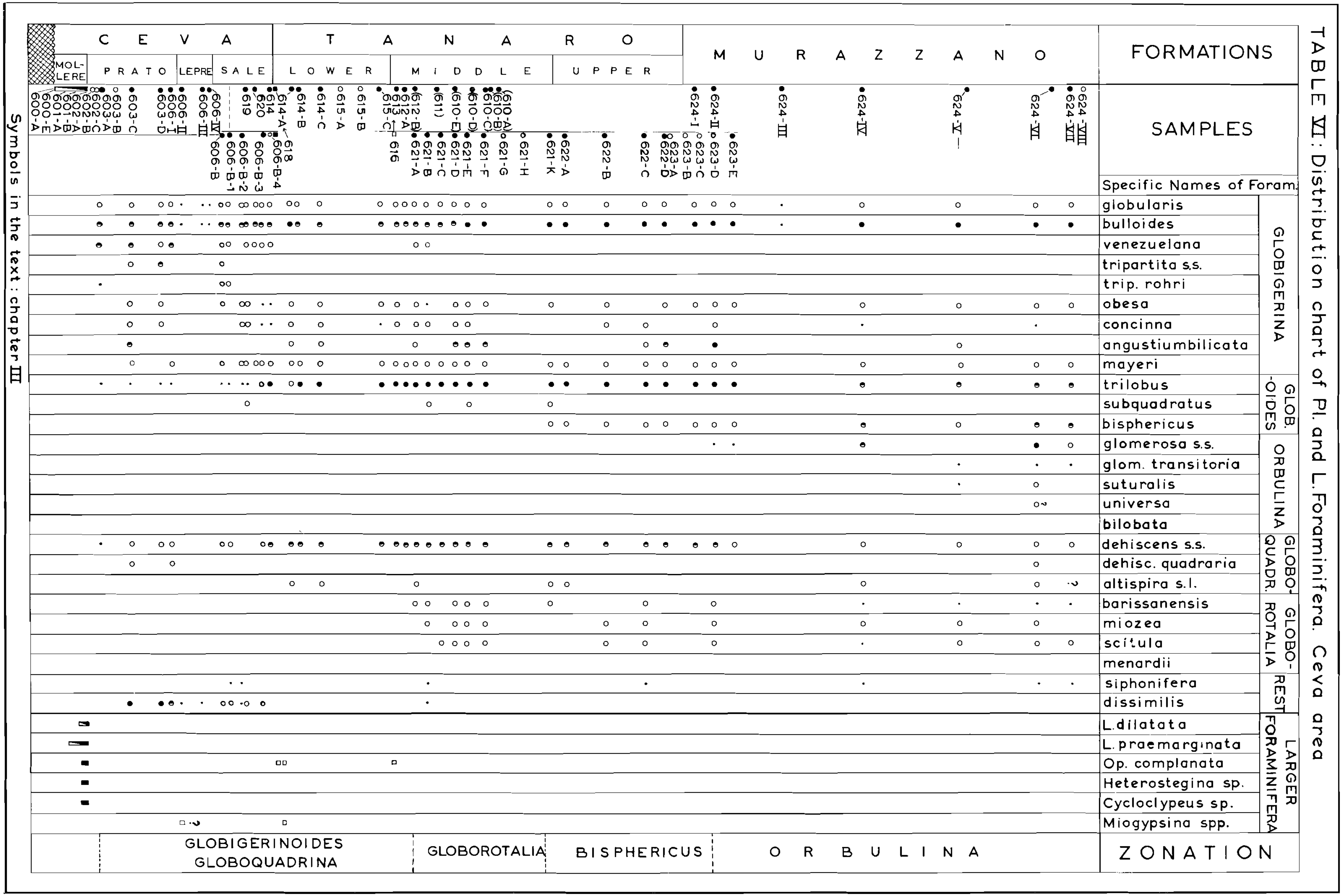
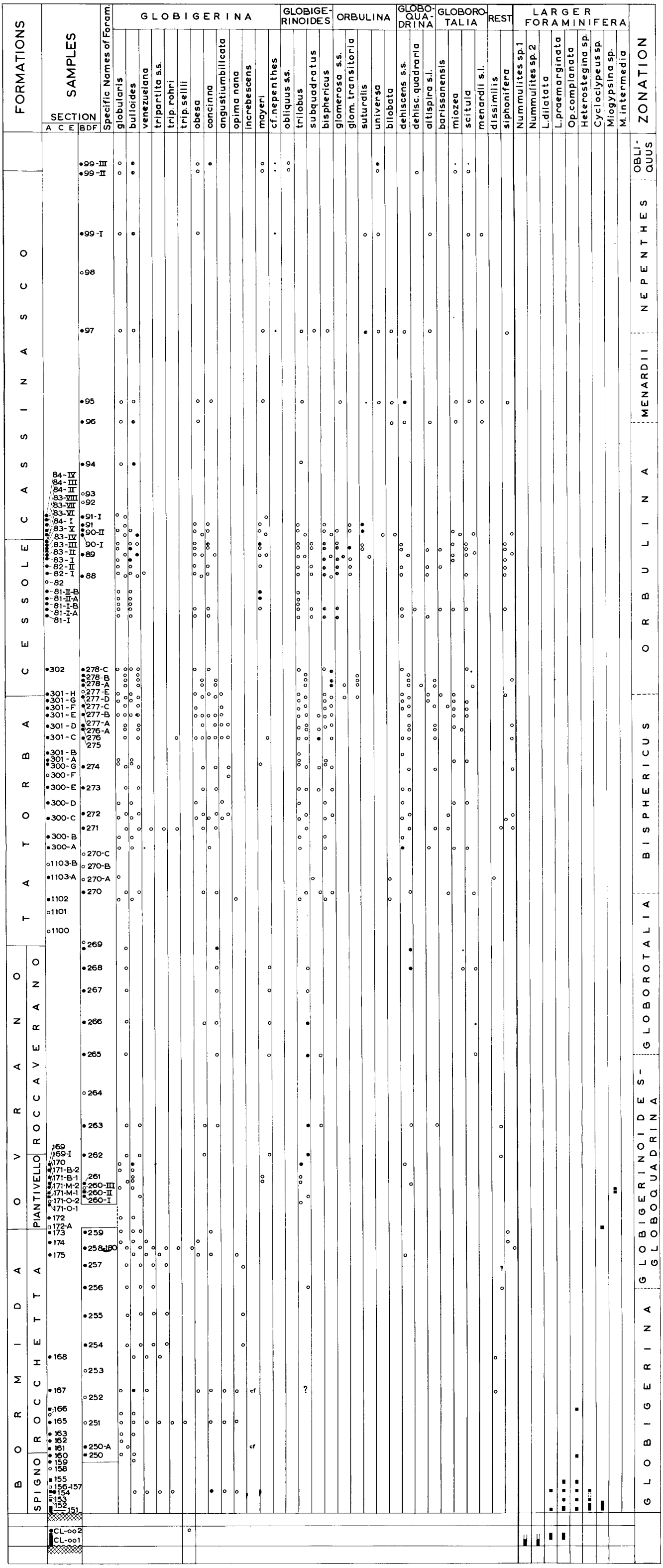


TABLE VI: Distribution chart of Pl. and L. Foraminifera. Ceva area

Symbols in the text: chapter III

TABLE VII: Distribution chart of Pl. and L. Foraminifera. Spigno Monferrato area.



Symbols in the text; chapter III

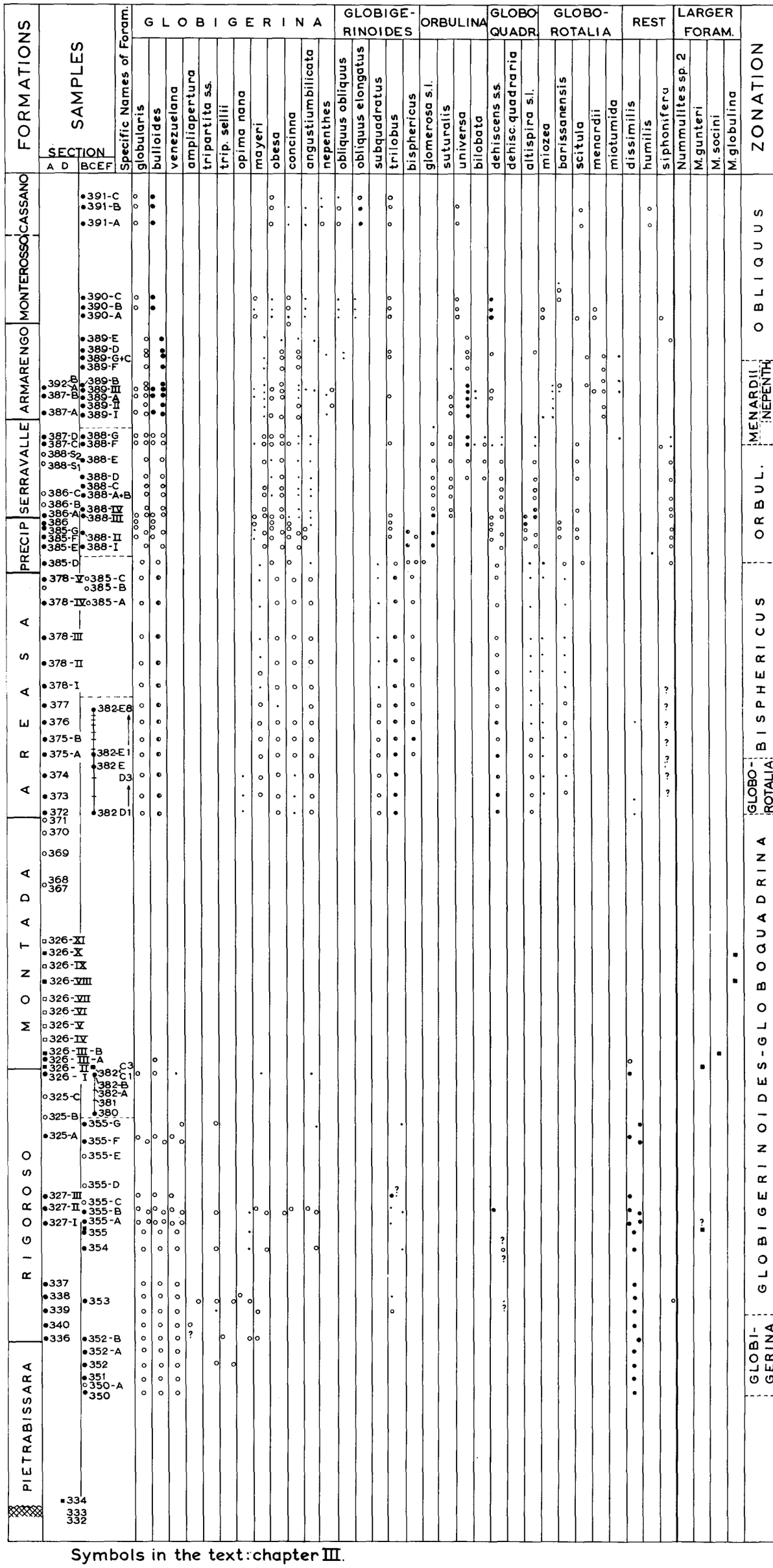
TABLE VIII: Distribution chart of Pl. and L. FORAMINIFERA

ACQUI-MOLARE AREA		GLOBIGERINA									GLOBIGERINOIDES		ORBULINA	GLOBOQUADRINA		GLOBOROTALIA			REST		LARGER FORAM.						ZONATION
FORMATIONS	SAMPLES	Specific Names of Foram.																									
		globularis	bulloides	venezuelana	tripartita s.s.	trip. rohri	mayeri	obesa	concinna	angustiumbilicata	trilobus	bisphericus	glomerosa s.l.	dehiscens s.l.	altispira s.l.	barissanensis	miozea	scitula	siphonifera	dissimilis	Nummulites sp.2	L. dilatata	L. praemarginata	Cycloclypeus sp.	M. gunteri	M. globulina	
	●33-B ●39-L	○	○	○		○	○	○	○	○	○			○						○							GLOBIGERINOIDES
	▮39-K																									▬	
	●33-A	○	○	○		○	○	●	○		○			○						○							
RAVANOSCO	●39-I	○	○	○			○	○	○	○	○	○	○	○			○	○	○	○							ORB
	●39-H						○	○	○	○	○	○		○					○	○							BISPHERICUS
	●39-G	○	○				○	○			○	○		○			○			○							
	●39-F							○			○	○		○													
	●39-E	○	○				○	●			○			○													
	●39-D	○	○					○	○		●	○							○								
	●39 C	○	○				○	○			○																GLOBIGERINOIDES
	●39-B	○	●				○	○	○	○	●			●						○							
	●13-A4	○	○					○	○		○			○	○				○								
	▪39-A ▪13-A3						○			○	○														□?	■■	
	13-A2																										
	●39 ●13-A1	○	○	○		○		○			○									○		■		■			
ORBA	105-IC ●105-IB						○				○			·													
	●105-IA			○			○				○			·						●							
	●104 ○103	○	○								○			○						○							
	■102-VI																				■						
	102-VB ■102-VA																				■						
	■102-I																					■	■				
	■102-II																				■	■					
	102-III																										

Symbols in the text; chapter III.

limestone of Acqui.

TABLE IX: Distribution chart of Pl. and L. Foraminifera. Serravalle Scrivia area.



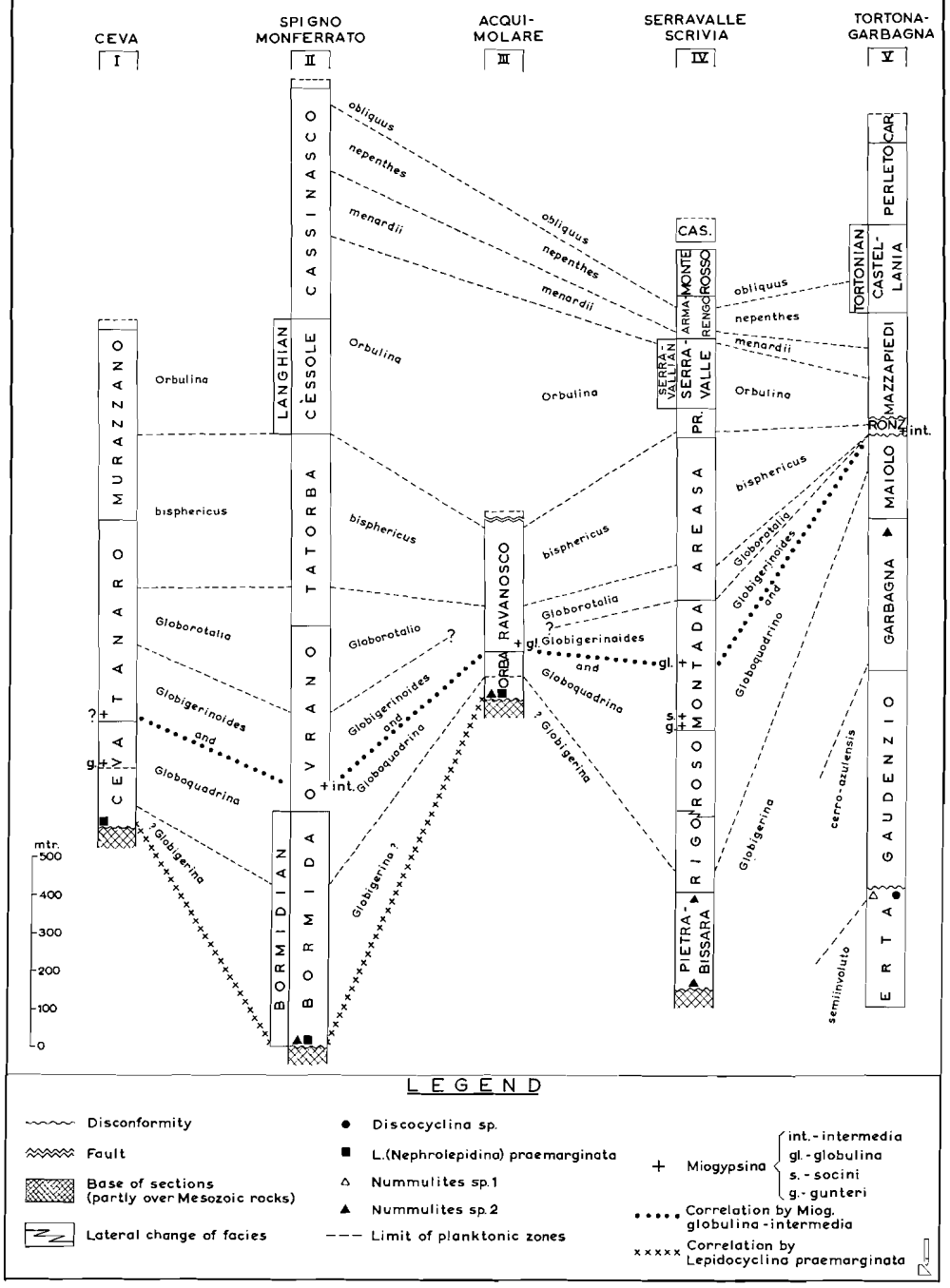
Symbols in the text: chapter III.

TABLE X: Distribution chart of Pl.and L. Foraminifera. Tortona Garbagna area

FORMATIONS	SAMPLES SECTION BDEG	SAMPLES SECTION CDEF	Specific Names of Foram.	GLOBIGERINA globularis	GLOBIGERINA bulloides	GLOBIGERINA venezuelana	GLOBIGERINA tripartita s.s.	GLOBIGERINA trip. rohri	GLOBIGERINA trip. sellii	GLOBIGERINA ampliapertura	GLOBIGERINA cf. regularis	GLOBIGERINA angustiumbilicata	GLOBIGERINA obesa	GLOBIGERINA concinna	GLOBIGERINA increbescens	GLOBIGERINA opima nana	GLOBIGERINA mayeri	GLOBIGERINA nepenthes	GLOBIGERINOIDES obliquus	GLOBIGERINOIDES obliquus elongatus	GLOBIGERINOIDES trilobus	GLOBIGERINOIDES subquadratus	GLOBIGERINOIDES bispherícus	ORBULINA glomerosa s.l.	ORBULINA suturalis	ORBULINA universa	ORBULINA bilobata	GLOBOQ. dehiscens s.l.	GLOBOQ. altispira s.l.	GLOBOROTALIA centralis	GLOBOROTALIA cerro-azulensis	GLOBOROTALIA barissanensis	GLOBOROTALIA miozea	GLOBOROTALIA scitula	GLOBOROTALIA menardii s.l.	REST dissimilis	REST semiinvoluta	REST siphonifera	LARGER FORAM. Nummulites sp.1	LARGER FORAM. Nummulites sp.2	LARGER FORAM. Discocyclina sp.	LARGER FORAM. M.(glob.)-interm.	ZONATION
CAR.	528			○	●													○	○	○						○		○																	
	527																																											
	526				○																																							
	525																																											
	513																																											
PERLETO	514				○																													○										
	515																																											
	516																																											
	518																																	○										
	519																																											
	520																																											
	521																																											
	510																																											
	509B2																																											
	509B1			○	●																																							
	509B			○	●																																							
CASTELLANIA	508-V			○	●																																							
	508-IV			○	●																																							
	508-III			○	●																																							
	508-II			○	●																																							
	508-I			○	○																													○										
	507-VI			○	●																																							
	507-V			○	●																																							
	507-IV			○	●																																							
	507-III			○	●																																							
	507-II			○	○																																							
	507-I			○	○																																							
	500-VI			○	○																																							
	500-V			○	○																																							
	500-IV																																											
	500-III			○	●																																							
	500-II																																											
	500-I																																											
	500																																											
	496-V	← 496-VI		○	●																																							
	496-IV			○	●																																							
	496-III			●	●																																							
	496-II			○	●																																							
MAZZA PIEDI	496-I			○	○																																							
	475-A	(460-H)		○	○																																							
	475	460-G		○	●																																							
		460-F		○	●																																							
		460-E		○	●																																							
		460-D		○	●																																							
		460-C		○	○																																							
		460-B		○	○																																							
	466	463 (III-VIII)		○	○																																							
	466 E	(399-B)		○	○																																							
	467																																											
RONZ	467-B	(399-A)		○	●	?																																						
		399		○	●	?																																						
	457-A	462-A		○	●	●	○																																					
	457-B			●	●	●	?	○							?	○	●																											
	456	463-I-II		○	●	○										●	?																											
		462-B		○	●	○										○																												
MAIOLO	455			○	●	○	○	○								○																												
	454			●	○	○	○	○	○								?																											
	453			○	●	○	○	○	○							●																												
	452																																											
	451			●	●	○	○		○							○																												
	450			●	●		○		○	●						●																												
	481			○	●					○						○																												
GARBAGNA	480-C			●	●	○	○	○		○						○																												
	480-B			○	●																																							
	480-A			○	●	○	○																																					
		576-F		○	○	○	○	○	○																																			
		576-E		○	○	○	○	○	○																																			
		576-D		○	○	○	○	○	○																																			
		576-C																																										
		576-B																																										
		576-A																																										
		575-A																																										
		575			○	○	○			○																																		
	570-H																																											
	570-G																																											
	570-F																																											
	570-E			○		○										○																												
	570-D																																											
	570-C																																											
	570-B																																											
	570-A			○	○	○		○		○						○																				○								
GAUDENZIO		560-E																																										
		560-D																																										
		560-C		○																												○				○								
		560-B																																										
		560-A																																										
		559																																										
		558-C																																										
		558-B																																										
		558		○						○																										○								
		557-E																																										
		557-D																																										
		557-C																																										
		557-B																																										
		557-A																																										
		556-C																																										
		556-A		○						?																										○								
		555																																										
		554																																										
	B-3	552-C																																										
	B-2	552-B													○															●														
	B-1	552-A								?																																		
	B	551		○			○			○					○															○	○					○								
		550								○																																		
	580	580-A3		○	?		○			○																										○	○							
		580-A2								?																																		
		580-A1					○								○															○	○													
ERTA		581-D		○			○								●															○	○					○								
		581-C		○						? ○																					○					○	○							
		581-B		○											○															○	○					○	○							
		581-A		○		○				?																				○						●	●							
	592	581		○			○	○																						○	○						○							

Symbols in the text: chapter III.

TABLE XI: Zonation and correlation of sections I - V in southern Piemont by means of the planktonic and larger foraminifera.



LEGEND

- Disconformity
- Fault
- Base of sections (partly over Mesozoic rocks)
- Lateral change of facies
- ● Discocyclina sp.
- ■ L.(Nephrolepidina) praemarginata
- △ Nummulites sp.1
- ▲ Nummulites sp.2
- --- Limit of planktonic zones
- + Miogypsina { int.-intermedia, gl.-globulina, s.-socini, g.-gunteri }
- ••••• Correlation by Miog. globulina-intermedia
- xxxxx Correlation by Lepidocyclina praemarginata

3. Areal distribution of the zones.
(Tables VI—XI)

The biozones, present in the Ceva area, are from bottom to top: The *Globigerinoides* Zone and all the following zones up to and including the basal part of the *Orbulina* Zone.

In the Spigno Monferrato area we found all the planktonic zones, starting from the upper part of the *Globigerina* Zone. The *Orbulina* to *obliquus* Zones are not well separable owing to the wide spacing of the samples. *Miogypsina intermedia* is found in the *Globigerinoides - Globoquadrina* Zone.

In the Acqui-Molare area we distinguished the association 3 of the larger Foraminifera at the base of the section; above it lie the *Globigerinoides - Globoquadrina, bisphericus* and the basal part of the *Orbulina* Zones. The onset of *Globorotalia* has not exactly been investigated.

The assemblage of species, found directly below and above the Limestone of Acqui (type locality, South of Acqui) includes a plankton fauna, characteristic for the *Globigerinoides - Globoquadrina* Zone: *Globigerina tripartita, Globigerinita dissimilis* and *Globigerinoides trilobus* in particular. We furthermore derived some *Miogypsina globulina* specimens from the conglomerates at the base of the Ravanosco Formation. On this evidence we could correlate these *Miogypsina* bearing beds. The appropriate position of the fault in between the beds with *Miogypsina* could be located by means of the planktonic Foraminifera.

In the Serravalle Scrivia area all plankton zones are present from the upper part of the *Globigerina* Zone onwards. In the *Globigerinoides* Zone *Miogypsina gunteri, Miogypsina socini* and *Miogypsina globulina* were found in successive levels.

In the Tortona area not all planktonic zones are present. At the disconformity in the Rio Mazzapiedi (point 463) the *Globorotalia, bisphericus* and perhaps the lower part of the *Orbulina* Zone are absent.

4. General conclusions.
(Table XI)

1. The planktonic Foraminifera are suitable to establish a rough biozonation of the Oligo-Miocene strata in Southern Piemont.
2. Environmental influences, reflected in the facies of the sediments, have certainly played an important part in the vertical distribution of the species. As a result we find indistinct zonal boundaries in several of the sections.
3. The association of larger Foraminifera with *Lepidocyclina praemarginata* from Mollere, Costa Lupara, Spigno Monferrato and Molare can be correlated with the *Globigerina* Zone.
4. In our area the miogypsinids start above the *Globigerinoides* surface and end below the onset of true *Orbulina.* Only a part of the *Miogypsina* lineage is fully represented in our area.
5. The relative thickness of the sediments corresponding to single zones appear to vary widely from one section to another.
6. At least two zones (the *Globorotalia* Zone and the *bisphericus* Zone) are lacking at the disconformity in the Tortona area.

Chapter V

CHRONOSTRATIGRAPHY

1. General

The stages bearing on the succession in Southern Piemont are:

Pliocene:	Plaisancian (= Piacenziano)
Miocene:	Messinian Tortonian Helvetian Burdigalian Aquitanian
Oligocene:	Chattian Rupelian Lattorfian
Eocene:	Priabonian

From the type deposits of the Late Eocene Priabonian no planktonic Foraminifera have been described so far. Bolli (1957b) assumed that the *semiinvoluta* and *cerro-azulensis* Zones belong to the Late Eocene.

Eames et al. (1962) distinguished the *turritillina* (= *gortanii*) Zone at the top of the Eocene. Although we found in the Tortona area some suspect specimens of *Globigerina gortanii* at the top of our *cerro-azulensis* Zone, the content of planktonic Foraminifera near this level is too little known for any greater precision. Hence, the Eo-Oligocene boundary can not be indicated accurately. Tedeschi & Coccocetta (1962) approximately placed it at the limit between our *semiinvoluta* and *cerro-azulensis* Zones, somewhat lower than it is drawn here.

It is impossible to distinguish the Lattorfian, Rupelian and Chattian with the help of planktonic Foraminifera, because the stratotypes of these stages occur in another faunal province (Batjes, 1958), where planktonic Foraminifera are scarce and not typical. A possible differentiation of the Oligocene can only be based on the larger Foraminifera, the biometric investigation of which is useful.

The "type" Chattian contains *Lepidocyclina morgani* and *Miogypsina septentrionalis* (Drooger, 1960). The former species, accompanied by *Miogypsinoides* has been found in the Turin hills at Villa Giuseppina and at Bric del Duca.

The more primitive *Lepidocyclina praemarginata,* occurring without *Miogypsinoides* at the localities of Mollere, Costa Lupara, Spigno Monferrato and Molare, may therefore belong to the Rupelian, whether it is accompanied by *Nummulites* or not.

We observed no *Miogypsinoides* in Southern Piemont except in association with *Miogypsina gunteri.*

The Oligocene-Miocene boundary can be found with the help of the phylogenetic series of the Miogypsinidae. *Miogypsina gunteri* was found in our series far above the first *Globoquadrina* and *Globigerinoides.* This find might indicate that in Southern Piemont the whole *Globigerina* Zone and probably the lower part of the *Globigerinoides* Zone belong in the Oligocene, and that the Miocene does not start with the onset of *Globigerinoides.* The presence of *Miogypsina* made it possible to recognize the Aquitanian and/or Burdigalian. These stages correspond to the middle part of the *Globigerinoides* Zone. These finds are in accordance with the opinions expressed at the meeting of the Committee on the Mediterranean Neogene at Berne (1964).

The type Tortonian coincides rather well with the range of *Globigerina nepenthes,* which may be equivalent to the *menardii-nepenthes* Zone of the tropical succession.

As a consequence the gap between the Burdigalian and the Tortonian becomes rather large, corresponding to the interval between the top of the *Globigerinoides-Globoquadrina* Zone up to approximately the *nepenthes* Zone.

Type sections	BIOZONES: PLANKTONIC FORAMINIFERA	BIOZONES: LARGER FORAMINIFERA	CHRONOSTRATIGRAPHIC UNITS
			Messinian
Tortonian	obliquus		Tortonian
·?	nepenthes		
Serrav.	menardii s.l.		Serravallian
Langhian	Orbulina		
	bisphericus		Helvetian
	Globorotalia		
	Globigerinoides - Globoquadrina	• M.intermedia • M.globulina	Burdigalian
		• M.socini • M.gunteri	Aquitanian
Bormidian		(• L. morgani)	Chattian
	Globigerina	• L.praemarginata Nummulites sp.2	Rupelian
	cerro-azulensis	• Nummulites sp.1 Discocyclina sp.	Upper Eocene
	semiinvoluta		

Figure 4
Type sections, the biostratigraphy and chronostratigraphy from Upper Eocene to Upper Miocene.

Several stage names have been mentioned at Berne, which belong in the interval: Helvetian, Karpatian, Langhian and Sallomacian. An additional one is proposed here: the Serravallian of PARETO (1865).

The Helvetian was thought at Berne to correspond to part of the *bisphericus* Zone, at any rate to underlie the *Orbulina* surface. For reasons of priority the Langhian and perhaps the Serravallian appear the most preferable for the rest of the missing interval.

The Langhian starts approximately at the level of the *Orbulina* surface, but it does not reach the base of the *menardii* Zone. In contrast with the table finally established in Berne (1964) we find that the Langhian-interval excludes that of the Burdigalian.

The second stage considered to fill a part of the above mentioned gap is the Serravallian of PARETO (1865). Its type is shown to range from about the middle to the top of the *Orbulina* Zone. At this point *Globorotalia menardii* s.s. and *Globigerina nepenthes* appear simultaneously, but *Globorotalia menardii miotumida* comes earlier, just as has been observed in the strata below the type Tortonian. **Summarizing:** the Langhian can not faunistically be limit-

ed at the top, while the base of the Serravallian is not clear.

In our opinion it would be an exaggeration to insert two stages in between the Helvetian and the Tortonian. If we had to use one of the names for the interval of both together, the Serravallian would be preferable, because of the long incorrect tradition according to which the Langhian is synonymous with the Burdigalian.

2. Conclusions

1. The *Globigerina* Zone and the lower part of the *Globigerinoides-Globoquadrina* Zone are of Oligocene age. The *Globigerinoides* surface can not serve as base of the Miocene.
2. A subdivision of the Oligocene and Lower Miocene in Southern Piemont can be established with the use of associations of planktonic Foraminifera. The phylogenetic series in the larger Foraminifera *Lepidocyclina* and *Miogypsina,* however, provide a better base.
3. The transgression over the basement in Southern Piemont started during the Late Eocene in the Tortona area and continued in western direction into Oligocene time, but not as late as the Aquitanian.
4. If the succession of Miocene stages is revised the Serravallian should be the first to be recognized as a valuable (sub)stage.

Chapter VI

SYSTEMATICS

1. GENERAL REMARKS, LINEAGES AND CLASSIFICATIONS.

General remarks

Although benthonic Foraminifera may be more frequent than the planktonic ones in some intervals of the sections, they have in this paper been left out of consideration, except for the species of *Nephrolepidina* and *Miogypsina* which have been studied in detail. Other larger Foraminifera have been determined on the external features, for instance the *Nummulites.*

The determinations of the planktonic Foraminifera appeared to be difficult, especially since in the literature the differences between many species have become so slight that they can only be differentiated in well-preserved material.

The Oligocene material of the sections I—IV is highly unsatisfactory. That of section V is better, and in the specimens more details could be observed. In this section the recognition of many species was possible, but it often seemed useless to make any differentiation at all, because in rich samples all kinds of intergradations were found As a consequence we applied a much wider species concept than many earlier authors.

The second factor that influenced our opinion on the species concept is based on the observed changes in the relative frequency of neighbouring morphotypes, which seemingly were related with changes in sediment.

Lineages.

A. The *Globigerina tripartita* group and its lineage to *Globoquadrina.*

In sandy or silty marls from the Oligocene, in section V, the form *Globigerina tripartita tripartita* is most frequent, whereas in the marls and clays the variants *Globigerina rohri* and *Globigerina sellii* were more abundant than the typical *G. tripartita.* In the more sandy Miocene of this section the form *Globigerina tripartita tripartita* remains and is only occasionally accompanied by the form *Globigerina rohri.* This fact points at the possibility, that the mentioned specific units are ecophenotypes of a single species.

We also include *Globigerina venezuelana* in this group. In the interval that the form *Globigerina tripartita tripartita* evolves in *Globoquadrina dehiscens dehiscens* its four-chambered variant *Globigerina tripartita quadripartita* (= *Globigerina venezuelana*) also changes into *Globoquadrina quadraria.* This correlated change supports our point of view that *Globigerina tripartita* and *Globigerina venezuelana* are conspecific, as are their respective descendants *Globoquadrina dehiscens* and *Globoquadrina quadraria.*

Although not supported by our own material, it is conceivable that the form *Globigerina rohri,* already recorded as a *Globoquadrina* by REISS & GVIRTZMAN (1964) is ancestral to *Globoquadrina altispira.* Hence, the variation in the *Globigerina tripartita* group (*tripartita, venezuelana, rohri*) corresponds approximately to that in the *Globoquadrina dehiscens* group (*dehiscens, quadraria, altispira*).

B. The *Globigerina bulloides* group and its lineages.

The general development from 3—4 chambered specimens (*G. globularis, G. woodi*) in the Oligocene to 4—5 chambered ones (*G. bulloides, G. concinna*) in the Upper Miocene, is commonly accepted nowadays, but the difficulties in interpretation still lead to large discrepancies in the record. There is a tendency in the literature (REISS & GVIRTZMAN 1964; JENKINS 1964) to let the range of *Globigerina bulloides* start somewhere in the Late Miocene. According to WADE (1964) this species starts much earlier.

In the Upper Eocene *G. globularis* is the only representative, but in the Oligocene it is already accompanied by *G. bulloides,* though the latter is less frequent. From this form the genus *Hastigerina* seems to have

evolved, via *Globigerina obesa,* that is by the lateral shift of the aperture from an umbilical-extraumbilical, finally to a spiro-umbilical position (observed in the Maiolo Formation, section V). Just as in the genus *Hastigerina,* both narrowly and widely coiled specimens of *Globigerina obesa* have been observed.

Throughout the scarce record of *Hastigerina* in our sections the relation with the *Globigerina bulloides* (c.q. *G. globularis*) group remains.

From the same parental stock the genus *Globigerinoides* has evolved. According to BANNER & BLOW (1962), *Globigerina praebulloides* is the ancestral form, but JENKINS (1964) derives *Globigerinoides* from *Globigerina woodi.* This demonstrates that both assumed ancestral forms may belong to one population, which, according to our wider species concept, should be named *Globigerina bulloides.* The *Globigerina ampliapertura* of WADE (1964a, pl. 5, figs. 13—15 and 17, 18) is not the ancestral form.

C. The *Globigerina ampliapertura* group.

In the Upper Eocene to Oligocene succession in the Tortona area, we could not make a distinction between the following forms, alledgedly succesive in time: *Globigerina pseudoampliapertura, Globigerina ampliapertura* and *Globigerina euapertura.* They have been grouped as *G. ampliapertura.*

D. *Globigerinoides trilobus* and the lineage to *Orbulina.*

Grouping has also been applied to *Globigerinoides trilobus* (*trilobus, irregularis, quadrilobatus, altiaperturus,* etc.) The warm water variant *G. sacculiferus* has been found mainly in the Lower Serravallian and Tortonian of the sections IV and V; they better resemble aberrant *G. trilobus* than the typical *G. sacculiferus.* Probably the water was not warm enough.

Our material of *Orbulina* is commonly too badly preserved to enable a distinction in the *O. glomerosa* group of the variants *glomerosa, curva* and *circularis.* The record of *O. transitoria* coincides with that of *O. glomerosa* and this bilobate form is considered to be another variant of the latter. *O. bilobata* is thought to be a variant of *O. suturalis* or *O. universa.*

The development of *O. glomerosa* into *O. universa* could hardly be recognized, because the specimens remain too small. For this reason we established only an *Orbulina* Zone.

Classification.

Within the Subfamily *Globigerininae* we placed all genera, which are in the possession of a spinose or cancellated wall, with an umbilical, intra-extra-umbilical or spiro-umbilical aperture, either covered by a bulla or not, with or without a rim, lip or tooth. Dorsal apertures may be present.

Within this framework the following genera are considered to belong: *Globigerina, Globoquadrina, Globigerinoides, Globigerapsis, Globigerinita, Orbulina* and *Hastigerina.* The species: *Globigerina mayeri, Globigerina obesa* and *Globigerina opima,* usually placed in the genus *Globorotalia* belong here too.

To the *Globorotaliinae* have been restricted the forms with a vitreous, porous wall, a keeled or non-keeled test and an intra-extra-umbilical aperture.

Our distinction of both subfamilies thus mainly depends on the surface texture.

The descriptive morphological terminology follows that of the publications of BANNER & BLOW (1959; 1960 a, b) and LOEBLICH & TAPPAN (1964).

The classification of the larger Foraminifera *Lepidocyclina* and *Miogypsina* is based on the works of VAN DER VLERK (1959 a, b; 1963), and DROOGER (1963).

2. PLANKTONIC FORAMINIFERA.

Family: **Globigerinidae** CARPENTER, PARKER & JONES, 1862;
Subfamily: **Globigerininae** CARPENTER, PARKER & JONES, 1862;
Genus: **Globigerina** d'ORBIGNY, 1826;
Type species: *Globigerina bulloides* d'Orbigny, 1826.

Globigerina ampliapertura Bolli, 1957.

Pl. 1, figs. 5a—c.

Globigerina ampliapertura BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 108, pl. 22, figs. 4a—7c. DROOGER & BATJES, 1959; Proc. Kon. Ned. Akad. Wetensch. A'dam, serie B, vol. 62, p. 174, pl. 1, fig. 1. REISS & GVIRTZMAN, 1964, pl. 1, figs. 6a—8c.
Globigerina euapertura JENKINS, 1960; Micropaleontology, vol. 6, p. 351, pl. 1, figs. 8a—c.
Globigerina pseudoampliapertura BLOW & BANNER, 1962; *in:* EAMES et al., 1962, p. 95, pl. 12, A—C; pl. 17, A and E; text fig. 12c.

Range: The range, as found in the Tortona area, corresponds to that given by BOLLI, that is from the *semi-involuta* Zone to somewhere below the onset of *Globoquadrina* and *Globigerinoides*.

This species was found in the Serravalle Scrivia and Tortona areas.

Globigerina angustiumbilicata Bolli, 1957.

Pl. VII, figs. 2a—c; Pl. VIII, figs. 3a—c.

Globigerina ciperoensis angustiumbilicata BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 109, pl. 22, figs. 12a—13c.
Globigerina angustiumbilicata Bolli, BLOW, 1959; Bull. Amer. Pal., vol. 39, no. 178, p. 172, pl. 7, figs. 33a—c, 34. REISS & GVIRTZMAN, 1964; pl.1, figs. 14a—15b.

Remarks: This species forms one of the morphotypes of the *Globigerina concinna* group at the top of the *Globigerina* Zone (Tortona area). All intermediates with *G. concinna ciperoensis* occur (see *G. concinna*). It has been specifically separated, however, because in the zones higher than the *bisphericus* Zone intermediates seem to be absent.

Range: From the middle part of the *Globigerina* Zone onwards; the full range was only observed in the Tortona area. Generally, there are, however, many interruptions in the record, probably due to unfavourable environmental circumstances.

Globigerina bulloides d'Orbigny, 1826.

Pl. VI, figs. 2a—c.

Globigerina bulloides d'ORBIGNY, 1826; Ann. Sci. Nat., p. 277, list 1, models 17 and 76. CUSHMAN, 1941; Contr. Cushm. Lab. Foram. Res., vol. 17, pt. 2, p. 38, pl. 10, figs. 4—7 (topotypes). BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 31, pl. 4, figs. 1a—c. BANNER & BLOW, 1960; selected lectotypes figured; Contr. Cushm. Found. Foram. Res., vol. 11, pt. 1, p. 3, pl. 1, figs. 1a—c.
Globigerina cf. *trilocularis* d'Orbigny, BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 110, pl. 22, figs. 8a—c only.
Globigerina parabulloides BLOW, 1959; Bull. Amer. Pal., vol. 39, no. 178, p. 179, pl. 10, figs. 46a—c.
Globigerina woodi JENKINS, 1960; Micropaleontology, vol. 6, p. 352, pl. 2, figs. 2a—c.

Remarks: In the material described by CUSHMAN (1941) from Rimini the variation is fairly wide, just as it is in other topotype material we examined. This variation includes flat to rather trochoid specimens, with moderately to rapidly enlarging chambers, while the sutures between the globular to slightly compressed chambers are usually deeply depressed.

The aperture varies in shape from small and rounded to highly arched and it is sometimes furnished with a distinct rim. The wall of the test is finely perforate; there are however, also specimens with more funnel-shaped and wide pores.

Range: From the top of the *cerro-azulensis* Zone upwards.

Globigerina concinna Reuss, 1850.

Pl. V, figs. 3a—c; Pl. VII, figs. 1a—c.

Globigerina concinna REUSS, 1850; Denkschr. Kon. Akad. Wiss., Wien, vol. 1, p. 373, pl. 47, fig. 8. NUTTALL, 1932; J. Paleont., vol. 6, pt. 3, p. 29, pl. 6, figs. 9—11. MARKS, 1951; Contr. Cushm. Found. Foram. Res., vol. 2, pt. 2, p. 70, pl. 8, figs. 6a, b.
Globigerina ciperoensis ciperoensis BOLLI, 1957; U.S. Nat. Mus. 215, p. 109, pl. 22, figs. 10a, b.

Remarks: The diameter, given by MARKS for *Globigerina concinna* from material of the Vienna Basin, varies from 0.35—0.55 mm. It overlaps in this way the range of variation of *Globigerina ciperoensis ciperoensis* Bolli (0.30—0.40 mm).

Our observations on large populations have revealed the following: At the top of the *Globigerina* Zone in the Tortona area, all intermediates between *G. angustiumbilicata* and *G. ciperoensis ciperoensis* occur. At higher levels the latter increases in size and can not be distinguished from *G. concinna*. As a consequence the name *Globigerina concinna* should be applied to the total population, being the older name. No size increase has been observed, however, in the *angustiumbilicata* type and the continuity in the population is lost above the *bisphericus* Zone. For this reason two different species have been recognized.

Range: From the upper part of the *Globigerina* Zone upwards.

Globigerina globularis Roemer, 1838.

Pl. II, figs. 11a—c; Pl. VI, figs. 3a—c; Pl. IX, figs. 1a—c.

Globigerina globularis ROEMER, 1838; Neues Jahrb. Min. Geogn. Geol. Petref. Kunde, p. 390, pl. 3, figs. 57a, b. BATJES, 1958; Mém. Inst. Sci. Nat. Belg., no. 143, p. 161, pl. 11, figs. 3—5.
Globigerina praebulloides BLOW, 1959; Bull. Amer. Pal., vol. 39, no. 178, p. 180, pl. 8, figs. 47a—c. BLOW & BANNER, 1962; *in* EAMES et al. 1962, p. 92, pl. 9, O—W; fig. 9 (v), fig. 14 (i—ii).

Remarks: The material of *G. globularis* Roemer, collected by BATJES (1958) from the German Upper Oligo-

cene was used for comparison. The specimens are small, their size probably being a matter of environmental circumstances. *G. praebulloides* is considered to be a large variant.

Range: Recorded throughout all sections.

Globigerina increbescens Bandy, 1949.

Globigerina increbescens BANDY, 1949; Bull. Amer. Paleont., vol. 32, no. 131, p. 120, pl. 23, figs. 3a—c.

Range: In the *semiinvoluta, cerro-azulensis* and *Globigerina* Zones of the Tortona-Garbagna area only. Some doubtful specimens occur in the *Globigerina* Zone of the Spigno Monferrato area.

Globigerina mayeri (Cushman & Ellisor), 1939.
Pl. VI, figs. 1a—c.

Globorotalia mayeri CUSHMAN & ELLISOR, 1939; Contr. Cushm. Lab. Foram. Res., vol. 15, pt. 1, p. 11, pl. 2, figs. 4a—c. BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 118, pl. 28, figs. 4a—c.

Remarks: In its early start this species is nearly indistinguishable from *Globigerina opima.*

Range: From about the top of the *Globigerina* Zone upwards. Large fluctuations in the relative frequency throughout the record; locally even absent, as in the Lower Tortonian for instance.

Globigerina nepenthes Todd, 1957.
Pl. VII, figs. 3a—c.

Globigerina nepenthes TODD, 1957; U.S. Geol. Survey, Prof. Paper 280—H, p. 301, pl. 78, figs. 7a, b. BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 111, pl. 24, figs. 2a—c.

Range: This species has been found by CITA, PREMOLI SILVA & ROSSI (Berne, 1964) from the base of the Tortonian onwards. We found already, though scarcely, some specimens at the base of the upper part of the Mazzapiedi Formation (table X).

Globigerina obesa (Bolli,) 1957.
Pl. II, figs. 9a—c; Pl. V, figs. 2a—c.

Globorotalia obesa BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 119, pl. 29, figs. 2a—c.

Remarks: This species has been given a wider sense than it has been done by BOLLI. We incorporated specimens, which are rather narrowly coiled and possess a slit-like umbilical to extra-umbilical aperture.

The species is thought to descend from *G. bulloides* by the lateral shift of the aperture from an umbilical to an umbilical— extra-umbilical position. In *Hastigerina* the later chambers become planispirally arranged, the *obesa*-spiral always being present internally. With both extremes *G. obesa* forms one intergrading series in several samples.

Range: From the top of the *Globigerina* Zone (Table X). In the sections I—IV its first appearance could not be accurately located.

Globigerina opima nana (Bolli), 1957.
Pl. IV, figs. 3a—c.

Globorotalia opima nana BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 118, pl. 28, figs. 3a—c.

Remarks: This species resembles *Globigerina mayeri,* only differing from the latter in the number of chambers. It shows a considerable overlap in range with this species.

Only a single individual of *Globigerina opima opima* (Bolli) has been observed in the Tortona area (sample 462 B).

Range: From the upper part of the *cerro-azulensis* Zone until approximately the top of the *Globigerinoides-Globoquadrina* Zone.

Globigerina sp. cf. regularis AGIP, 1957.
Pl. II, figs. 10a—c.

cf. *Globigerina regularis* AGIP, 1957; Agip Mineraria: Foraminiferi Padani, pl. 45, fig. 9, not: *Globigerina regularis* TERQUEM, 1880; Mém. Soc. Dunkerq., fasc. 3, vol. 21, p. 49, pl. 16, figs. 2 a, b.

Remarks: Small specimens; maximum diameter: 0.3 mm.

Range: From the top of the *cerro-azulensis* Zone into the basal part of the *Globigerinoides-Globoquadrina* Zone (only distinct in the Tortona area).

Globigerina tripartita Koch, 1926.
Pl. I, figs. 7a—c; Pl. II, figs. 5a—c; Pl. III, figs. 3—5.

Globigerina bulloides d'Orbigny *tripartita* KOCH, 1926; Ecl. Geol. Helv., vol. 19, no. 3, p. 746, pl. 21 a, b.
Globigerina bulloides d'Orbigny *quadripartita* KOCH, 1926; Ecl. Geol. Helv., vol. 19, no. 3, p. 745, pl. 20a—c.
Globigerina rohri BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 109, pl. 23, figs. 1a—4b.

Globigerina sellii BORSETTI, 1959; Ann. Mus. Geol. Bologna; Giorn. Geol., vol. 2, no. 27, p. 205—212, pl. 1.
Globigerina oligocenica BLOW & BANNER, 1962; *in:* EAMES et al. 1962, p. 88, pl. 10, figs. G, L—N.
Globigerina tripartita s.l. BLOW & BANNER, 1962; *in:* EAMES et al., 1962, p. 96—97, pl. 10, figs. A—F and H—K, text fig. 18.

Range: The variant *G. tripartita tapuriensis* is found throughout the range of *G. tripartita* s.s. In the *semi-involuta* Zone (Tortona area) the former is often furnished with a small triangular bulla (pl. I, figs. 7a—c). The variant *G. tripartita rohri* (pl. II, figs. 5a—c; pl. III, figs. 4a—c) occurs in the *cerro-azulensis* and *Globigerina* Zones. *G. tripartita sellii* (pl. III, figs. 5a—c) is restricted to marls and it extends higher in the *Globigerina* Zone than *G. ampliapertura,* while *G. tripartita* s.s. ranges beyond the *Globigerina* Zone.

For the evolution of this species the reader is referred to *Globoquadrina dehiscens.*

Globigerina venezuelana Hedberg, 1937.
Pl. II, figs. 6—7.

Globigerina venezuelana HEDBERG, 1937; J. Paleont., vol. 11, no. 8, p. 681, pl. 92, figs. 7a, b. BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 110, pl. 23, figs. 6a—8b.
not: *Globoquadrina venezuelana* (Hedberg), BLOW & BANNER, 1962; *in:* EAMES et al., 1962; p. 103, fig. 11 (XV).

Remarks: HEDBERG (1937) did not mention a tooth in the aperture and his figure gives no evidence on this point. Consequently, the assignment of this species to *Globoquadrina* is doubtful. We consider *G. venezuelana* and *G. tripartita* to be conspecific, which opinion is based on their simultaneous evolution into *Globoquadrina.*

Range: From about the top of the *cerro-azulensis* Zone upwards into the *Globigerinoides-Globoquadrina* Zone.

Genus: **Globigerinita BRÖNNIMANN, 1951.**
Type species: *Globigerinita naparimaensis* Brönnimann, 1951.

Globigerinita dissimilis (Cushman & Bermudez), 1937.
Pl. I, figs. 6a—c; Pl. IV, figs. 1a—c.

Globigerina dissimilis CUSHMAN & BERMUDEZ, 1937; Contr. Cushm. Lab. Foram. Res., vol. 13, pt. 1, p. 25, pl. 3, figs. 4—6.
Catapsydrax dissimilis (Cushman & Bermudez), BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 36, pl. 7, figs. 6a—8c.
Globigerinita dissimilis (Cushman & Bermudez), BLOW & BANNER, 1962; *in:* EAMES et al., 1962, p. 106, pl. 14, A—D.
Catapsydrax unicavus BOLLI, LOEBLICH & TAPPAN, 1957; Bull. U.S. Nat. Mus. 215, p. 37, pl. 7, figs. 9a—c.

Remarks: This species is abundant in the sections. We tried to separate *G. unicava* (Pl. IV, figs. 2a—c) from *G. dissimilis,* but between both forms all intermediates have been observed in the Oligocene-Miocene. For this reason *G. unicava* is not separately recorded. In our opinion it is no more than a bullate form of those *Globigerina* specimens, in which the aperture is not strictly confined to the umbilicus.

Range: From the base of the sections *G. dissimilis* occurs very commonly as far as the *Globorotalia* Zone and then gradually disappears towards the *bisphericus* Zone, the upper limit of the range being very different from one section to the other.

Globigerinita humilis (Brady), 1884.
Pl. VI, figs 4a—c.

Truncatulina humilis BRADY, 1884; Rept. Voy. Challenger, Zool., vol. 9, pt. 22, p. 665, pl. 94, figs. 7a—c.
Globigerinita humilis (Brady), BANNER & BLOW, 1960; Contr. Cushm. Found. Foram. Res., Spec. Publ., Vol. 11, p. 36, pl. 8, figs. 1a—c. PARKER, 1962; Micropaleontology, vol. 8, p. 249, pl. 10, figs. 1—25.

Remarks: Only rarely found.

Genus: **Globoquadrina FINLAY, 1947.**
Type species: *Globorotalia dehiscens* Chapman, Parr & Collins, 1934.

Globoquadrina dehiscens (Chapmann, Parr & Collins), 1934.
Pl. IV, figs. 4a—c.

Globorotalia dehiscens CHAPMAN, PARR & COLLINS, 1934; Linn. Soc. London, Journ. Zool., vol. 38, no. 262, p. 569, pl. 11, figs. 36a—c.
Globorotalia quadraria CUSHMAN & ELLISOR, 1939; Contr. Cushm. Lab. Foram. Res., vol. 15, pt. 1, p. 11, pl. 2, figs. 5a—c.
Globoquadrina dehiscens (Chapman, Parr & Collins), BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 111, pl. 24, figs. 3a—4c.
Globoquadrina venezuelana BLOW & BANNER, 1962 (not: *Globigerina venezuelana* Hedberg); *in* EAMES et al., 1962, p. 103, text fig. 11 (XV).

Remarks: The evolution of *Globigerina tripartita tripartita* into *Globoquadrina dehiscens dehiscens* was observed in the *Globigerinoides-Globoquadrina* Zone in the Tortona area. Gradually the shoulder on the ventral face of the *Globigerina* specimens becomes more acute, while a faint rim or small tooth appears in the aperture. Over

a height of about 50 m in the stratigraphical column, the specimens are neither clearly referable to *Globigerina* nor to *Globoquadrina;* these specimens have been indicated on table X with the notation cf. in the column of *G. dehiscens.*

A similar development was observed from *Globigerina venezuelana* to *Globoquadrina quadraria* at about the same stratigraphical height. The former species is thought therefore to be conspecific with *Globigerina tripartita* and the latter with *Globoquadrina dehiscens.*

Range: In the sections I and III *Globoquadrina* appears at about the same stratigraphical level as *Globigerinoides trilobus;* in the sections II and IV, in which the stratigraphical column seems more complete, they start somewhat later, but in section V earlier.

Globoquadrina altispira (Cushman & Jarvis), 1936.
Pl. V, figs. 1a—c.

Globigerina altispira CUSHMAN & JARVIS, 1936; Contr. Cushm. Lab. Foram. Res., vol. 12, pt. 1, no. 166, p. 5, pl. 1, figs. 13a—c, 14.
Globoquadrina altispira altispira (Cushman & Jarvis), BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 111, pl. 24, figs. 7a—8b.
Globoquadrina altispira (Cushman & Jarvis) *globosa* BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 111, pl. 24, figs. 9a—10c.

Remarks: In Southern Piemont the specimens are forms intermediate between the variants of BOLLI. The main distinction of this group from that of *G. dehiscens* is the higher trochospiral.

Range: The appearance of this species is not distinct and varies from section to section. There are many interruptions in the record; in the *obliquus* Zone it was only occasionally found, just as *G. dehiscens,* probably due to environmental circumstances.

Genus: **Globigerinoides** CUSHMAN, 1927.
Type species: *Globigerina rubra* d'Orbigny, 1839.

Globigerinoides trilobus (Reuss), 1850.
Pl. X, figs. 1a—2c.

Globigerina triloba REUSS, 1850; Denkschr. Kon. Akad. Wiss. Wien, Math. Natur. Cl., vol. 1, p. 374, pl. 47, figs. 11a—d.
Globigerinoides triloba (Reuss), BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 112, pl. 25, figs. 2a—8.

Remarks: The four-chambered variant of *G. trilobus* is thought to be the first to appear in the succession. If not found in this relative position, there may be a gap in the record due to too wide sampling.

Range: From the *Globigerinoides-Globoquadrina* Zone upwards throughout the sections. The lower limit of this zone is, however, not very distinct, owing to the scarcity in the early record of *Globigerinoides.*

Globigerinoides bisphericus Todd, 1954.
Pl. X, figs. 3a—c.

Globigerinoides bispherica TODD, 1954; in: TODD, CLOUD, LOW & SCHMIDT, 1954; Amer. Journ. Sci., vol. 252, no. 11, p. 681, pl. 1, figs. 1a—c, 4. BLOW, 1956; Micropaleontology, vol. 2, no. 1, text fig. 1, nos. 4—8, text fig. 3, stage A. BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 114, pl. 27, figs. 1a, b.

Range: The *bisphericus* Zone is based on the first appearance of this species. The upward range of the species is variable in the sections.

Globigerinoides ruber (d'Orbigny) **subquadratus** Brönnimann, 1954.
Pl. X, figs. 4a—c.

Globigerinoides subquadratus BRÖNNIMANN, 1954; *in:* TODD, CLOUD, LOW & SCHMIDT, 1954; Amer. Journ. Sci., vol. 252, no. 11, p. 680, pl. 1, figs. 5, 8a—c.

Remarks: This variant is recorded in the tables as *G. subquadratus.* The specimens are sometimes rather trochoid and more resemble *G. ruber;* both forms might belong to one population.

Range: Irregular. From the *Globorotalia* Zone upwards, sometimes starting higher and locally up to the top of the sections, but with many interruptions.

Globigerinoides ruber (d'Orbigny) **pyramidalis** (Van Den Broeck), 1876.
Pl. XI, figs. 1a—c.

Globigerina bulloides d'Orbigny *ruber* d'Orbigny *pyramidalis* VAN DEN BROECK, 1876; Ann. Soc. Belg. Micr., vol. 2 (1875—'76), p. 127, pl. 3, figs. 9—10.
Globigerinoides ruber pyramidalis (Van den Broeck), REISS & GVIRTZMAN, 1964, pl. 6, fig. 11.

Remarks: This variant occurs rarely, in the *obliquus* Zone.

Globigerinoides obliquus obliquus Bolli, 1957.
Pl. XI, figs. 2a—c.

Globigerinoides obliqua BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 113, pl. 25, figs. 10a—c.

Remarks: According to BANNER & BLOW (1960), *Globigerinoides elongatus* is conspecific with *G. obliquus*. In the sections IV and V *G. elongatus* appears somewhat later.

Range: On the appearance of this species a datum plane is based, that lies in the lower part of the Tortonian.

Globigerinoides obliquus Bolli **elongatus** (d'Orbigny), 1826.
Pl. XI, figs. 3a—4c.

Globigerina elongata D'ORBIGNY, 1826; Ann. Sci. Nat., ser. 1, vol. 7, p. 277, list 4. BANNER & BLOW, 1960; Contr., Cushm. Found. Foram. Res., vol. 11, pt. 1, p. 12, pl. 3, figs. 10a—c.
Globigerinoides obliqua BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 113, pl. 25, figs. 9a—c.

Remarks: In this variant the chambers are more angular in shape and the apertures of all chambers are highly arched. This variant evolves from *G. obliquus obliquus* in that the angular shape of the chambers progressively shifts in successive levels to earlier ontogenetic stages.

Range: From a level in the Tortonian upwards.

Genus: **Globigerapsis** BOLLI, LOEBLICH & TAPPAN, 1957.
Type species: *Globigerapsis kugleri* Bolli, Loeblich & Tappan, 1957.

Globigerapsis semiinvoluta (Keijzer), 1945.
Pl. III, figs. 2a, b.

Globigerinoides semiinvoluta KEIJZER, 1945; Univ. Geogr. Geol. Meded. Utrecht, Physiogr.-Geol. Series, vol. 2, no. 6, p. 206, pl. 4, figs. 58a—e.
Globigerapsis semiinvoluta (Keijzer), BOLLI, 1957; Bull. U.S. Nat. Mus. 215, p. 165, pl. 36, figs. 19, 20.

Range: This species is recorded from and limited to the *semiinvoluta* Zone, in the Tortona area only.

Genus: **Orbulina** D'ORBIGNY, 1839.
Type species: *Orbulina universa* d'Orbigny, 1839.

Orbulina glomerosa (Blow), 1956.
Pl. II, fig. 2.

Globigerinoides glomerosa BLOW, 1956; Micropaleontology, vol. 2, p. 64, text fig. 1, nos. 9—19; text fig. 2, nos. 1—4.
Globigerinoides transistoria BLOW, 1956; Micropaleontology, vol. 2, no. 1, text fig. 2, nos. 12—15; text fig. 3, stage B.
Orbulina glomerosa (Blow), PAPP, 1963; Mitt. Geol. Ges. Wien, vol. 56, p. 245, pl. 3, figs. 5—7.
Orbulina transitoria (Blow), PAPP, 1963; Mitt. Geol. Ges. Wien, vol. 56, p. 246, pl. 3, figs. 11, 12.

Remarks: These globular and biglobular forms can be distinguished from *O. suturalis* and *O. universa* by their possession of sutural apertures only.

Range: The *Orbulina* surface in the sections is based on the appearance of this species, which is restricted to the *Orbulina* Zone.

Orbulina suturalis Brönnimann, 1951.
Pl. II, figs. 1 and 3.

Orbulina suturalis BRÖNNIMANN, 1951; Contr. Cushm. Found. Foram. Res., vol. 2, pt. 4, p. 135; text fig. 2, nos. 1—2, 5—8, 10; text fig. 3, nos. 3—8, 11, 13—16, 18, 20—22; text fig. 4, nos. 2—4, 7—12, 15—16, 19—22. BLOW, 1956; Micropaleontology, vol. 2, p. 66, text fig. 2, nos. 5—7; text fig. 3, stage C 6.

Range: From slightly above the base of the *Orbulina* Zone upwards in all sections.

Orbulina universa d'Orbigny, 1839.
Pl. II, fig. 4; Pl. VII, figs. 4a—c.

Orbulina universa D'ORBIGNY, 1839; *in:* R. DE LA SAGRA, Foraminifères, p. 2, pl. 1, fig. 1. BLOW, 1956; Micropaleontology, vol. 2, p. 66, text fig. 2, nos. 8—9.
Biorbulina bilobata d'Orbigny, 1846; Foraminifères fossiles du basin tertiaire de Vienne, p. 164, pl. 9, figs. 11—14.
Biorbulina bilobata (d'Orbigny), BLOW; Micropaleontology, logy, vol. 2, p. 69, text fig. 2, no. 16.

Remarks: Only distinguishable in well preserved material.

Range: From the upper part of the *Orbulina* Zone upwards in all sections.

Genus: **Hastigerina** THOMSON, 1876.
Type species: *Hastigerina murrayi* Thomson, 1876.

Hastigerina siphonifera (d'Orbigny), 1839.
Pl. II, figs. 8a—c.

Globigerina siphonifera D'ORBIGNY, 1839; *in:* R. DE LA SAGRA; Hist. Phys. Pol. et Nat. de l'Ile de Cuba, Paris; vol. 8, p. 83, pl. 4, figs. 15—18.
Globigerina aequilateralis BRADY, 1884; Rept. Voy. Challenger, Zool., vol. 9, p. 605, pl. 80, figs. 18—21.
Hastigerina siphonifera (d'Orbigny), BANNER & BLOW, 1960; Micropaleontology, vol. 6, p. 22, text fig. 22a—c.

Remarks: BANNER & BLOW (1960b) already indicated

Globigerina obesa as possible ancestor of *Hastigerina.* We have observed that in the *Globigerina* Zone of the Tortona area the transition is actually present (see *G. obesa* in this paper).

Range: From the *Globigerinoides-Globoquadrina* surface upwards throughout the sections, but with many interruptions in the record.

Subfamily: Globorotaliinae CUSHMAN, 1927.
Genus: Globorotalia CUSHMAN, 1927.
Type species: *Pulvinulina menardii* (d'Orbigny) *tumida* Brady, 1877.

Globorotalia centralis Cushman & Bermudez, 1937.
Pl. I, fig. 4a—c.

Globorotalia centralis CUSHMAN & BERMUDEZ, 1937; Contr. Cushm. Lab. Foram. Res., vol. 13, pt. 1, p. 26, pl. 2, figs. 62—65. BLOW & BANNER, *in:* EAMES et al, 1962; p. 117, text figs. 12c—d; pl. 12, K—M; pl. 17, B, G.

Range: The species is restricted to the *semiinvoluta* Zone in the Tortona area (table X).

Globorotalia cerro-azulensis (Cole), 1928.
Pl. I, figs. 1—3; Pl. III, figs. 1a—c, 6a—c.

Globigerina cerro-azulensis COLE, 1928; Bull. Amer. Pal., vol. 14, no. 53, p. 217, pl. 32, figs. 11—13.
Globorotalia cocoaensis CUSHMAN, 1928; Contr. Cushm. Lab. Foram. Res., vol. 4, pt. 3, p. 75, pl. 10, fig. 3.
Globorotalia (Turborotalia) cerro-azulensis (Cole), BANNER & BLOW, 1962; *in:* EAMES et al., 1962, p. 118, pl. 12, D—F; text fig. 12d—c.

Range: From the base of the *semiinvoluta* Zone to the top of the *cerro-azulensis* Zone, in the Tortona area only (Table X).

Globorotalia scitula scitula (Brady), 1884.
Pl. IX, figs. 3a—c.

Pulvinulina scitula BRADY, 1884; Proc. Roy. Soc. Edinburgh, vol. 11, p. 716; figs. in BRADY, 1884; Rept. Voy. Challenger, Zool., vol. 9, pl. 103, figs. 7a—c.
Globorotalia scitula scitula (Brady), BOLLI, 1957; Bull. U. S. Nat. Mus. 215, p. 120, pl. 29, figs. 7a—c.
Globorotalia scitula scitula (Brady), BLOW, 1959; Bull. Amer. Pal., vol. 39, no. 178, p. 219, pl. 19, figs. 126a—c.

Range: On the appearance of this species or of the variant *G. scitula miozea,* the *Globorotalia* surface has been based. From that datum plane upwards the species is recorded throughout the sections, with many interruptions.

Globorotalia scitula miozea Finlay, 1939.
Pl. VIII, figs. 1a—2c.

Globorotalia miozea FINLAY, 1939; Proc. Roy. Soc. Nw. Zealand, vol. 69, pt. 3, p. 326, pl. 29, figs. 159—161.
Globorotalia scitula praescitula BLOW, 1959; Bull. Amer. Pal., vol. 39, no. 178, p. 221, pl. 19, figs. 128a—c.

Remarks: This small variant is mostly the first to appear in the sections as a representative of the *G. scitula* group, only differing from the typical in the smaller size (smaller than 0.25 mm).

Range: From the *Globorotalia* surface upwards; recorded throughout the sections with many interruptions. Environmental factors certainly have played a part.

Globorotalia barissanensis Le Roy, 1939.
Pl. VIII, figs. 4a—c.

Globorotalia barissanensis LE ROY, 1939; Natuurk. Tijdschr. Ned. Indië, pt. 99, afl. 6, p. 265, pl. 1, figs. 8—10.
Globorotalia fohsi barissanensis Le Roy, BOLLI, 1957; Bull. U. S. Nat. Mus. 215, p. 119, pl. 28, figs. 8a—c.

Range: Because of the suspect specimens, the range of this species is not distinct in our sections.

Globorotalia menardii (Parker, Jones & Brady), 1865.
Pl. IX, figs. 4a—c.

Rotalia (Rotalie) *menardii* d'ORBIGNY, 1826; Ann. Sci. Nat. Paris ser. 1, vol. 7, p. 273, list no. 26 (*nomen nudum*).
Rotalia menardii PARKER, JONES & BRADY, 1865; Ann. Mag. Nat. Hist., vol. 16, ser. 3, p. 20, pl. 3, fig. 81.
Globorotalia menardii miotumida JENKINS, 1960; Micropaleontology, vol. 6, p. 362, pl. 4, figs. 9a—c.

Remarks: This species is taken in a wide sense; in fact all intermediates between the mentioned variants were observed in section V (Lower part of the Mazzapiedi Formation).

Range: In the sections II and IV the first records lie on the *miotumida* side of the variation, whereas, in sections IV and V with the marls of the Armarengo and Castellania Formations *G. menardii s.s.* is prevailing. This change points strongly at the influence of the environment on the variation.

Family: **Hantkeninidae** CUSHMAN, 1927.
Subfamily: **Planomalininae** BANNER & BLOW, 1959.
Genus: **Pseudohastigerina** BANNER & BLOW, 1959.
Type species: *Nonion micrus* Cole, 1927.

Pseudohastigerina micra (Cole), 1927.

Nonion micrus COLE, 1927; Bull. Amer. Pal., vol. 14, no. 51, p. 22, pl. 5, fig. 12.
Hastigerina micra (Cole), BOLLI, 1957; Bull. U. S. Nat. Mus. 215, p. 161, pl. 35, figs. 1a—c, 2a, b.
Pseudohastigerina micra (Cole), BANNER & BLOW, 1959; Paleontology, vol. 2, pt. 1, p. 19, text fig. 4 (g—i).

Remarks: Not recorded in the tables. The specimens are badly preserved.

Range: Throughout the *semiinvoluta* and *cerro-azulensis* Zones in the Tortona area.

3. Larger Foraminifera.

Family: **Lepidocyclinidae** SCHEFFEN, 1932.
Genus: **Lepidocyclina** GÜMBEL, 1868.

In text figure 5 the measurements on the embryonic-nepionic apparatus of *Lepidocyclina* (*Nephrolepidina*) specimens from the localities Mollere and Costa Lupara were compared with those carried out on the nephrolepidinids from two localities in the hills of Turin (collection DROOGER): Villa Giuseppina ("Chattian" with *Miogypsinoides complanatus;* see DROOGER, 1954) and the Bric del Duca ("Aquitanian" with *Miogypsina gunteri;* see DROOGER, 1954).

For a detailed explanation and discussion of the characteristics and measurements applied the reader is referred to the papers by VAN DER VLERK (1959, 1963) and especially to that of DROOGER & FREUDENTHAL (1964).

The measured factors are the following:

The *A-factor,* which represents the degree of embracement of the protoconch (I) by the deuteroconch (II) in the equatorial plane (the "grade of enclosure" of VAN DER VLERK, 1963).

The *B-factor* is the number that expresses the degree, in which the outer circumference of the nucleoconch (I and II) is covered by the primary and accessory auxiliary chambers.

The *C-factor* is the number of accessory auxiliary chambers (AAC).

Of each sample a certain number (N) of specimens was measured, so that a mean value (M) could be calculated for the factors (M_A, M_B and M_C). The sum of the factors A and B (M_{A+B}) represents the "grade of evolution" (VAN DER VLERK, 1959) of the *Nephrolepidina* specimens in the samples. The M_C values may give another criterion for the nepionic acceleration. In our countings the accessory auxiliary chambers around the protoconch have been incorporated, but these were so rarely observed that they do not significantly (no more than 0.1) influence our mean values (M_C).

Biometric investigations.

1. The histograms of figure 5a reveal a modal shift in the number of accessory auxiliary chambers (AAC) from 2 to 4, going from assumed older to younger localities.
2. In figure 5b the averages of A + B (M_{A+B}) have been plotted against the mean diameter of the protoconchs (M_{DI}). The M_C values of the *Nephrolepidina* specimens have been entered in the figure as well. The vertical lines in the figure represent the variation in the factor A + B of the individuals in one sample.

The correlated increase of M_C, M_{A+B} and M_{DI} corresponds to the assumed stratigraphical position of the localities. Such a development has been clearly expressed by VAN DER VLERK (1959) for the M_{A+B} factor.

Especially in their M_C values the *Nephrolepidina* assemblages of Mollere and Costa Lupara differ significantly from those of Villa Giuseppina and Bric del Duca. On this basis it might be concluded that the deposits at Mollere and Costa Lupara in Southern Piemont are older than the Aquitanian (Bric del Duca) and Chattian (Villa Giuseppina) of the Turin hills, dated by means of the miogypsinids. This might correspond to a Rupelian age for the localities in Southern Piemont.

The *Nephrolepidina* assemblages of the Turin area have been named *Lepidocyclina morgani* Lemoine & R. Douvillé. Those of the localities in Southern Piemont are named *Lepidocyclina praemarginata* R. Douvillé.

Subgenus: **Nephrolepidina** H. DOUVILLÉ, 1911.
Type species: *Nummulites marginata* Michelotti, 1841.

Lepidocyclina (Nephrolepidina) morgani

Lemoine & R. Douvillé, 1904.

Lepidocyclina morgani LEMOINE & R. DOUVILLÉ, 1904; Mém. Soc. Géol. France, Pal.; vol. 12, p. 17, pl. 1, fig. 12. DROOGER & FREUDENTHAL, 1964; Ecl. Geol. Helv., vol. 57, p. 518, p. 521.

Remarks: The M_C values of the material of the Turin hills (ca. 4.0) are distinctly lower than those of *L. tournoueri* of Rosignano (ca. 6.0; age: Burdigalian, DROOGER & SOCIN, 1959) and they correspond to the M_C values of *L. morgani* in S.W. France (Chattian-Aquitanian, DROOGER & FREUDENTHAL, 1964).

Distribution: Turin hills: Villa Giuseppina and Bric del Duca.

Age: Chattian-Aquitanian.

Lepidocyclina (Nephrolepidina) praemarginata

R. Douvillé, 1908.

Pl. II, photos 1—4.

Lepidocyclina praemarginata R. DOUVILLÉ, 1908; Bull. Soc. Géol. France, sér. 4, vol. 8, p. 91, figs. 1—4a.

Nephrolepidina praemarginata (R. Douvillé), H. DOUVILLÉ, 1924; Mém. Soc. Géol. France, nouvelle sér. vol. 1, no. 2, pt. 2, p. 77, pl. 6, figs. 5—7.

Lepidocyclina (*Nephrolepidina*) *tournoueri* Lemoine & R.

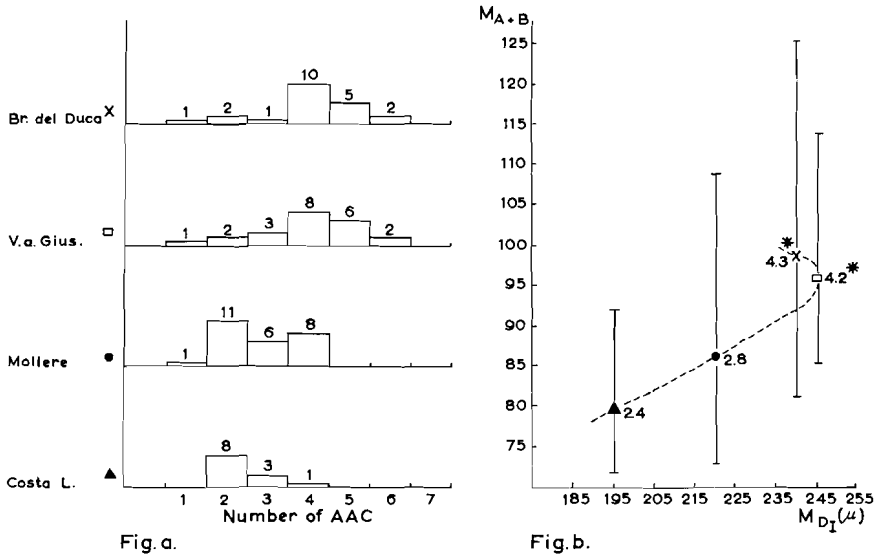


Fig. a. Fig. b.

Fig.a. Histograms of number of accessory auxiliary chambers (AAC).

Fig.b. Correlation between M_{A+B} and M_{D_I}

N.B. Insetnumbers represent M_C.

Fig.c. Explication of symbols:

PAC: Primary auxiliary chambers.

AAC: Accessory auxiliary chambers.

I: Protoconch; II: Deuteroconch.

D_I: Diameter-I; D_{II}: Diameter-II.

H_{II}: Height of I + II.

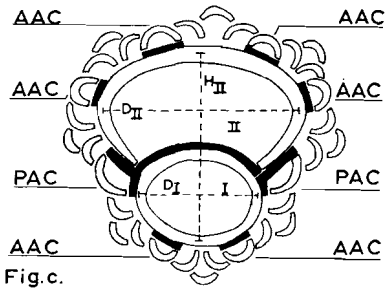


Fig.c.

	LOCALITIES	SAMPLE	N	MEAN VALUE			MEAN VALUE (in μ)			M_{II}/M_I	$M_C \pm \sigma M$
				A	B	A + B	H_{II}	D_I	D_I		
×	Bric del Duca	S-655^C	21	44.6	53.4	98	340	240	345	1.44	4.3* ± 0.38
□	Villa Guiseppina	JT49-S1-S2	24	46.8	48.8	95.6	375	245	385	1.57	4.2* ± 0.34
●	Mollere	C-601-602	20	41.9	44.1	86	315	220	315	1.43	2.8 ± 0.30
▲	Costa Lupara	C-L-001	13	3.66	42.8	79.4	295	195	285	1.27	2.4 ± 0.21

* Including AAC on I

Figure 5

Data, obtained from the *Nephrolepidina* at some localities in Piemont (N. Italy).

Douvillé *praetournoueri* H. Douvillé, BRÖNNIMANN, 1940; Schweiz. Pal. Abh.; 63, p. 50, pl. 3, figs. 1, 2.

Remarks: In the original description R. DOUVILLÉ (1908) mentioned microspheric specimens of *L. praemarginata* from Costa Lupara. H. DOUVILLÉ (1924) found megalospheric individuals here and described them as belonging to the subgenus *Nephrolepidina.*

Our material from the type locality Costa Lupara contained several megalospheric individuals. The data, obtained from the biometric study of this species are listed in text figure 5. The *Nephrolepidina* from the locality Mollere belong to the same species, according to the biometric investigations.

Lepidocyclina praemarginata shows close resemblance with the material, which BRÖNNIMANN (1940, p. 50) described as *L. tournoueri praetournoueri* from Morocco.

BRÖNNIMANN separated *L. praetournoueri* from his *L. tournoueri* (which is close to our *L. morgani*) using the $M_{D\,II}/M_{D\,I}$ value of the specimens in some samples from different levels. This splitting of the group of specimens of single samples into two species hampers a good comparison. Taking all the specimens from BRÖNNIMANN's tables (p. 53) together, we calculated the M_C at 3.1 ($AAC_I + AAC_{II}$). That of our *L. praemarginata* is only slightly lower than this value (2.4—2.8), which leads to the assumption that BRÖNNIMANN's material from Morocco might belong to the same species *L. praemarginata.* Our distinguishing this species from *L. tournoueri* and *L. morgani* (see text figure 5) is based on the distinctly lower M_A, M_B and M_C values. This species seems to have lived before the rise of the miogypsinids.

Occurence: Southern Piemont, at the localities Mollere, Costa Lupara and probably near Spigno Monferrato and Molare.

Age: Probably Rupelian.

Family: **Miogypsinidae** VAUGHAN, 1928.
Genus: **Miogypsina** SACCO, 1893.
Type species: *Nummulina globulina* Michelotti, 1841.

Remarks and **occurence:** See textfigure 6. The genus *Miogypsina* has not been recorded from Southern Piemont until recently. LORENZ (1960) described *Miogypsina gunteri-socini* from the sandstones of Montezémolo, a village, 10 km East of Ceva (text figure 1). If the M_X value is 11 (no other data are given) these specimens might as well belong to *M. gunteri.* The series of sandstones of the Lepre Member (Ceva Formation, section I) are the lateral equivalent of the upper part of the sandstones of Montezémolo, in which this *M. gunteri-socini* occurs. For this reason the Lepre Member might be placed in the Aquitanian.

LORENZ (1962) furthermore mentioned *Miogypsina* s.s. in the outcrops along the Rio Ravanosco, South of Acqui (section III). We found a few specimens of *Miogypsina globulina* in the conglomerates at the base of the Ravanosco Formation. This species was also found in the Acqui Limestone near Acqui and Visone. These occurrences might indicate a Burdigalian age for these layers.

The Limestone of the Bric Albarella (section II) contains primitive *Miogypsina intermedia.* At the base of the Ronzone Formation (Tortona area, section V) *Miogypsina globulina - intermedia* were found. These occurrences may also be placed in the Burdigalian.

Finally, *Miogypsina gunteri, M. socini* and *M. globulina* were found in succession at the base of the Montada Formation near the village of Rigoroso (Catena Montada, section IV).

SECTION	FORMATION / MEMBER	SAMPLE	N	X MEAN	X RANGE	γ MEAN	γ RANGE	V=200 α/β MEAN ± σ M	V=200 α/β RANGE	M_{II}/M_I	DETERMINATION MIOGYPSINA
SCRIVIA	MONTADA	326-II	16	9.0	7-12	-55°	-120°→+45°	?		0.95	gunteri-(socini)
SCRIVIA	MONTADA	326-III	16	8.0	4-11	-30°	-90°→+30°	14±4.2	0→58	1.13	(gunteri)-socini
SCRIVIA	MONTADA	326 VIII/X	4	7.5	6-9	+20°	+5°→+45°		20→45		globulina
ACQUI (VISONE)	CALCAIRE d'ACQUI (VISONE)	(13-14)	6	7.3	6-9	+30°	+10°→60°	<45		1.29	globulina
ACQUI	CALCAIRE d'ACQUI	39-K									
ACQUI	RAVANOSCO	39A	3	7.0	6-8	+25°	+20°→30°		20→50		globulina
TORTONA	RONZONE	462-A	17	7.2	5-9	+30°	+15°→60°	49.5±4.2	15→76	1.39	(globulina)-interm.
SPIGNO-M.	PIANTIVELLO (CAP. la COLLA)	260	28	5.9	5-7	+40°	+5°→70°	52.5±4.2	20→80	1.33	intermedia
SPIGNO-M.	PIANTIVELLO	171									

Figure 6
Determination table of the *Miogypsina* from several localities in Southern Piemont (N. Italy).

Miogypsina gunteri Cole, 1938.
Pl. XII, fig. 6; text fig. 6.

Miogypsina gunteri COLE, 1938; Florida St. Dept. Conserv., Geol. Bull. 16, p. 42, pl. 6, figs. 10—12, 14; pl. 8, figs. 1—9. DROOGER, 1952; Akad. Thesis, Utrecht; p. 21, 51; pl. 2, figs. 11—15.

Remarks and **occurrence:** See text fig. 6. Just above the boundary between the Rigoroso Formation and Montada Formation (sample 326 II, section IV A), Serravalle Scrivia area.

Miogypsina socini Drooger, 1954.
Text figure 6.

Miogypsina (Miogypsina) socini DROOGER, 1954; Kon. Ned. Akad. Wetensch., A'dam, ser. B, vol. 57, p. 233, text fig. 2, pl. 2, figs. 20—24.

Remarks and **occurrence:** See text fig. 6. About 20 m above the base of the Montada Formation (sample 326 III, section IV A), Serravalle Scrivia area.

Miogypsina globulina (Michelotti), 1841.
Pl. XII, fig. 5; text fig. 6.

Miogypsina (Miogypsina) globulina (Michelotti), DROOGER & SOCIN, 1959; Micropaleontology, vol. 5, p. 420, figs. 5—6, table 2.

Remarks and **occurrence:** See text fig. 6. In the conglomerates at the base of the Ravanosco Formation, and in the Acqui Limestone near Acqui and Visone; scarce. In the Montada Formation, samples 326 VIII—X, escarpment of the Catena Montada (section IV A), Serravalle Scrivia area.

Miogypsina intermedia Drooger, 1952.
Text fig. 6.

Miogypsina (Miogypsina) intermedia DROOGER, 1952; Akad. Thesis, Utrecht, pp. 35, 55; pl. 2, figs. 30—34; pl. 3, fig. 4.

Remarks and **occurrence:** See text fig. 6. Bric Albarella Limestone; section II, Spigno Monferrato area, samples: 171, 176, 181 and 260 (II).

Family: **Nummulitidae** DE BLAINVILLE, 1825.
Subfamily: **Nummulitinae** DE BLAINVILLE, 1825.
Genus: **Nummulites** LAMARCK, 1801.
Type species: *Camerina laevigata* Bruguière, 1792.

On external features the *Nummulites* in Southern Piemont could be separated in two groups:

Group 1. This group, called **Nummulites sp. 1,** resembles *Nummulites vascus* Joly & Leymerie, 1848. (Mém. Ac. Sc. Toulouse, sér. 3, vol. 4, p. 149).

Remarks: The diameter of the specimens of our rich collections varies from 2 mm to about 1 cm. The small individuals are relatively thick in comparison to the large ones. Their sutures are usually nearly straight to slightly undulating and curve moderately backward toward the peripheral margin.

Occurrence: Near the top of the Erta Formation (section V), Tortona-Garbagna area, together with *Operculina* sp. and *Discocyclina* sp.

Group 2. Called **Nummulites sp. 2,** is close to *Nummulites intermedius* d'Archiac, 1846. (Mém. Soc. Géol. France, vol. 2, p. 199).

Remarks: These specimens are thinner than those of *Nummulites vascus.* The small ones possess irregularly curved sutures, while the larger specimens show a distinct reticulate surface pattern. Between the two extremes all intermediates were observed.

Occurrence: Locality Mollere (section I; not in table VI); occurence dubious. Locality Costa Lupara (section II). Locality Molare: in the lower part of the Orba Formation (section III). In the lower part of the Pietrabissara Formation (section IV). In the upper portion of the Garbagna Formation (section V).

Family: **Discocyclinidae** GALLOWAY, 1928.
Genus: **Discocyclina** GÜMBEL, 1868.
Type species: *Nummulites papyracea* Gümbel, 1832.

Discocyclina sp.

Remarks: 5 specimens were collected from sample 551, about 25 m below the top of the Erta Formation (section V).

The *Cycloclypeus, Heterostegina, Operculina* and *Eulepidina* specimens from various localities were not studied in detail. The bad preservation, especially of the internal features hampered the specific determination. Some determinations have been derived from earlier authors, who dealt with the larger Foraminifera of some of the localities (LEMOINE & R. DOUVILLÉ, 1904; R. DOUVILLÉ, 1908; H. DOUVILLÉ, 1924; LORENZ, 1959, 1960).

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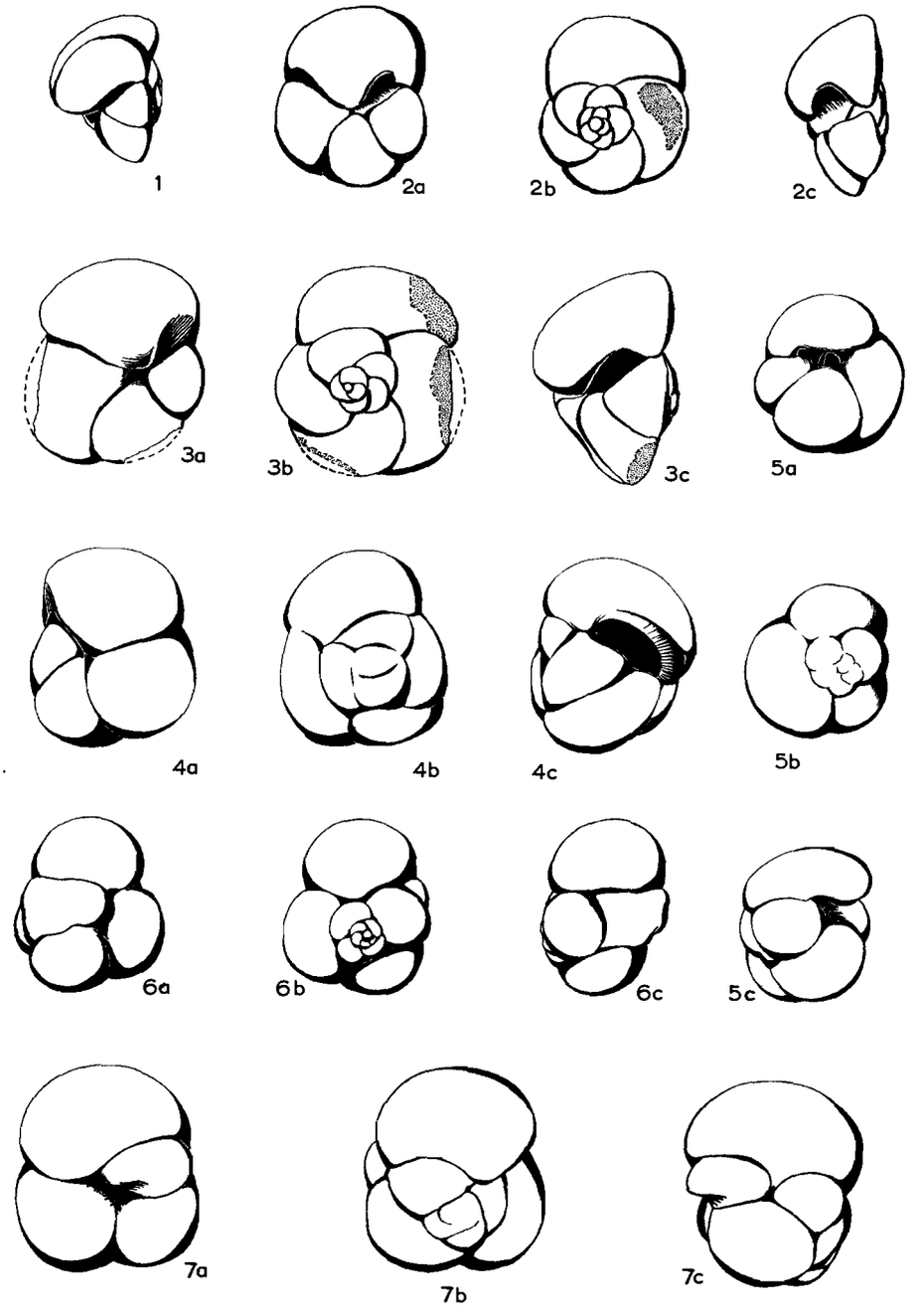

PLATE I

PLATE I

(all figures 50x; a. ventral view, b. dorsal view, c. side view)

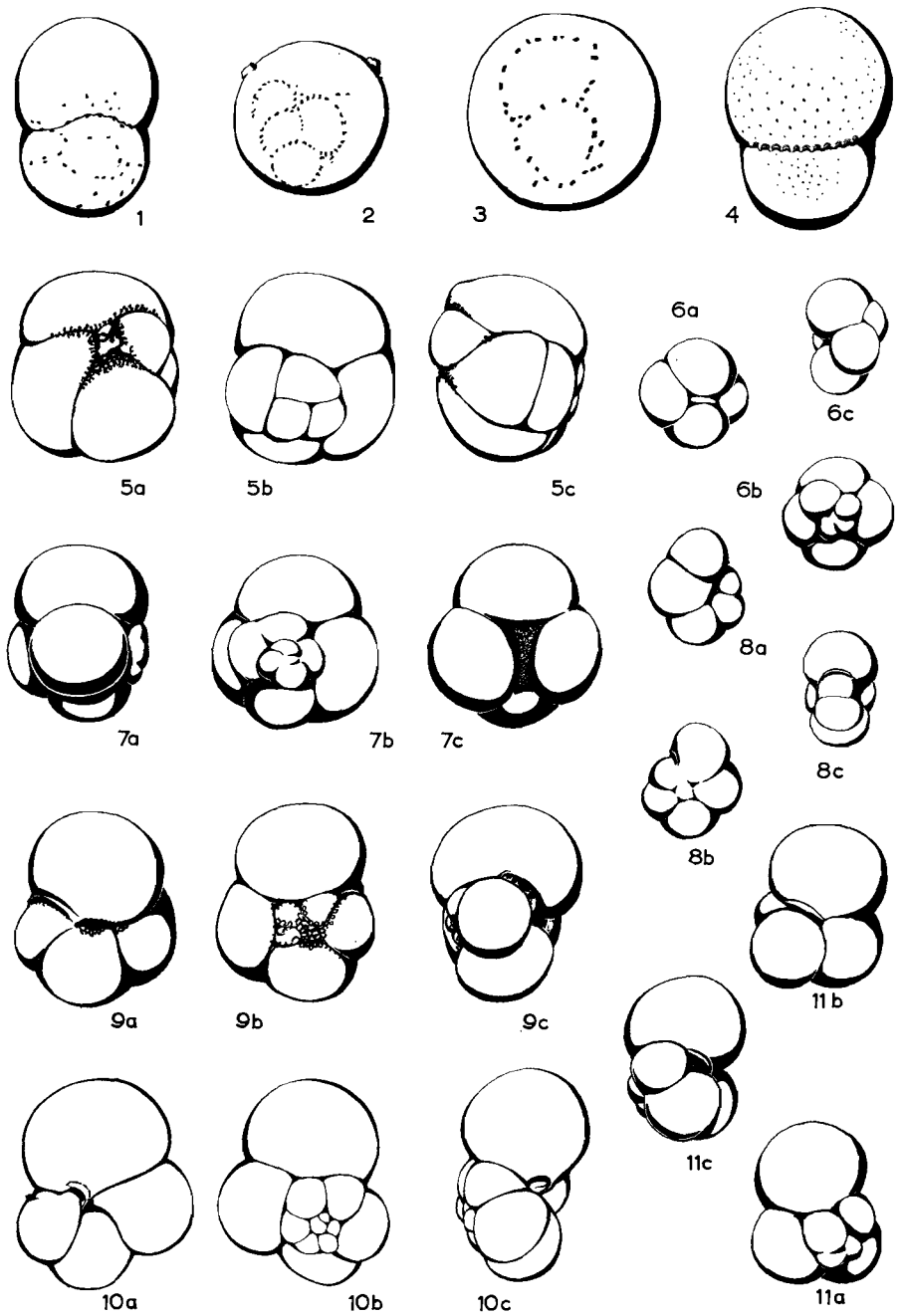
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PLATE II

PLATE II

(figures 1—9, 11: 50 x; fig. 10: 100 x.
a. ventral view, b. dorsal view, c. side view)

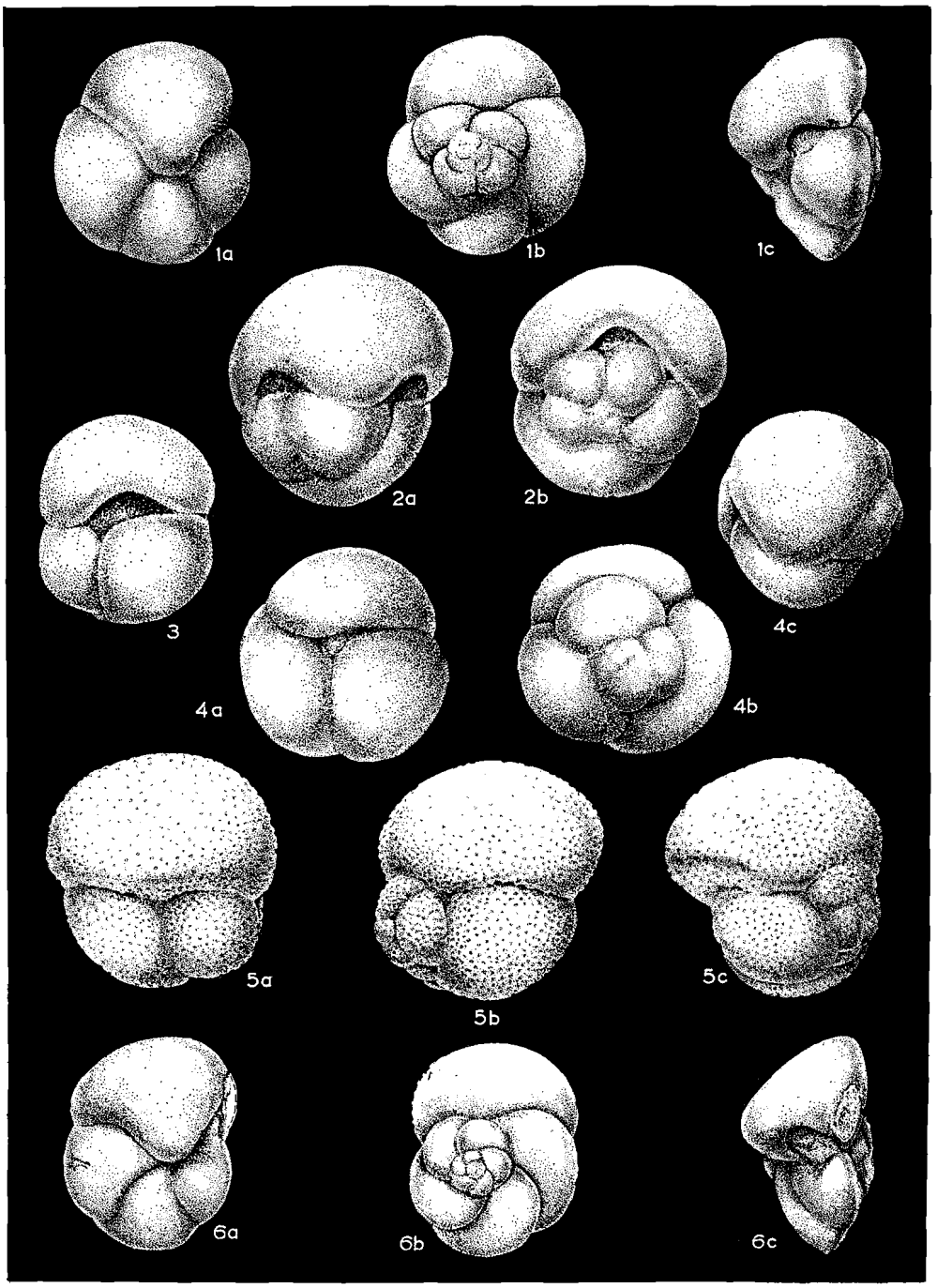


PLATE III

PLATE III

(fig. 1 : 100x; figs. 2—6: 50x)

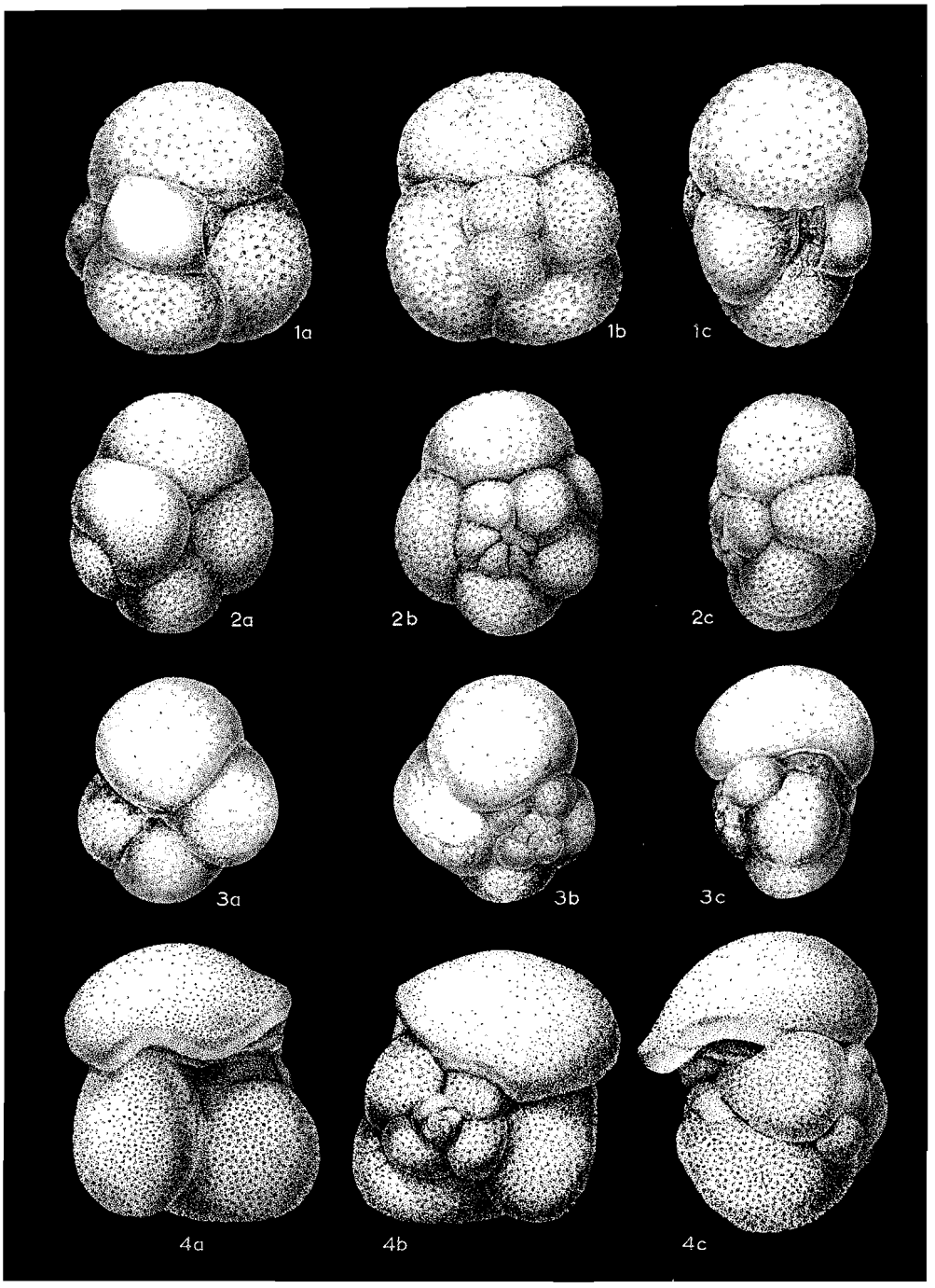


PLATE IV

PLATE IV

(all figures: a. ventral view, b. dorsal view, c. side view)

page

Fig. 1a—c: *Globigerinita dissimilis* (Cushman & Bermudez); 100x; Sample 382C, Rigoroso Formation (section IV) 54

Fig. 2a—c: *Globigerinita unicava* (Bolli); 100x. Sample 382 C, Rigoroso Formation (section IV). 54

Fig. 3a—c: *Globigerina opima nana* Bolli; 50x. Sample 355, Rigoroso Formation (section IV) . 53

Fig. 4a—c: *Globoquadrina dehiscens* (Chapman, Parr & Collins); 100x. Sample 388 A, Serravalle Formation (section IV) 54

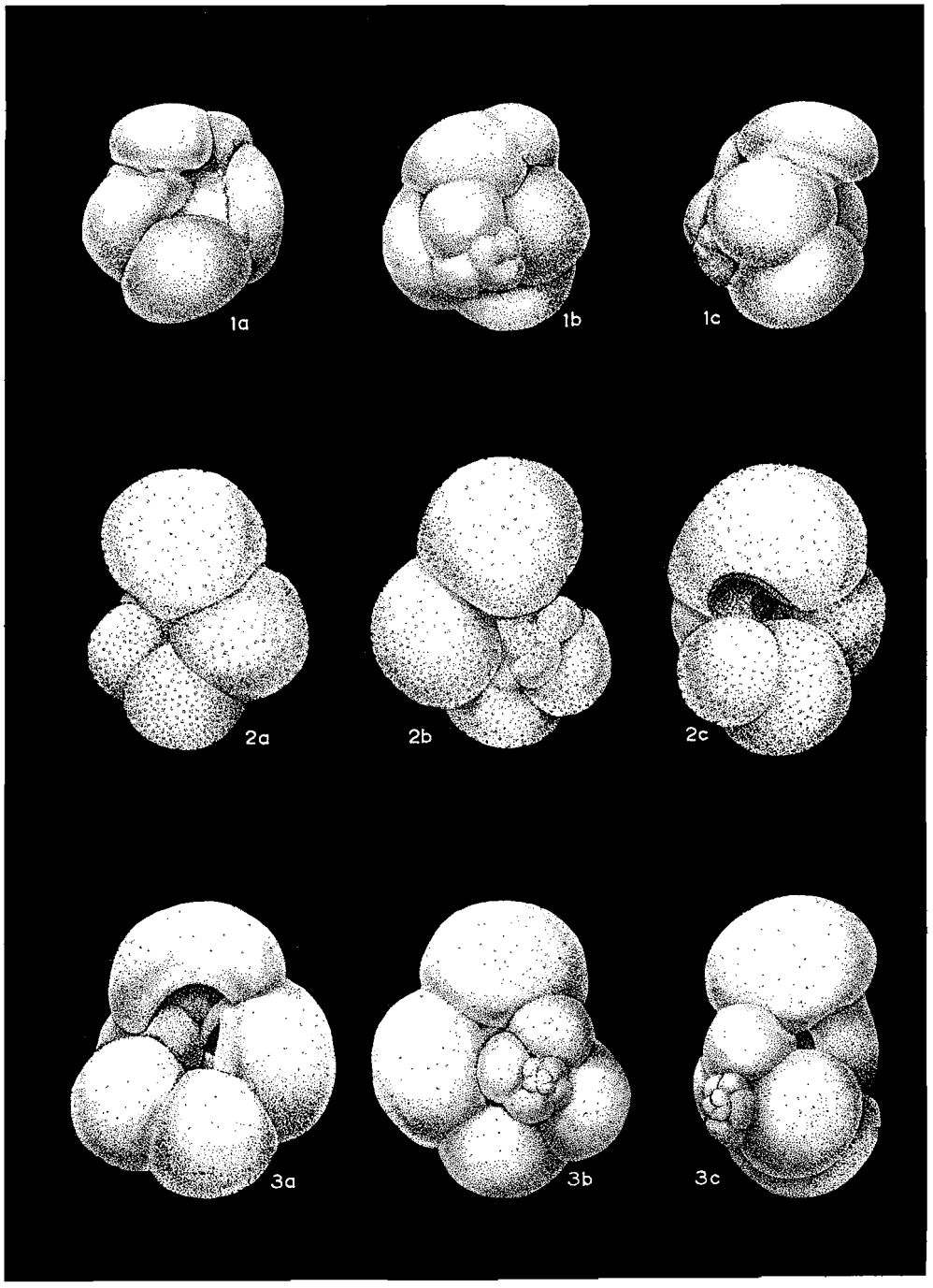


PLATE V

PLATE V

(all figures: a. ventral view, b. dorsal view, c. side view)

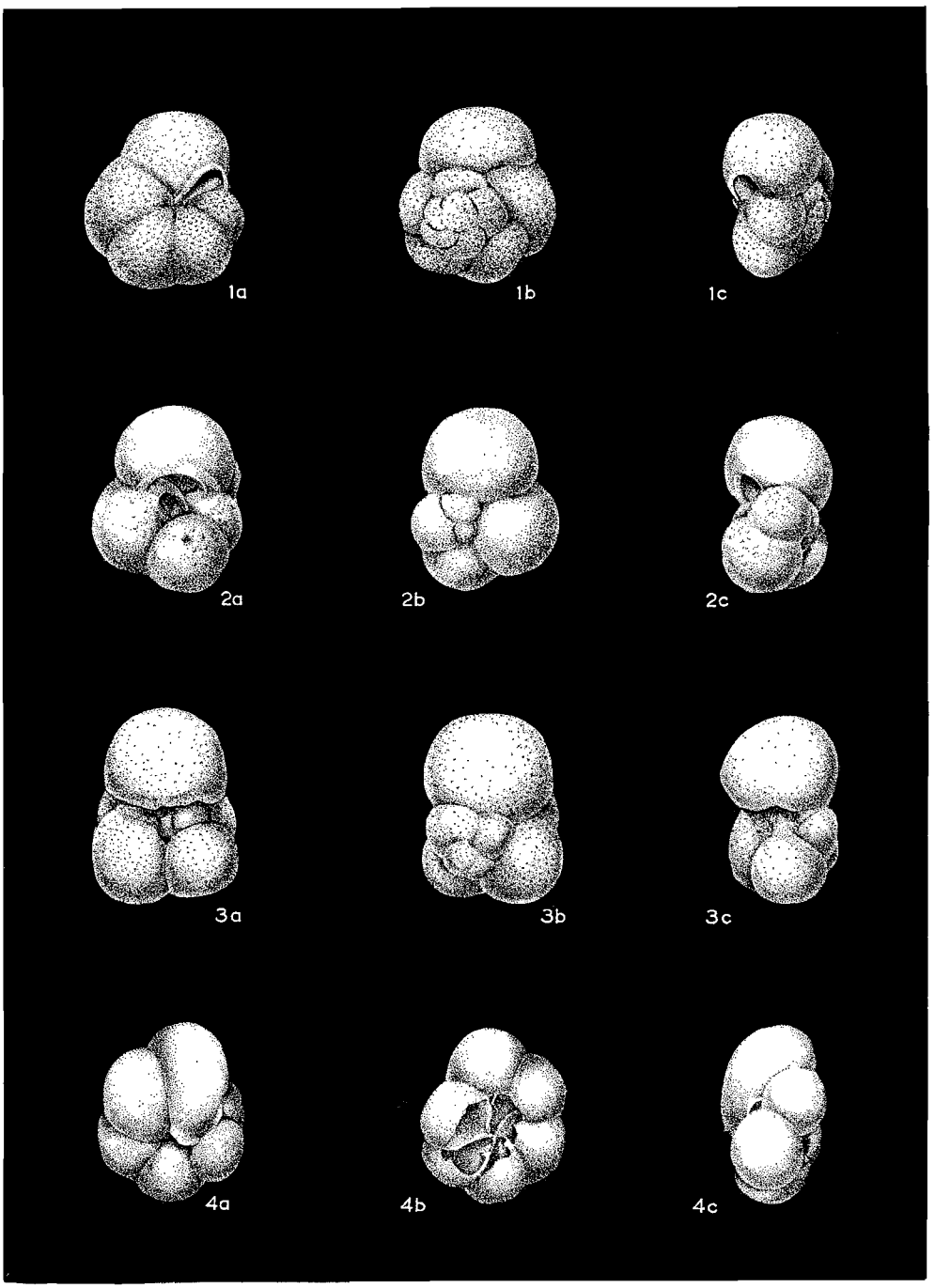


PLATE VI

PLATE VI

(all figures: a. ventral view, b. dorsal view, c. side view, 50x)

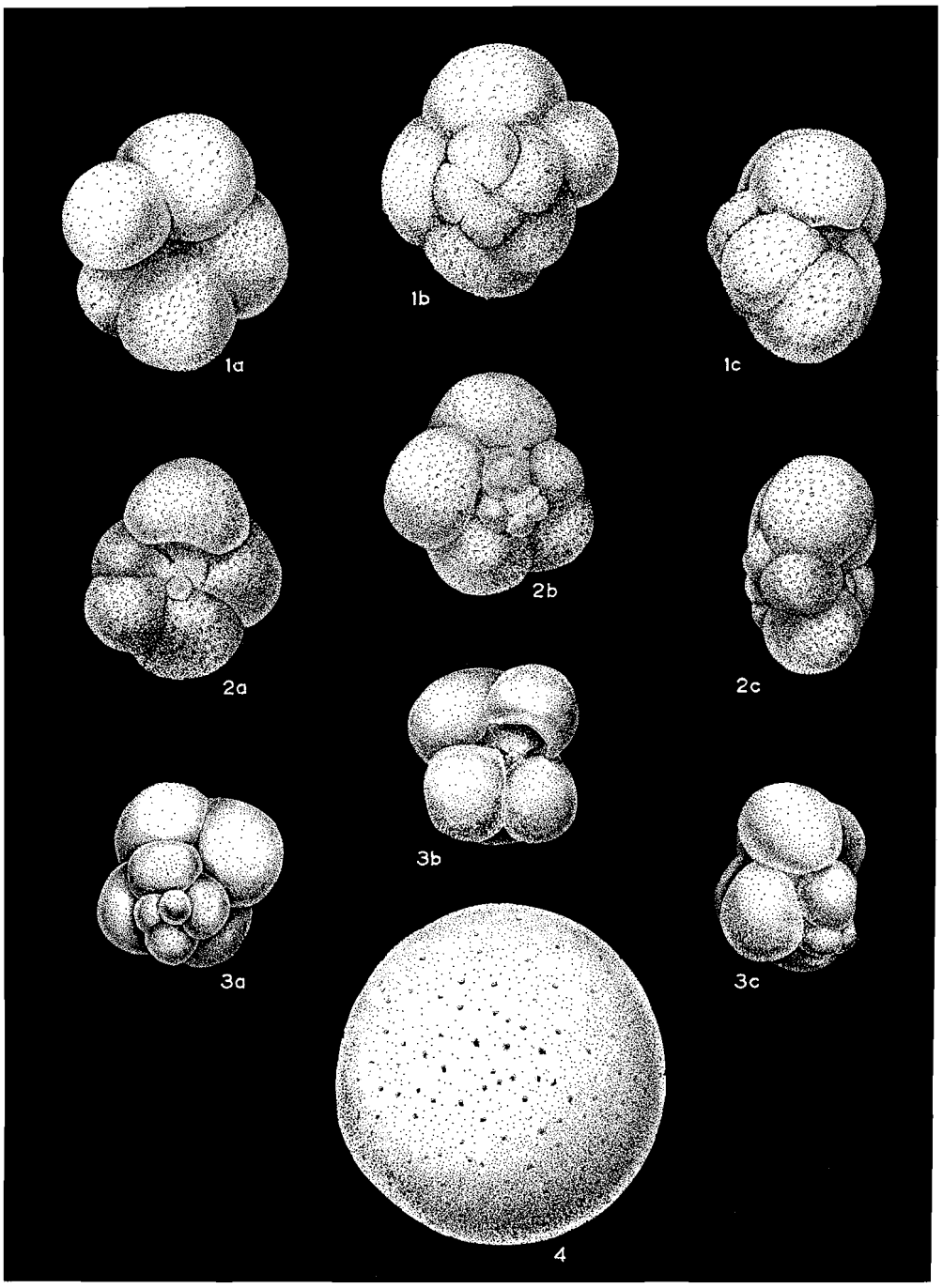


PLATE VII

PLATE VII

(all figures: a. ventral view, b. dorsal view, c. side view)

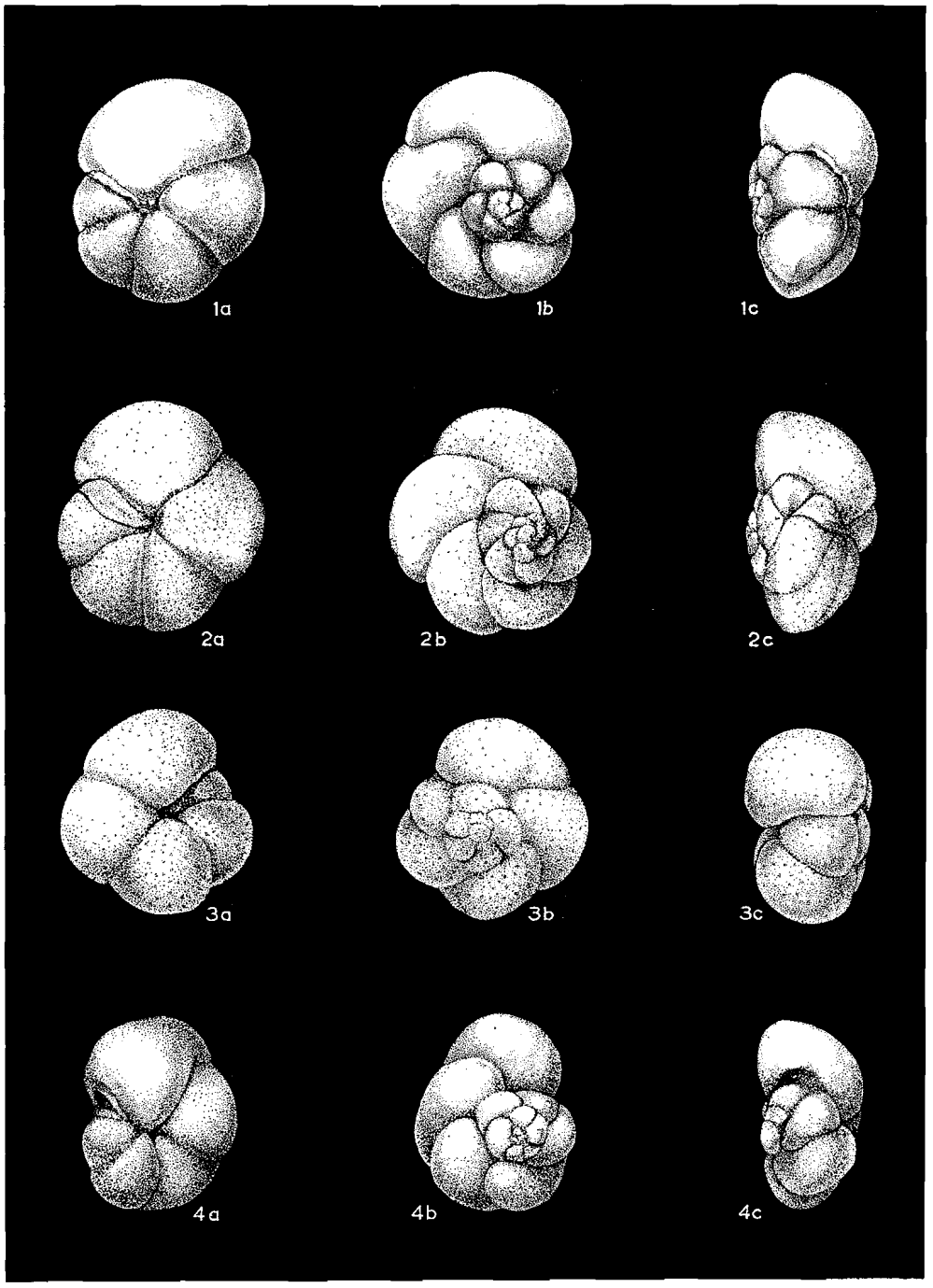


PLATE VIII

PLATE VIII

(all figures: a. ventral view, b. dorsal view, c. side view)

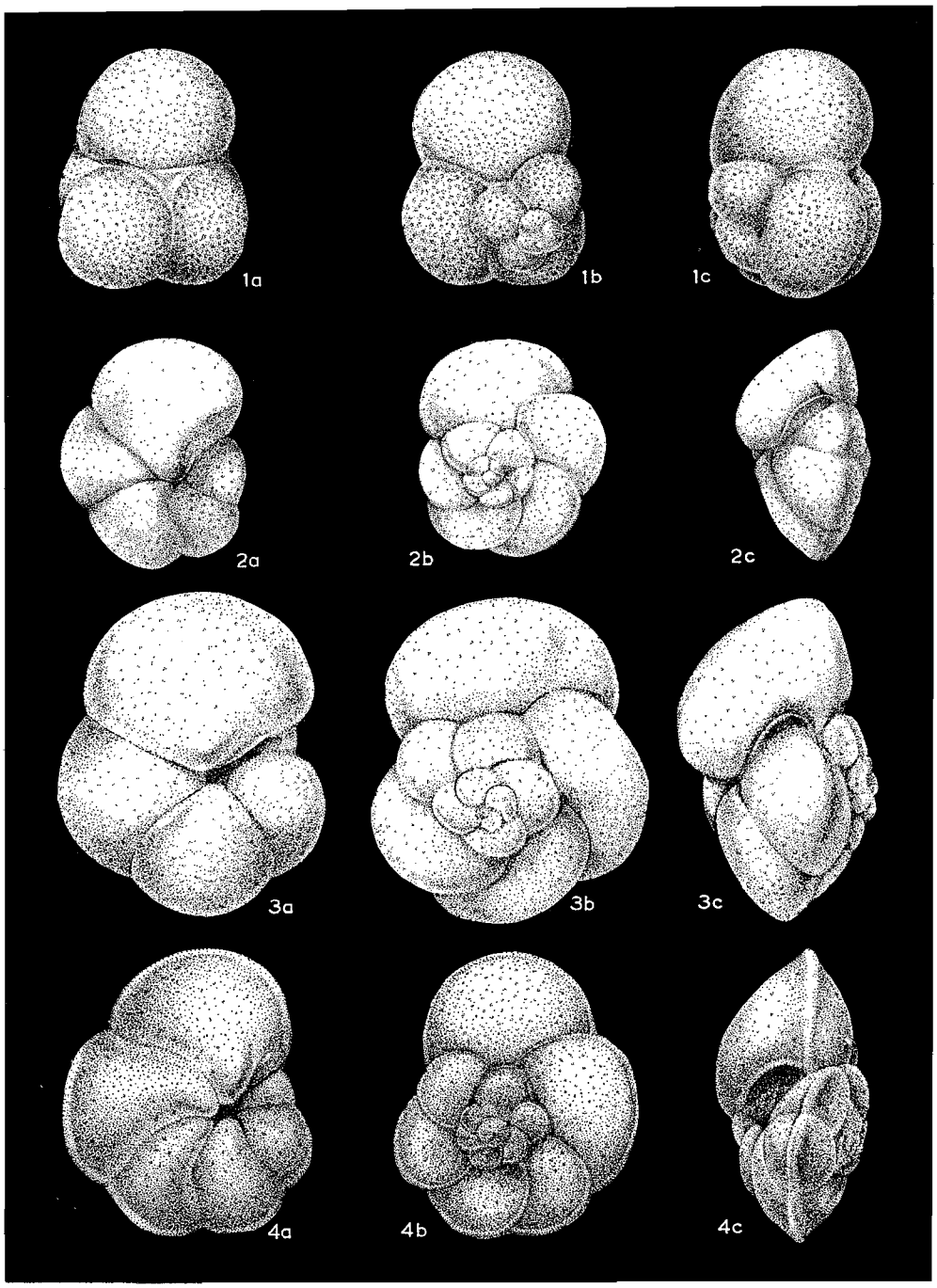


PLATE IX

PLATE IX

(all figures: a. ventral view, b. dorsal view, c. side view)

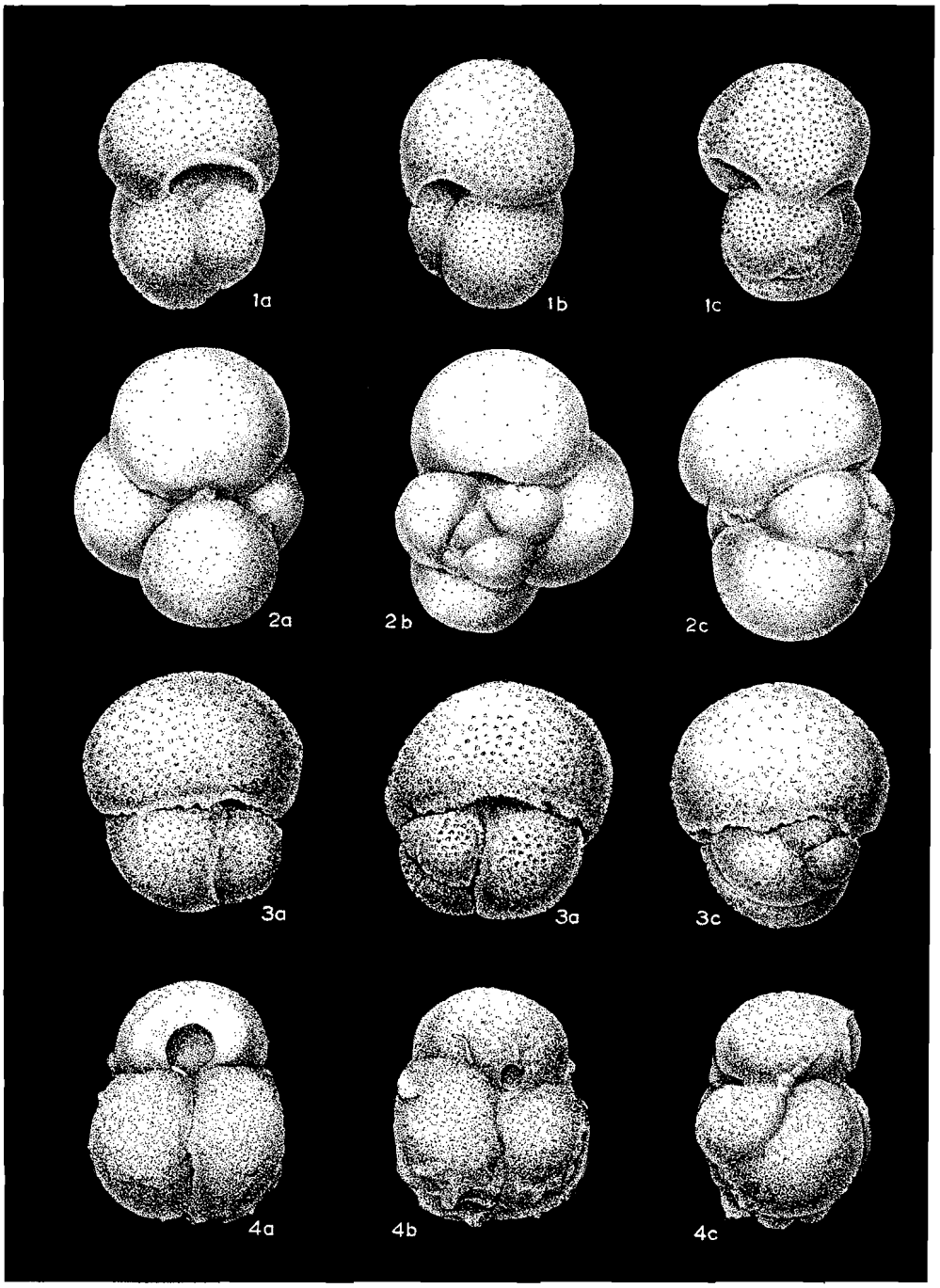


PLATE X

PLATE X

(all figures 50x; a. ventral view, b. dorsal view, c. side view)

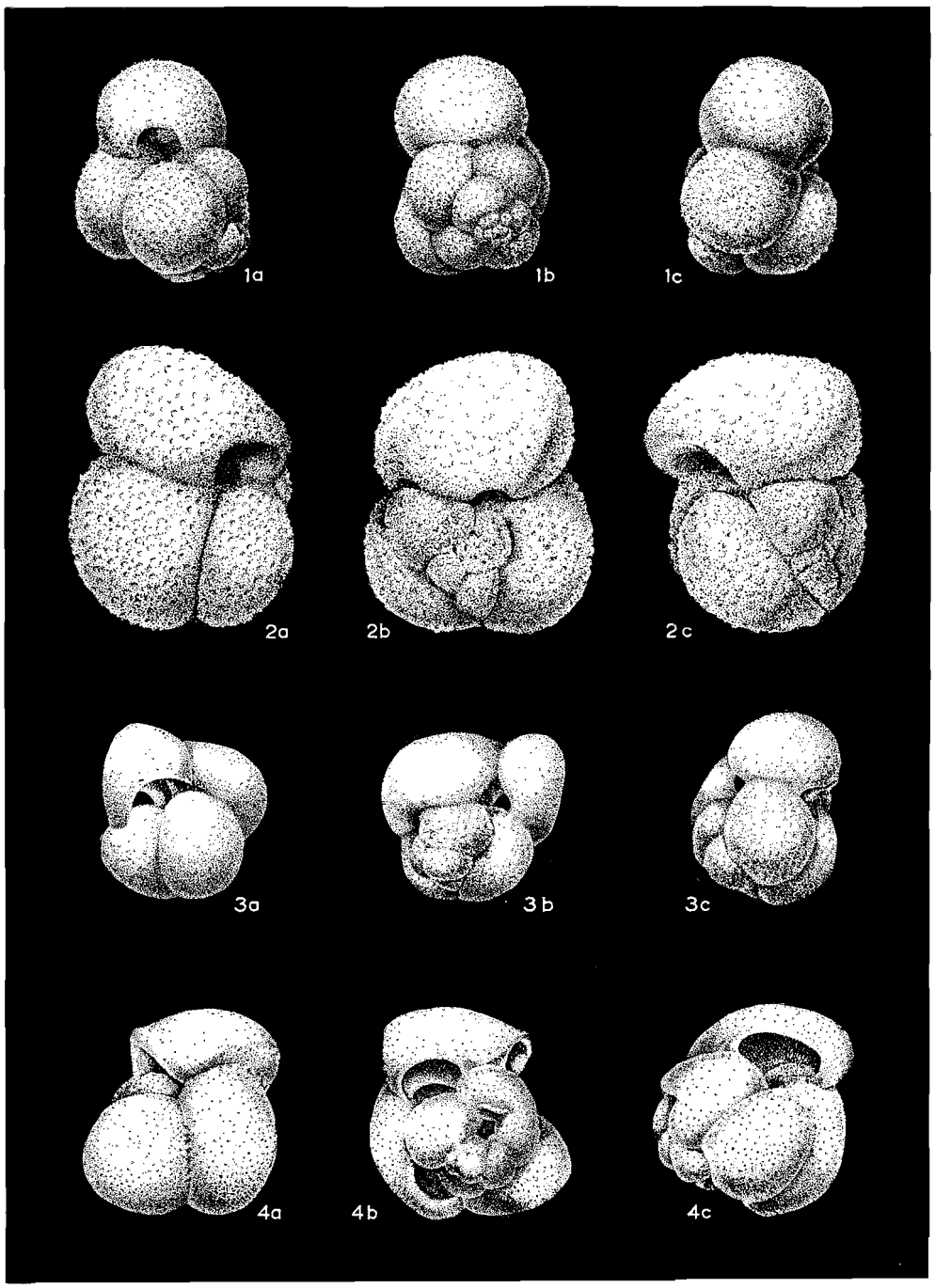
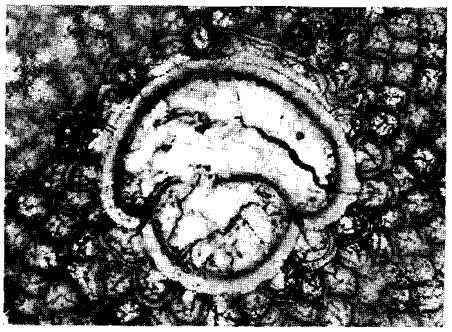


PLATE XI

PLATE XI

(all figures: a. ventral view, b. dorsal view, c. side view)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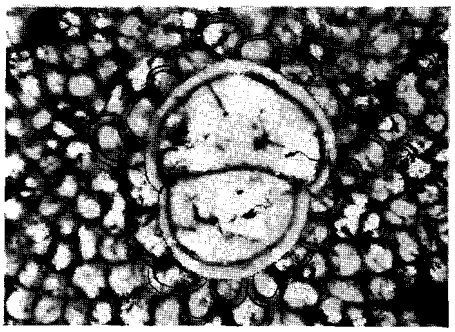
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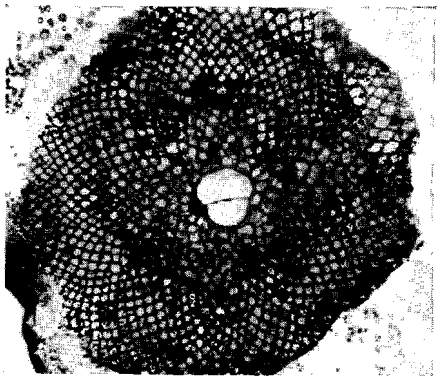
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PLATE XII

(Photos of thin sections of larger Foraminifera)

page

Photos 1, 2, 3: *Lepidocyclina (Nephrolepidina) praemarginata* R. Douvillé equatorial sections through the nucleoconchs, showing the arrangement of nepionic chambers.
Photos 1—2 from sample 601 A, Oligocene near the locality Mollere (section I) (40x). Photo 3 from sample CL 001, showing the transition from spatulate to rhomboid and hexagonal chambers. Oligocene near Costa Lupara (section II). (10x) 59

Photo 4: *Lepidocyclina (Nephrolepidina) praemarginata* R. Douvillé; transverse sections through the nucleoconch. Sample 39 from the Oligocene near Casa Ferri (section II) (10x).

Photo 5: *Miogypsina globulina* (Michelotti); transverse section. Sample 13 A 3 from the Limestone of Acqui (near Visone, section III). Burdigalian (10x) 61

Photo 6: *Miogypsina gunteri* Cole; transverse section Sample 326 II from the Aquitanian. Montada Formation near Rigoroso (section IV) (10x) . 61