UTRECHT MICROPALEONTOLOGICAL BULLETINS

J. G. VERDENIUS

3

NEOGENE STRATIGRAPHY OF THE WESTERN GUADALQUIVIR BASIN (SOUTHERN SPAIN)

UTRECHT MICROPALEONTOLOGICAL BULLETINS

In the same series has appeared:

Bulletin 1:

FREUDENTHAL, T. — Stratigraphy of Neogene deposits in the Khania Province, Crete, with special reference to Foraminifera of the family Planorbulinidae and the genus Heterostegina. (Statistical analysis, evolution and stratigraphic application of *Planorbulinella, Linderina, Hellenocyclina* and others. Material from localities in Europe, America and the Indopacific is included).
208 pages, 15 plates, 53 text figs., 10 tables.

US $ 8

Bulletin 2:

MEULENKAMP, J. E. — Stratigraphy of Neogene deposits in the Rethymnon Province, Crete, with special reference to the phylogeny of uniserial Uvigerina from the Mediterranean region. (Statistical analysis, evolution and stratigraphic application of uniserial Uvigerinids in the Mio-Pliocene of the Mediterranean area).
172 pages, 6 plates, 53 text figs., 22 tables.

US $ 7

The following titles are planned to appear in the near future:

TJALSMA, R. C. — Stratigraphy and Foraminifera of the Neogene of the eastern Guadalquivir Basin (S. Spain). (Planktonic and larger foraminifera).

DROOGER, C. W., P. MARKS, A. PAPP et al. — Nummulites from the Upper Eocene and Lower Oligocene of the North Sea Basin. (Statistical analysis of *Nummulites variolarius, N. orbignyi* and related species).

FELIX, R. — Oligo - Miocene stratigraphy of Malta and Gozo.

HARDENBOL, J. — Stratigraphy and Foraminifera of the Type Priabonian, Northern Italy.

The prices are for the single bulletins, postage included.

NEOGENE STRATIGRAPHY
OF THE
WESTERN GUADALQUIVIR BASIN
(SOUTHERN SPAIN)

PRINTED IN THE NETHERLANDS
BY
SCHOTANUS & JENS UTRECHT INC. - UTRECHT

NEOGENE STRATIGRAPHY OF THE WESTERN GUADALQUIVIR BASIN (SOUTHERN SPAIN)

J. G. VERDENIUS

1970
SCHOTANUS & JENS
UTRECHT - THE NETHERLANDS

CONTENTS

ABSTRACT

In the Neogene sediments of the western part of the Guadalquivir Basin eight formations have been distinguished. The planktonic foraminifera in five of these formations have been attributed to seven separate planktonic faunal associations. With these lithostratigraphic and biostratigraphic data the depositional and tectonic history of the basin during the Neogene can be reconstructed. Part of the basin filling appears to be allochthonous. There is ample evidence of a marly sedimentation in the south in a bathyal environment during Late Miocene time; sedimentation may have started in the Early Miocene already. Simultaneously older Tertiary sediment masses slided into this part of the basin from the south. Early Pliocene clayey sediments in the centre and north testify of a much shallower sea depth by their lithology and foraminiferal fauna. The chaotic structure of the bathyal marl and their actual position on top of the younger clay is explained by the assumption of a northward translation of these marls, the gypsiferous Mesozoic sediments that are present below the Tertiary strata facilitating the movement. Middle Pliocene sediments, deposited over both the Late Miocene marl and the Early Pliocene clay testify of a further shallowing of the basin.

In search of a section that could be considered a marine equivalent of the Upper Miocene Messinian, PERCONIG proposed the section near Carmona as stratotype for the Andalusian Stage, coeval with the Messinian stratotype and Stage. This is not substantiated by his evidence. A study of the planktonic foraminifera from the Andalusian stratotype indicates that they are homotaxial with those of the stratotypes of the Tabianian and Piacenzian Stages, of Early and Middle Pliocene Age, thus refuting its parallelisation to the Messinian, of Late Miocene Age.

ACKNOWLEDGEMENTS

At the completion of this paper, the result of several years of strenuous fieldwork and laboratory research, I wish to express my gratitude to the various persons, who, at one stage or another, have contributed to its achievement, and to my traning in the earth sciences.

At the first place I want to gratefully acknowledge the encouragement and constructive criticism provided by Prof. C. W. Drooger, who originally suggested the subject of the thesis and who has, with unflagging energy, supervised the process of its conception and birth.

I am much obliged to P. Marks for his company in the field and for his willingness to discuss the manuscript while it was being written.

My sincere thanks to R. C. Tjalsma who was my companion during the long days of fieldwork under the hot Andalusian sun, and who joined in many a profitable discussion on the many difficult problems that planktonic foraminifera provide.

Thanks are due also to J. E. van Hinte, my first adviser in the field; and to T. Arnold Bik, R. Geyskes and A. Fortuin for their agreeable company during much of the fieldwork in Spain.

Particular thanks are also due to J. E. Meulenkamp, whose practical suggestions during the completion of this paper have been invaluable.

I wish to thank W. H. Blow for his kindness in critically discussing the planktonic foraminifera at the occasion of his visit to Utrecht, and for placing unpublished data at my disposal.

F. Barbieri (Parma), H. P. Bolli (Zürich), U. Follador (Pescara), E. Perconig (Madrid), G. Salvatorini (Pisa) and S. Sartoni (Bologna) provided topotype material of various classical neogene localities to the Department of Micropaleontology in Utrecht, at my request, and much to my benefit. I wish to thank them most cordially for their kindness.

A. van Doorn, P. Hoonhout and J. P. van der Linden made the illustrations. I thank them for their patience and for the excellent quality of their work.

Last, but not least, I wish to express my gratitude to Miss N. M. Kroll for her help in typing the final version of the manuscript.

Chapter I

INTRODUCTION

I.1. General remarks

The chronostratigraphic subdivision of the Tertiary, i.e. the sequence of stages this system shows, has been established along various lines of approach since the origin of stratigraphy as a science. Originally much use was made of molluscs in stratigraphic correlation and many time-stratigraphic units were based on formations that contained molluscan faunae.

The increasing application of foraminifera to biostratigraphical subdivision and correlation presents difficulties, because various stratotypes, chosen for their abundance of mollusc fossils, turned out to be disappointing as to their foraminiferal content and therefore proved to be difficult to link to foraminiferal biozonation.

Most stratotypes of Neogene stages have been established in the Mediterranean region. This choice may be considered to be correct. However, difficulties arose in the choice of a stage for the terminal Miocene, since during this time sediments indicating extreme conditions of salinity were deposited in the Mediterranean area. Both molluscs and foraminifera prove these conditions. They often are of no help in the correlation over larger distances.

These conditions were expected to be absent in the Guadalquivir Basin, in southern Spain. The rocks cropping out in this area have led to the traditional picture of a sea strait, the Betic Strait, a connection assumed to exist between Atlantic Ocean and the Mediterranean into the Middle Miocene. With the closure of the strait at the end of the Miocene, a bay is supposed to have remained at its western side, gradually being filled with sediments.

So far, in the Guadalquivir Basin only superficial geological investigations had been carried out, as far as the Neogene is concerned. Sediments were „pinpointed" in the accepted chronostratigraphy on the merits of single index fossils. If the scarcity of macrofossils did not allow sediments to be placed in the „classical" Tertiary stratigraphy, one correlated with the accepted mediterranean stages on gross similarities in lithology. Several authors emphatically start with the assumption that each stage should consist of a complete sedimentary cycle with transgression and regression. They arrange remote lithological units on top of each other to obtain a sequence of rock units, each with the right facies for its assigned place in the „cycle", to present the resulting composite „unit" as a stage.

Hardly any interest was given to foraminifera from the Neogene sediments of the Guadalquivir Basin. It is true, some of the fundamental studies of LEMOINE and R. DOUVILLE on *Lepidocyclina* were carried out with material from the Guadalquivir Basin, but only little attention was given to smaller foraminifera, if they were mentioned at all. CARBONELL, as late as 1926, denies their stratigraphical applicability, but he thinks that they may have some use in ascertaining the facies of the sediments they are found in.

The increasing use of foraminifera in stratigraphy, and the scarcity of open-marine sediments of younger Miocene Age in southern Europe were the incentives for an attempt to make a foraminifera-based study of the Neogene sequence of the Guadalquivir Basin presented in this paper.

During the summers of 1963 and 1966 the author carried out fieldwork in the western part of this region.

A geological map was made because such a map had so far been lacking. Formations (rock units) were distinguished and described. To avoid the introduction of faulty stratigraphic relations between formations their superposition is not considered proved unless they were actually found exposed on top of one another.

Because of the very small numbers of exposures the resulting map is sketchy and many of the interrelations between formations could not be solved in the field.

Along with the mapping a number of sections was sampled for the study of their foraminiferal content. Wherever no long exposed sections were found isolated samples were taken so as to have some information about the continuity of the formations.

The laboratory work was carried out in the Micropaleontological Department of the Geological Institute, State University, Utrecht.

I.2. Geographical description of the Guadalquivir Basin

The Guadalquivir Basin in a geographical sense is situated between the mountains of the Sierra Morena to the north and the Sierra Nevada to the southeast. It consists of flat or gently rolling country with shallow rivers flowing in broad valleys. The major drainage pattern of the basin is markedly asymmetrical. The main river, the Rio Gualdalquivir, follows the northern boundary of the basin. Tributaries on the left-hand side of the Rio Guadalquivir follow a general north-north-western direction. They largely derive their water from the mountains to the south of the basin. The most important among them, the Rio Genil, is the least susceptible to droughts as it gets its water from the snowy peaks of the Sierra Nevada. Other, less important tributaries obtain their water from sources in the basin proper. The largest of them is the Arroyo de Madrefuentes, which has its origin to the south of Fuentes de Andalucia.

Tributaries on northern side of the Rio Guadalquivir have their origin and the major part of their course in the Sierra Morena and hardly traverse the basin proper.

There are no important natural barriers in the basin to influence the direction of the main roads. However, some formations, on account of their lithology and surface expression are much better suited for building roads on than others. Witness the N IV highway, from Madrid to Sevilla and the Sevilla - Estepa road, both built on a sandy or clastic subsoil wherever possible. Minor roads are built rather indiscriminately over all rock units. Ancient cattle tracks, called "vereda" or "cañada" on the Spanish Geographical Institute maps, often follow the lower contours of sandy and clastic formations, presumably because of the presence of wells, necessary for watering the cattle, on the lower contact of these formations.

As elsewhere in Spain, many towns have been built on higher ground for strategical reasons. Some of them are situated around or on the slope of a hill, with a castle on the hilltop, as seen at Estepa, Osuna and Marchena. Others occupy the rim of a cuesta, like Carmona, El Viso del Alcor and Mairena del Alcor. Towns like Ecija and Puente Genil, on the other hand, had their origin where major roads crossed a river.

The Guadalquivir Basin forms an almost continuous stretch of cultivated land and has been the granary of Spain since ancient times. Nowadays, agriculture is still the main source of income. Different crops are grown in a pattern that reflects both the lithology of the subsoil and the presence of water. Soils derived from clay are usually covered with wheat; olives are grown on marly and sandy soils. Together they provide the main crops of the area. The growing of wine is of minor importance; it is restricted to sandy soils. Near the rivers, where irrigation is possible, one may find cotton and citrus fruits, the latter also on soil derived from limestone. Forests of cork-oak and pine trees appear where the soil gets too poor for a regular crop.

Going from north to south across the basin, one may distinguish a number of areal units, each with their typical scenery and vegetation.

A. The Guadalquivir valley. Main products are wheat and cotton, the latter especially on irrigated land.

B. The northern plains. These are to a large extent covered by quartzite pebbles, mostly confined to the topsoil; in part the pebbles are a residual eluvium from the underlying Cuesta del Espino Formation, in part they belong to high terraces of the Guadalquivir river. In places these pebbles form an almost continuous layer, where only a steppe-like vegetation can grow, suitable for cattle grazing. Where pebbles are scarce or absent, olive trees and, to a minor extent, wheat and corn are grown. At present irrigation works are carried out in part of the northern plains, which will eventually influence their agricultural use.

C. A hilly country with a partly clayey, partly marly subsoil. On the clayey subsoil along the southern tributaries of the Rio Guadalquivir wheat is grown almost exclusively.

The areas with a marly subsoil in between occupy the more elevated parts. On this soil mainly olive trees are grown.

D. The southern plains with sandy subsoil. As to their vegetation they are not as uniform as the units described. Wine is grown as well as olive trees, while large stretches are covered by brushwood with some pines and oak trees.

E. Scattered all over the basin there are isolated occurrences of detrital limestone. The smaller ones do not give a recognizable vegetational expression; they may be quite barren. On the largest of them are citrus plantations. The cultivation of these fruits is not only related to the quality of the soil, but also and especially to the presence of water trapped in the lower part of the porous limestone.

Some of the sediments of the Guadalquivir Basin supply the raw material for local industries. Most places have their local brickworks; Puente Genil has some brick and tile factories. Building stone is quarried from the detritic limestone near Osuna and Alcalá de Guadaira. Many abandoned quarries testify to a much more extensive quarrying activity in earlier times, especially near Carmona and in the area along the northern boundary of the basin.

I.3. Previous work

In contrast with the early and intensive study of the geology in the "classical" areas, which attracted the interest of stratigraphers from the beginning of the 19th century, the geological investigation of the Guadalquivir Basin started late. Several reasons can be mentioned for this lack of interest. Because of the absence of minerals in the basin there were no incentives on prospecting.

During the first decades of the 20th century, much attention was given to the stratigraphy and structure of the Betic Cordillera. On its northern boundary, however, the Guadalquivir Basin was left unstudied. The supposed oil resources of this area and the resulting interest in its geology have been the stimulus for a number of studies in the last few decades. Today, the geology of the Guadalquivir Basin is fairly well known in outline, but knowledge is still lacking in details.

In the following paragraphs the publications dealing with the Tertiary stratigraphy of the Guadalquivir Basin that could be traced are summarized and commented on when necessary.

The oldest reference to Tertiary formations in the area discussed is that of CALDERON & PAUL, who in 1886 propose the name "Moronite" for the white-grayish siliciferous marls found widely distributed in southern Spain. The name was derived from the town Morón de la Frontera, in the neighbourhood of which they studied these sediments. The authors assume that the Moronite layers are alternating with limestone layers considered to be of "Nummulitic" Age, and that they are of the same age as the latter. The presence in close proximity of ophites, limestones, Moronite, gypsum, dolomitic limestone and marble made them suggest a single cause for explaining the interrelation of these rocks, i.e. contact metamorphosis of the succession of limestone and Moronite layers by the intrusion of ophites bringing about gypsum, dolomitic limestone and marble.

Today the dolomitic limestone and gypsum in this part of Spain are considered to be of Triassic Age. The observation by CALDERON & PAUL that the fossils in the Moronite and the limestone layers do not show any sign of metamorphism did not influence their ideas; on the contrary, it led them to suggest a more thorough investigation of other rocks that had been subjected to contact-metamorphic influence. The unusual ideas of the authors about the extent of metamorphism have been refuted by R. DOUVILLE (1906).

In 1888, CALDERON remarked upon, and further investigated the remarkable abundance of foraminifera in the "Pliocene" formations near Sevilla. However, owing to technical limitations, he could do no more than report the presence of the following genera: *Triloculina, Nodosaria, Lagena, Dentalina, Cristellaria, Textularia, Globigerina, Rotalia, Operculina, Polystomella.*

In 1893 CALDERON, after a generalized description of the development of the Guadalquivir Basin, discussed a section taken along a line running across Sevilla and Alcalá de Guadaira. He noted that Pliocene sediments of quite different lithology, like the marls and sands north of Sevilla and the detritic limestone of Alcalá de Guadaira, are at nearly the same height above sea level. He considered the marls and sands to be younger than the limestone, and he assumed that they were deposited in much deeper water than the latter. To explain this discrepancy he assumed that the part of the basin where marls are found must have been descending prior to their deposition, to rise again afterward. These vertical movements were to have occurred along fault planes: one situated along the Meseta rim, a second and third parallel to the first and passing over Sevilla and Alcalá de Guadaira.

In 1897 a lengthy paper by M. CALA was published postshumously dealing with the geology of the surroundings of Morón de la Frontera, with special regard to the so-called "Moronite" and its microfauna.

The ideas of CALDERON & PAUL (1886) about the origin of the gypsum in the surroundings of Morón de la Frontera are repeated. The chemical composition of the Moronite is mentioned, with an iron and aluminium content of 20% and a calcium content of 25%. When dealing with the foraminiferal fauna, the author quotes data communicated to him by SCHLUMBERGER and SCHROTT. The first correspondent mentions some similarity of the fauna sent to him to that from the neighbourhood of Vienna and considers it to be of Miocene or Pliocene Age. The second correspondent refers to 33 species from the fauna; he suggests a Neogene, perhaps Pliocene Age for the strata they were derived from and thinks that these were deposited in a rather deep sea. Both contributors especially point out the great abundancy of *Globigerina* species.

Reporting about the radiolarians found in the Moronite, CAYEUX (in CALA) lists 31 genera.

CALA himself deals with the Diatomacea; he mentions 53 species from the Moronite and figures 18.

In his concluding remarks, CALA gives as his opinion that the Moronite is a special and quite unique class of sediment, in some aspects comparable to the silica-rich Tripoli, Diatomite or Kieselguhr.

He considers the co-existence of *Globigerina* species and Diatomacea, especially free-living forms, to be in favour of a fully marine origin of this sediment at a depth between 2500 and 3000 m.

In 1906 R. DOUVILLE published an "Esquisse géologique des Préalpes subbétiques (partie centrale)". The data presented and the problems discussed cover a much wider area than is mentioned in the heading or figured in the maps: the region around Jaén, Martos and Jódar. For a review of the literature published before 1906 about the Guadalquivir Basin and the adjacent mountain ranges the reader may profitably consult the excellent survey given by this author.

Contrary to the ideas of CALDERON & PAUL (1886) and CALDERON in subsequent publications of 1888 and 1903, R. DOUVILLE rejects the genesis of gypsum as a result of contact metamorphism acting on siliceous marls. All apparent evidence for this hypothesis is more readily explained by the extreme plasticity of gypsum. Moreover, he never found any evidence of metamorphism in the mineral content of various rocks that, according to CALDERON & PAUL, should show traces of metamorphism.

The author considers the white marls of the region studied by him to be similar to the Moronite described by CALDERON and others. In his opinion these marls are characteristic for a bathyal environment of sedimentation. He mentions the occurrence of calcareous lenses in a neritic facies with *Lepidocyclina schlumbergeri* and *Lepidocyclina marginata* intercalated in the white marls which leads him to the conclusion that the whole sequence is of Aquitanian Age. Previous authors mentioned the occurrence of *Orbitolites* (misspelled for *Orbitoides* according to R. DOUVILLE) and *Nummulites* in outcrops of the same rock unit, partly in the region discussed by R. DOUVILLE, partly elsewhere. These sediments were therefore considered to be of Eocene Age. In two instances, R. DOUVILLE had the opportunity to examine the material, which, however, turned out to consist of *Lepidocyclina.*

Another lithological unit mentioned by the author is the detritic fossiliferous limestone "molasse", found immediately overlying the Paleozoic rocks of the Meseta. It contains macrofossils that suggest to him a Burdigalian or even Helvetian Age.

He considers the blue clays found near the Rio Guadalquivir to be of Pliocene Age. As fossil molluscs are scarce in these strata, they were mostly disregarded by previous investigators. These "Pliocene" strata are lying nearly horizontal, whereas older Tertiary strata may show a considerable dip. This difference in dip has been used elsewhere in the Guadalquivir Basin for making a first subdivision of Tertiary sediments.

In 1911, R. DOUVILLE published a survey of the Geology of Spain in the "Handbuch der regionalen Geologie". In describing Neogene sediments of the Guadalquivir region he draws from his own observations for the eastern part, whereas for the western part he quotes DE VERNEUIL & COLLOMB, MALLADA and CALDERON.

Some additions to the literature about the Tertiary of the Guadalquivir Basin came in at the 14th International Geological Congress held in Madrid in 1926. Some publications were prepared to serve as general information and guide for an excursion to the south of Spain.

E. HERNANDEZ-PACHECO gave a summary of the state of geological knowledge in "La Sierra Morena et la plaine Bétique (synthèse géologique)". The data and ideas about the Betic plain are derived from MCPHERSON, CALDERON and CALA while R. DOUVILLE and GROTH are the most recent authors mentioned. In the controversy about the presence of a Meseta boundary fault, HERNANDEZ-PACHECO takes the side of MCPHERSON in supposing that a fault does occur, while he further assumes that this fault was active at various times during the Permian and during the Miocene, but that in the Miocene it was rather a flexure than a fault.

This author assumes that during the Pliocene an uplift of the Meseta took place, as there are two drainage systems with different patterns in the Sierra Morena: the older one consists of pebbly dry valley plains well above the actual waterbearing valleys, which form the younger system. As marine Pliocene sediments are being eroded by the active drainage pattern, the uplift cannot have taken place earlier than the Pliocene.

P. NOVO, A. CARBONELL, J. CARANDELL & F. GOMEZ LLUECA prepared the guide for an excursion in the south of Spain: "De Sierra Morena a Sierra Nevada (reconocimiento orogenético de la region Bética)". The part dealing with the Guadalquivir Basin was written by CARBONELL, while the stratigraphy was mainly dealt with by GOMEZ LLUECA. The information given does not go beyond that already presented in previous publications. No synthesis is attempted for the Tertiary sediments.

In 1926 too A. CARBONELL gives in "Notas explicativas de la geología de las immediaciones de Córdoba" some explanations concerning the localities and phenomena visited by the congress excursion, mainly about the fault between the Meseta and the Guadalquivir Basin.

In the same year, in a „Nota sobre los depósitos de foraminíferos Terciarios de Córdoba" CARBONELL presented a general sketch of the environments of deposition and the sea depth to be deduced from the foraminiferal content of the sediments in the Guadalquivir Basin. The white *Globigerina*-rich marls are considered by him to be of Early Miocene or Oligocene Age. According to this author foraminifera are less favourable for stratigraphic use than echinoderms and molluscs, buut they offer some possibilities for paleo-geographic reconstructions.

In 1951 COLOM & GAMUNDI, in their paper "Sobre la extensión e importancia de las "Moronitas" a lo largo de las formaciones aquitano-burdigalienses del estrecho nort-betico", discuss the diatomaceous *Globigerina* marls found in an area from the Gulf of Cadiz to Alicante, on the Baleares and in the Rhone Basin. The conspicuous microlamination observed in sections of this marl is the expression of different mineralogical and faunistic composition of the single laminae. In-between the marly sediments, clastic layers are occasionally found to consist of well-rounded sand with *Lepidocyclina*, and occasionally with *Miogypsina* species. Different ages are obtained by the stratigraphical application of larger foraminifera on the one side and planktonic foraminifera on the other. The authors suggest that these discrepancies are due to an incomplete knowledge of the actual stratigraphical ranges of the larger foraminifera.

The age of the various exposures on the Spanish mainland are all within the Aquitanian-Burdigalian interval. The extensive distribution of the Moronites on both the Atlantic and Mediterranean coasts of Spain the authors considered as an additional proof for the existence of a connection between the Atlantic Ocean and the Mediterranean in this area, commonly called the Betic Strait, during the Aquitanian and the Burdigalian.

COLOM & GAMUNDI assume that the Moronite strata have been deposited close to the shoreline, to account for the presence of the clastic layers. The diatomaceous *Globigerina* marls should have been deposited by strong bottom currents sweeping these sediments from their oceanic environment to a secondary place of deposition in the Betic Strait. According to present-day opinion the latter sediments are at their place of primary deposition, whereas the clastic layers have been deposited by turbidity currents.

In 1952 and 1953, PAN ARANA published two short notes about the foraminiferal content of a marl sample from the environment of Sevilla. Twenty-five species are figured and described and their frequency is mentioned. Together these data give some idea about the foraminiferal fauna of this sample.

In 1955, CANTOS FIGUEROLA presents a paper on gravimetric investigations carried out between the Meseta boundary and the city of Carmona. Some of the results have a bearing on the regional geology of the Guadalquivir Basin. There is a regular decrease in the value of gravity going from the Meseta in the direction of the central part of the basin. On the Meseta boundary positive anomalies of about 30 mgal. occur, gradually changing to negative anomalies of 10 mgal. near Carmona.

This gradual change in anomalies suggests a continuous regular plunge of the heavier Meseta rocks below the lighter sediments of the basin.

After compensation for the regional effect the residual anomalies are interpreted by CANTOS FIGUEROLA as the effect of a pattern of faults in the basement parallel with the Meseta boundary.

In 1961 SAAVEDRA published a pictorial review of 370 species of foraminifera from the Neogene and Quaternary of the Guadalquivir valley.

The determinative characters of the genera are mentioned and a reference is made to their original description; single species are described superficially, without any reference to the literature. All species are entered into distribution charts, where their estimated frequency in a number of consecutive "zones" is mentioned.

These "zones" are placed in relation to the Aquitanian, Burdigalian, Helvetian, Tortonian and Sahelian Stages, the Lower, Middle and Upper Pliocene and the Quaternary. The lithological properties of the sediments occurring in each "zone" are reported without any reference to localities where these sediments are exposed, and without offering arguments for the supposed relation between a certain "zone" and the stage or chronostratigraphic unit that he mentions together.

The first attempt at a stratigraphical and tectonical analysis of the Guadalquivir Basin is found in the paper of PERCONIG, who in 1962 presented a summary of the geology of the Guadalquivir Basin, in the "Livre à la mémoire du Professeur Paul Fallot". The general outline of the basin and its environments are sketched. A number of borings made in the search of oil provide the material for this author's discussion of the stratigraphy. Various stratigraphic units are distinguished, their age almost wholly based on foraminiferal evidence.

Basing his criteria partly on stratigraphic, partly on tectonic nature, the author distinguishes the following areas within the basin:

1. A *central-northern area,* consisting of the region near the Meseta boundary,

between Sevilla and Córdoba, where a transgressive Helvetian sandstone overlies the Paleozoic, and is in turn overlain by marls that go without interruption from the Helvetian up into the Sahelian. A Sahelian limestone closes the sedimentary cycle.

2. South of a line running from Sevilla over Ecija he recognizes a *central-southern area,* where the lowermost unit is of a mixed character. Because of the tectonical uplift of the Sierra Nevada, Cretaceous, Paleocene and Oligocene sediments slided to the north, the plastic Triassic gypsiferous strata facilitating this translation. As this was to have taken place during Early Miocene time the Aquitanian and Burdigalian sediments became to some extent involved in the movement, and in the mixing that was its consequence.

The evidence from bore-holes and the interpretation of seismic data leaves no doubt on the presence of these chaotic masses. Part of the Oligocene found in borings is similar to that found in the "Campo de Gibraltar", a reason for PERCONIG to consider that area to be the place of origin of the youngest displaced sediments.

3. The *eastern area* is the area east of Córdoba. It is characterised by the presence - in outcrops - of Miocene strata, older than those occurring to the west. Here, too, the surface sediments are underlain by chaotic slide-masses containing Triassic to Paleocene elements. Along the northern boundary, autochthonous Triassic marls and sands overlie the Paleozoic of the Meseta; these strata are absent further to the west.

4. In the *western area,* situated to the west of Sevilla, the structural and stratigraphical units of the central provinces are continued. Southward and westward the Neogene grows in thickness. Immediately below the Tertiary basin-filling, Triassic, Liassic and Upper Jurassic sediments are met with in the order mentioned when going from east to west.

From the evidence obtained by borings and seismic data, PERCONIG concludes the absence of a major fault on the southern side of the Meseta. The sediments exposed at the surface get progressively younger from east to west; during sedimentation the axis of the basin was displaced from south to north.

The main interest of his paper lies in the discussion of the Neogene history of the genesis of the basin and of the structural units involved. Micropaleontological data are presented in lists of foraminiferal species names.

In the Proceedings of the Committee on Mediterranean Neogene Stratigraphy held in 1961 (published in 1964) PERCONIG again states the main points of his ideas as published in 1962, and presents in another paper a description of the stratigraphical units both exposed near Carmona and met with in a boring in the neighbourhood of that town.

Oligocene, Aquitanian, Burdigalian, Helvetian and Tortonian strata can be recognized by their foraminiferal content. Except for the Helvetian and the Tortonian, these units are not in a stratigraphically normal contact, being found in displaced masses or "olistostromes".

The highest local unit, a sandy, loosely cemented limestone, locally called the "Caliza tosca", is suggested as type for a youngest Miocene stage. The need for such a stage has been expressed by various authors, and in the opinion of PERCONIG the Caliza tosca has the proper stratigraphic position for serving as the terminal Miocene and to possess the right lithology for paleontological investigations.

With each stage the various lithologies in which it is represented are mentioned, together with lists of planktonic and benthonic foraminifera, while in the discussion on the chronostratigraphy their planktonic faunae are compared with those from the central American and Italian Tertiary.

In 1964 SAAVEDRA gives a synthesis of the development of the Guadalquivir Basin during the Secondary and the Tertiary; the main points of this synthesis are reproduced here. The Mesozoic sedimentation basin reached much further to the south than the actual basin border; Triassic sediments reflect extreme salinity, the Jurassic and Cretaceous strata, on the other hand, testify to fully marine conditions. Small transgressions and regressions cause some changes in basin shape and local minor interruptions in sedimentation.

During the Eocene a kind of "sub-basin" developed at the actual place of the "Campo de Gibraltar", where a thick sequence of sandy marls and sandstones was deposited. Sedimentation may have continued up into the Oligocene. Along the southern boundary of the basin proper, sedimentation of the same nature took place, but with a much reduced thickness. In the Early Miocene, because of the uplift of the Sierra Nevada, large parts of the sediments of the Campo de Gibraltar and along the southern boundary of the basin got involved in submarine sliding in a northward direction. Sedimentation continued over and among the sliding masses. Part of the subjacent sediments, already prone to mobility because of the presence of Triassic gypsiferous strata, were incorporated in the sliding masses or "olistostromes". During these movements the Betic Strait became closed somewhere east of its central part, and the remaining western gulf was much reduced in width and depth. There sedimentation continued up into the Pliocene.

SAAVEDRA's scheme of basin-development is given rather extensively, because it presents an excellent review on the structural data. The description of the stratigraphy, on the other hand, is less lucid, as his use of chronostratigraphic units precedes the definition of lithologic ones and the complex problems concerning planktonic biostratigraphy are dealt with regardless of the absence of reasonably continuous sections. A discussion of the different lithologies from the point of view of faunal distribution is not given either.

During the 1964 congress of the Committee on Mediterranean Neogene Stratigraphy, PERCONIG made a formal proposal for an Andalusian Stage, to characterise the interval between the deposition of the type Tortonian and the Pliocene. The proposal is included in the Congress Proceedings, published in 1966. Although the author does not indicate a type section, he publishes a stratigraphic column measuring a hundred meters of Tortonian, three hundred meters of Andalusian and more than a hundred and fifty of Pliocene strata, all together a thickness of more than five hundred and fifty meters. The distribution of both benthonic and planktonic foraminifera over the three units is listed. The faunae show that the Andalusian strata have no striking individuality as compared to the units immediately below and above.

During the 1967 congress of the Committee on Mediterranean Neogene Stratigraphy, (Proceedings 1968), PERCONIG presented some additional stratigraphical notes concerning the section of Carmona, thereby for the first time explicitly stating that it is this section he is proposing as stratotype for the Andalusian Stage. Again for the first time, a geological map of the environments of Carmona is added, showing the boundaries of the lithological units involved and the places where samples were taken.

The planktonic content of the three units, Tortonian, Andalusian and Pliocene, is compared with the faunae from the Tortonian stratotype and from other Miocene as well as Lower Pliocene formations from Italy. Their similarity is expressed as the percentage of the total number of species from an Italian unit occurring also in each of the units of the Carmona section.

After a discussion of planktonic lineages, mainly on data from Italy, the lowermost unit of the Carmona section is placed in the *Globorotalia menardii-Globigerina nepenthes* Zone of the type Tortonian (CITA, PREMOLI SILVA & ROSSI 1965) and the *Globorotalia acostaensis* Zone of BOLLI & BERMUDEZ (1965). The middle, Andalusian unit is divided into two cenozones, the lowermost characterized by the appearance of *Globorotalia bononiensis* and *Globigerina quadrilatera* and the presence of *Globorotalia margaritae, Globorotalia apertura, Globoquadrina altispira* and *Globoquadrina globosa.* The uppermost cenozone derives its name from *Globigerinoides obliquus* and *Globorotalia puncticulata* and is characterised by abundant specimens of *Globorotalia margaritae,* by the extinction of *Globoquadrina globosa* in its lower part, and of *Globoquadrina altispira* and *Globorotalia apertura* in its upper part.

From both Andalusian zones only a single sample is recorded in the distribution chart.

In a separate paper, PERCONIG describes six new species and one subspecies from the Carmona samples. All of them are present throughout the section.

Chapter II

LITHOSTRATIGRAPHY

II.1. General introduction

In the Neogene sediments mapped for the present study a number of formations are distinguished, to which, in accordance with the resolutions of the International Subcommission on Stratigraphic Classification and Terminology, presented at the 21st International Geological Congress of Copenhagen, local geographic names have been given (Repts. I.G.C. 21.sess.pt.25, Copenhagen 1961).

According to the same rules a formation should be a mappable body of rock with unifying properties based on its lithology, sedimentology, surface expression and fossil content.

To be mappable, a formation must have a reasonable continuity in the field, traced on the presence of actual exposures or on the sum of indirect evidence. The lithology of a formation is made up of its mineralogical composition and the grain size of the components. The sedimentology mainly refers to the relative position of the components, their size, arrangement and origin. Fossils may be used to characterize a formation, but their timestratigraphic implication has no bearing on the definition of a lithological unit.

Since in the area we are considering exposures are scarce one has to use all sorts of indirect means to gather geological information for the compilation of one's map. First and foremost the characteristics of the soil are used, especially the colour. Several formations have a typical dominant vegetation that is of great help in determining their general extension. Other surface properties may be used in the same way. Especially when one is mapping the boundaries of adjacent formations, the difference in resistance to erosion, the change in the slope of hillsides and even the quality of the roads are helpful.

The water content of streams, the presence, place and depth of wells, the pattern of old cattle tracks and the kind of rock used for paving and building in some villages, all can and have to be used to obtain information of geological interest.

II.1.1. PRETERTIARY ROCKS

II.1.1.1. *Introduction.*

Both the northern and the southern boundaries of the Guadalquivir Neogene Basin are formed by Pretertiary rocks that show great differences in composition and age. The western part of the basin is bordered to the north by the "Meseta" or High Plateau of central Spain, the southern part of which is currently called the Sierra Morena. It is by no means a true mountain chain, but is, in fact a gently dipping upland plain that descends to the south, dissected by deep river valleys. To the south and south-east the Guadalquivir Basin is bordered by the chains that form together the Betic Cordillera. Here, every single mountain chain that shows some individuality and extension has its own name. Many of these names are used to denote tectonical units of the Betic Cordillera. In the following paragraphs, however, all names are used in their geographical sense, without any other implication.

In the southern part of the basin proper some exposures of Pretertiary rocks were found. Comparison of their lithology with those of the rock units in the Betic Cordillera allows adequate identification of these outcrops. They are considered to be transported blocks, as will be discussed when we describe the Chaves Formation.

Some of the Neogene formations in the basin contain clastic rock fragments and reworked foraminifera, derived from the rocks bordering the basin. Here, too, it was possible to trace their origin in a general sense.

II.1.1.2. *Sierra Morena.*

The northern boundary of the basin consists of a gently dipping erosional slope over metamorphous and sedimentary rocks that are reported to have a Precambrian or Paleozoic Age (McPherson 1879, R. Douville 1911). To the north of Palma del Rio (exp. 44) and near Hornachuelos (exp. 49) a very dark micaschist is exposed which shows an intensive crumpling. In exp. 53 some steeply dipping layers of quartzitic sandstone are exposed. Other exposures of the basin boundary show schists of a rather light colour, containing much quartz. Pieces of the schist are often found mixed in the lower part of the Bembezar Formation, which directly adjoins the basin boundary.

The micaschists of the Meseta are of Precambrian Age, other schists and sandstone should be Cambrian according to McPherson (1879). Granites and porphyrites of the same age mentioned by this author were not found by me; they are not exposed in the southern part of the Meseta, nor were they found in the pebbles derived from this area. Various authors, quoted by R. Douville (1911) and P. H. Sampelayo (1942) mention Silurian, Devonian and Carboniferous strata in the Meseta, at places, however, that have no connection with the area under discussion.

No systematic mapping of sediments other than Neogene was carried out. No formations were defined for the various rocks found along the northern boundary of the Guadalquivir Basin. The rocks found exposed there have all been mentioned in the literature.

In the following paragraphs and on the map these rocks will be referred to as "Paleozoic and older rocks of the Meseta".

II.1.1.3. *Betic Cordillera.*

Two lithologic units are involved in the southern and south-eastern boundary of the Guadalquivir Neogene: gypsum together with marls and brecciated dolomites are found around Morón de la Frontera and to the south of La Puebla de Cazalla and Osuna, whereas massive layered limestone is exposed immediately to the south of Estepa. Only part of these rocks have been entered on the map as Mesozoic strata, without further subdivision. To the north of this Mesozoic consisting mainly of gypsum-containing strata, an elongated zone is observed where intensive mixing of gypsum with Tertiary marls has taken place. This strip is referred to as the "Zone of mixed lithology" on the geological map. In the area of Aguadulce and Estepa this zone is absent. However, north of the line Osuna-Estepa-Puente Genil a great number of isolated smaller exposures of gypsum and related sediments were observed, e.g. near El Rubio, Matarredonda and Puente Genil. Many of them are not indicated on the map. The abundance of geographic names like Agua Salada, Arroyo Salado, etc. testify to the ubiquity of saliferous rocks.

Exposures of limestone comparable to those exposed in the mountain ranges south of the boundary are found far to the north of the basin border as well. They are too small to be shown on the map.

The occurrence of two highly different Mesozoic rock units along the southern boundary of the Guadalquivir Basin has a marked influence on the appearance of this boundary. The gypsiferous strata have small resistance to erosion. Where they form the boundary there is no difference in topographic altitude and geomorphology as compared to that of the Neogene sediments of the Guadalquivir Basin. The boundary of the geographical basin should be placed where the mountain chains form a natural border of the depression. However, when the basin is considered in relation to the Neogene sediments, its southern boundary should be placed between the Neogene marls and Preneogene gypsum. Therefore, it does not coincide with a prominent geographical feature, quite unlike the northern boundary, which is clearly expressed by the slope of the Meseta.

Nearly all work connected with the southern boundary of the Guadalquivir

Basin can be found in descriptions of the Betic Cordillera. Stratigraphical investigations south of the Guadalquivir Basin were mainly carried out to elucidate the structure of this mountain chain. Only a few of these works do concern the northern parts of the Betic Cordillera or do present basic data that are applicable to the whole range.

Publications concerning stratigraphy of a restricted area are those of KILIAN (1889), ALASTRUE & PRIETO (1954) and PEYRE (1958). Much local and general information is given in the works of MALLADA (1895-1907). R. DOUVILLE (1911) gives a compilation of the work of various authors, including his own. Other data concerning the stratigraphy can be drawn from the compilation on the Betic Cordillera by FALLOT, beginning with his series of publications from 1931 to 1934, and continued in many subsequent papers on the same subject. The picture presented by all these data is incomplete in detail, but gives a satisfactory general outline.

The irregular row of mountain chains, immediately bordering the Gualdalquivir Basin, consists of Jurassic and Cretaceous strata. From the Sierra de Montellano Liassic is mentioned (ALASTRUE & PRIETO 1954); also from the Sierra de Esparteros (CALDERON & CALA, quoted by MALLADA 1902) and the mountains immediately to the east of Cabra (KILIAN 1889). FALLOT (1934) gives a description of the same mountains and those to the east and southeast. He mentions Jurassic and Cretaceous strata and discussed the tectonic implications of the relative position of the stratigraphic units. In the mountains near Estepa, PEYRE (1958, 1962) mentions a section consisting of strata of Early Jurassic up to Late Cretaceous Age.

The other rock unit involved in the southern boundary of the Guadalquivir Basin: the gypsum and related sediments, are found in between the mountain ranges mentioned earlier and on their basinward side. In these strata no section of any length is mentioned by any author, nor is such a section likely to be found in this plastic type of rock, subject to the effect of tectonical forces. In separate exposures contorted layers of vivid red gypsum are visible, together with marly layers and dark, brecciated dolomites.

R. DOUVILLE (1911) gives a Triassic Age for all these gypsiferous sediments, and says that single exposures can be attributed to certain Triassic Stages on the evidence of rare fossils. FALLOT (1931) presents a compilation of data on the Triassic sediments of the Betic Cordillera and discusses the exact age of certain outcrop areas, none, however, near the northern boundary of the mountain chain.

For the Triassic sediments, as found in southern Spain, the term "Germano-andalusian facies" is used in the literature.

II.1.2. NEOGENE FORMATIONS

In the Guadalquivir Basin, the following Neogene formations were mapped:

The Genil Formation, consisting of turbidites. The layers of this formation always show a considerable dip.

The Chaves Formation: clayey marls, frequently without any structure, sometimes with a wavy lamination.

The Ecija Formation: blue-grey clays, containing some silt.

The Guadaira Formation: a limestone, composed of organic debris.

The Canteras Formation: a limestone, like the Guadaira Formation, but distinguished from the latter because of its isolated occurrence.

The Marchena Formation: sand and sandstone.

The Cuesta del Espino Formation: alternating sand and clay layers with intercalated pebble lenses.

The Bembezar Formation: a recrystallized limestone, rich in *Heterostegina;* in the base of this formation debris of the Precambrian and Paleozoic rocks of the Meseta are present.

Except for the Genil Formation, which mostly shows a considerable dip, and

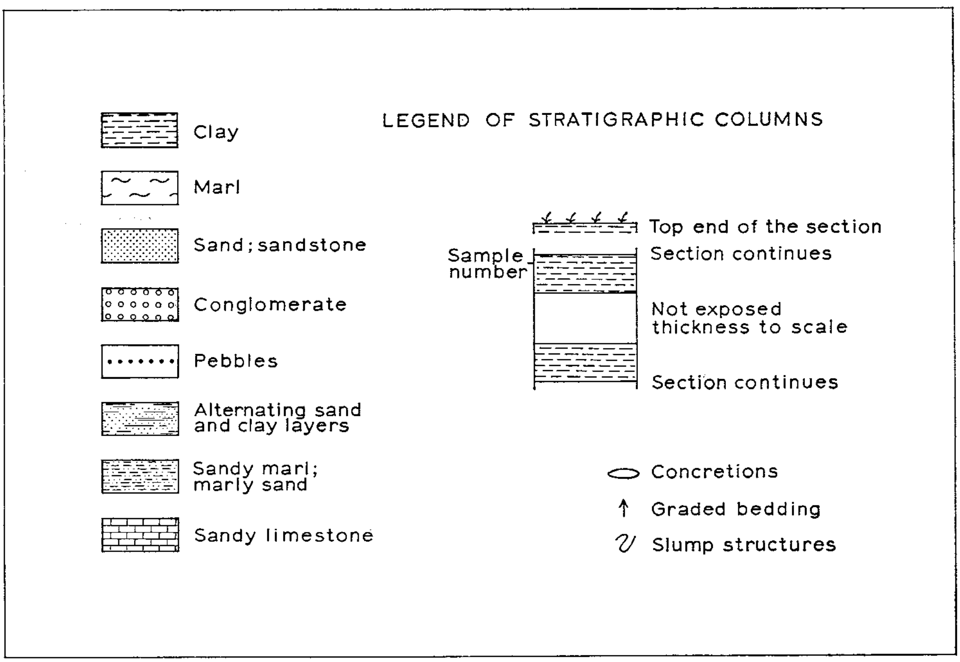


Fig. 1. Legend of stratigraphic columns.

the Chaves Formation, which only occasionally presents the opportunity to see whether it is layered or not, all formations are lying almost horizontal. The maximum dip measured in them is not more than 3 to 5 degrees, and generally to the north.

II.2. Description of the Neogene formations

II.2.1. GENIL FORMATION

Name: After the Rio Genil (Genil river).
Type locality: In the E. bank of the Rio Genil, near the power station San Callixto, at the road from Ecija to Puente Genil, 19 km. from Ecija, exposure 218, fig. 2A.
Diagnosis: Sandstone layers alternating with sandy marly clays (turbidites).

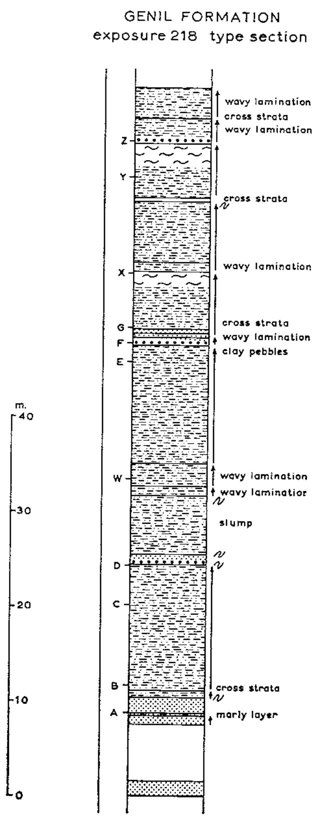


Fig. 2. Stratigraphic column of the Genil Formation.

Type section: A sequence of 70 m. of sandy to silty marls alternating with layers of sandstone is exposed downstream from the power station barrage. The general dip is downstream, the river running roughly S. to N. At the stratigraphically lower part of the section a strike and dip is measured of 225° and 75° respectively. Going upward in the section the dip gradually diminishes to 35° at the top.
Description: The formation shows a combination of features that are typical for a turbidite succession. The single layers of sandstone of this formation, although different in grain size and thickness, show a similarity to each other in many other features that make it possible to give a generally valid description. They are graded, the coarsest grains measuring about 1 mm. in diameter. Occasionally mollusc debris or clay pebbles are present near their lower boundary. The expression of the lower boundary is very clear by the abrupt change in grain size. Distinct erosional features are absent. The contact with the underlying clay is always irregular, sometimes with clear slump features. In one instance the whole layer is intricately folded by slumping.

The lower part of such a turbiditic cycle may be either without stratification, or may show some sets of strata. Upwards these sets are overlain by a coset of cross-strata, still in the same grain size. The lower boundary of this coset is non--erosional, whereas the contacts of the various wedge-shaped sets of cross-strata are erosional. Sets of parallel strata may be intercalated, giving the layer a banded appearance, and resulting in a more tabular form of the sets of cross-strata. It was not possible to gain information about the symmetry of the sets of cross--strata and the attitude of the axis, if present.

The dimensions of all features are of a common order without notable exceptions: single strata and cross-strata are thinner than 1 mm, sets of strata and cross-strata are from 1 to 10 cm thick, in a few instances somewhat more than that. An exception is a lenticular set of cross-strata in a curved surface of erosion. The set is bilaterally symmetrical in shape, cross-strata are concave, their concavity diminishing upward. The feature as it is exposed has a thickness of 50 cm and a length of some m. All together it is an example of trough cross-stratification, forming a channel-filling.

Almost all sandstone layers show traces of post-depositional movement. Fluxoturbidites occur. Smaller features of disturbance may be divided in two classes, one of slumping, the other of small-scale faulting and folding. Both are visible in in sets of strata as well as in sets of cross-strata, obscuring them and making their evaluation difficult.

Slumping of sets of cross-strata may be seen in Plate 1, fig. 1. The slumps have no preferential orientation.

Faulting structures may be seen in Plate 1, fig. 2. These features are the expression of a directional movement, displacing the upper part from E. to W.

In most cases the upper boundaries of the sandstone layers are not sharply expressed. Within the coset of cross-strata or the composite set, which because of their grain dimensions pertain to the sandstone layer, the number of grains smaller than sand size and the relative clay component increase upward. The interval of passage from sand to clay is stratified, single laminae being thinner than 1 mm. Between straight sets some wavy ones occur. Higher up in the silty-clayey layer all visible traits of lamination disappear. A thoroughly dried part may show a papery splitting, whereas the fresh exposure appears altogether homogeneous. In almost all sequences this clayey part contains some grains of silt size. The uppermost part of the textbook turbidite sequence, that should consist of unlaminated pelagic clay, is absent.

Intercalated in the layers consisting largely of clay, some layers of fine sand and silt are present, often only made visible by an impregnation with gypsum. When well exposed, they may show some sets of strata and cross-strata not unlike those described for the upper part of a sandstone layer, and probably representing the basal part of a small accessory turbidite interruption. However, no structures were found on the boundaries of these layers. Their thickness does not exceed 10 cm.

There are a few exceptions to the gradual change from sandstone to clay as described. Some sandstone layers, notably the thicker ones, have a well expressed upper boundary. These layers are indurated and very constant as to their thickness within the reach of the exposure. Their upper boundary is expressed by an abrupt lowering of grain size and an absence of induration in the overlying layer.

There is no difficulty in differentiating the Genil Formation from the other ones. Among them, only the Cuesta del Espino Formation contains both sand and clay layers, but, as it is not a turbidite succession at all, no difficulty will arise in separating both formations.

Exposures: The type section (218) is the only exposure showing all features mentioned in the description. The second best exposure (206) is near the farm Agofrio, on either side of the road from Ecija to Puente Genil, about 15 km from Ecija. The Genil Formation is recognizable here by its alternation of sandstone and clay layers. No sedimentological features are visible in this exposure, but some structures may be seen on detached pieces of sandstone. Other exposures of this formation mostly consist of one or a few weathered sandstone layers, crumbling into sand.

The presence of this formation can be recognized by indirect means: its hardness causing a greater resistance to erosion than the underlying formation; its porosity being betrayed its lesser runoff. Some ranges of hills, notably higher than the surrounding country, are interpreted as consisting of this formation. The

course of the Rio Genil, which flows over this formation over some distance, is predetermined in its direction by the strike of the tilted sandstone layers.
Extension: The south and west boundaries of the areal extension of the Genil Formation are placed at the terminations of the hill ranges, crossed by the road from Ecija to Herrera, from km 10 to km 20 from Ecija approximately. To the north and the east the Genil Formation is bordered by the Rio Genil. No contacts with another formation were found.

An isolated outcrop of the Genil Formation is present about 10 km to the south of Ecija, somewhat east of the road from Ecija to Osuna. The outcrop consists of a conspicuous hill, where some exposures of a hard sandstone are found. Although no contacts are visible it may be inferred from the surrounding flat country that here the Genil Formation overlies the softer Ecija and Chaves Formations.

II.2.2. CHAVES FORMATION

Name: after the Barranco de Chaves.
Type locality: Exposure 71 in a dry gully leading to the Barranco de Chaves, somewhat to the southeast of the road from Ecija to Marchena 7 km from Ecija, where a secondary road branches off to the south.
Diagnosis: a white or off-white marl, containing a variable quantity of clay. Layering or lamination may be present. At some places layers of calcareous debris were found intercalated in the marl.
Type section: A grey-white marl is exposed without visible layering. Locally it is indurated, while at other places it is soft and friable. There are no sharp boundaries between patches with different hardness. As no bedding is present the thickness of the exposed section cannot be ascertained.
Description: Two types of marl can be distinguished, one unlaminated, the other with laminae, visible because of colour differences. Usually one single lamina is much less than 1 mm thick, and may be followed laterally over a distance of some cm. Laminae are grouped together in units, each one mm to some cm thick, that can be traced over some tens of cm, where they wedge out or are faulted out. Although separate laminae in such a unit are alternating light yellow gray and greenish gray, units as a whole are light or dark gray, depending on which sort of lamina is predominating. Units of laminae may be intensively folded without losing their identity, but consecutive units of laminae often do not follow the same folds. Discrepancies are solved by increase and decrease in thickness of the units. The laminae within the units are folded even more intensively than the units they are part of.

The unlaminated marl consists of a random mixture of different-coloured pieces of marl, each not larger than some mm at most. All stages between undisturbed laminae and an unlaminated mass of unoriented and unrelated marl chips do occur. Laminated and unlaminated marl may be found side by side. No explanation of their relation is presented by the relative position of the different kinds of marl.

The type locality consists of unlaminated marl only. In a rather large exposure (250), on the road from Ecija to Osuna, 15 km from Ecija both types are present. Exposure 163, situated 3 km to the SE. of Osuna, contains only laminated marl. This is the only exposure where a stratigraphical section of some length could be taken: 25 m of laminated marl is exposed here.

In two exposures (271 and 275) some layers of graded calcareous sand and organic debris with larger foraminifera (*Lepidocyclina morgani*) are found in this formation. In 271 they overlie a greenish-white clayey marl. Some loadcasting of the graded layer into the underlying marl has taken place.

The following features are important in separating the Chaves Formation from the other ones:

a) The absence of sand, that distinguishes it from the Cuesta del Espino and Marchena Formations;

b) The absence of detritic organic limestone, except in exposure 271 and 275, which allows the distinction from the Guadaira, Canteras and Bembezar Formations;

c) Its colour and the presence of lamination, by which it may be separated from the Ecija Formation.

If only the type localities are compared, the differences between the Ecija and Chaves Formations may seem clear. However, by an increase in clay content, and by the absence of lamination, a clear "Chaves" marl passes into the "Ecija" clay. The marly clay exposed near Puente Genil resembles the Chaves marl in its colour and has a much stiffer consistency than the Ecija clay. Yet the clay content of this Puente Genil marly clay is sufficient for a brick industry. This clay has been considered to belong to the Chaves Formation.

Exposures: Most exposures of the Chaves Formation are very small and give no information about the stratification, defying most attempts either to determine the thickness of the exposure, or to construct the thickness of the whole formation. However, the longest section, as mentioned before, does show a thickness of 25 m. Even though good exposures are scarce it is possible to map with some measure of certainty the presence of this formation because the grey-white colour of the tilled soil betrays the presence of a substratum of this formation. Extensive surfaces underlain by the Chaves Formation are covered by a hard crust, formed by the deposition of salts from evaporating ascending groundwater.

The layers of graded calcareous debris cannot be clearly related to the marls of the formation. There is no reason to distinguish the former as a separate formation. Their occurrences are very small, have no special surface expression, and do not show whether or not they are intercalated normally in the adjacent part of the marl. The age of the larger foraminifera, *Lepidocyclina morgani,* does not conflict with that of some of the planktonic foraminifera of the marls, e.g. *Globigerinita dissimilis.*

In exposure 170 a contact of the Chaves Formation with the overlying Marchena Formation is present. This is the only case that a contact between the Chaves Formation and another one is actually visible.

Other contacts are inferred from the surface expressions of the different formations. Near La Luisiana, in the northern part of its distribution area, the Chaves Formation is overlain by the Cuesta del Espino Formation. The boundary between both is mapped at the visible change in the topography from a flat tableland to an irregularly dissected surface. Between the hills formed by the Chaves Formation, the flat valley floors mark the occurrence of the Ecija Formation.

The boundary between the Marchena and Chaves Formations is rather well expressed, both topographically and in the vegetation. The boundary with the overlying Canteras Formation, where this forms two flat-topped hills, one immediately east of Osuna, the other to the north of Estepa (exposure 91 and 93) presents even less difficulty. The boundary of the Chaves Formation with the Genil Formation is very uncertain. As the accessibility is very bad and exposures are scarce the boundary lacks both detail and exactness of position.

Near Estepa the Chaves Formation lies against the rim of the basin, formed by Jurassic limestones. Towards the west masses of gypsum and accompanying rocks crop out in contact with the Chaves Formation. This may be seen near Morón de la Frontera (not on the map) and to the south of Aguadulce. Mostly a zone of irregularly mixed Chaves marl and gypsum is present. Between El Rubio and Herrera isolated outcrops of gypsum and Mesozoic limestone occur. They are surrounded by the Chaves Formation, and there is no regularity in their distribution.

Extension: The Chaves Formation is mainly present in the south of the mapped region. Within the triangle La Lentejuela-Osuna-El Rubio the area is entirely underlain by this formation. Further to the north the exposures are not so extensive. The formation is here mostly restricted to the hills, while the plains are underlain by the Ecija Formation. These northward extensions find their end at a vague boundary line connecting Ecija and La Luisiana, while more to the east and the west they do not even reach as far north as this line.

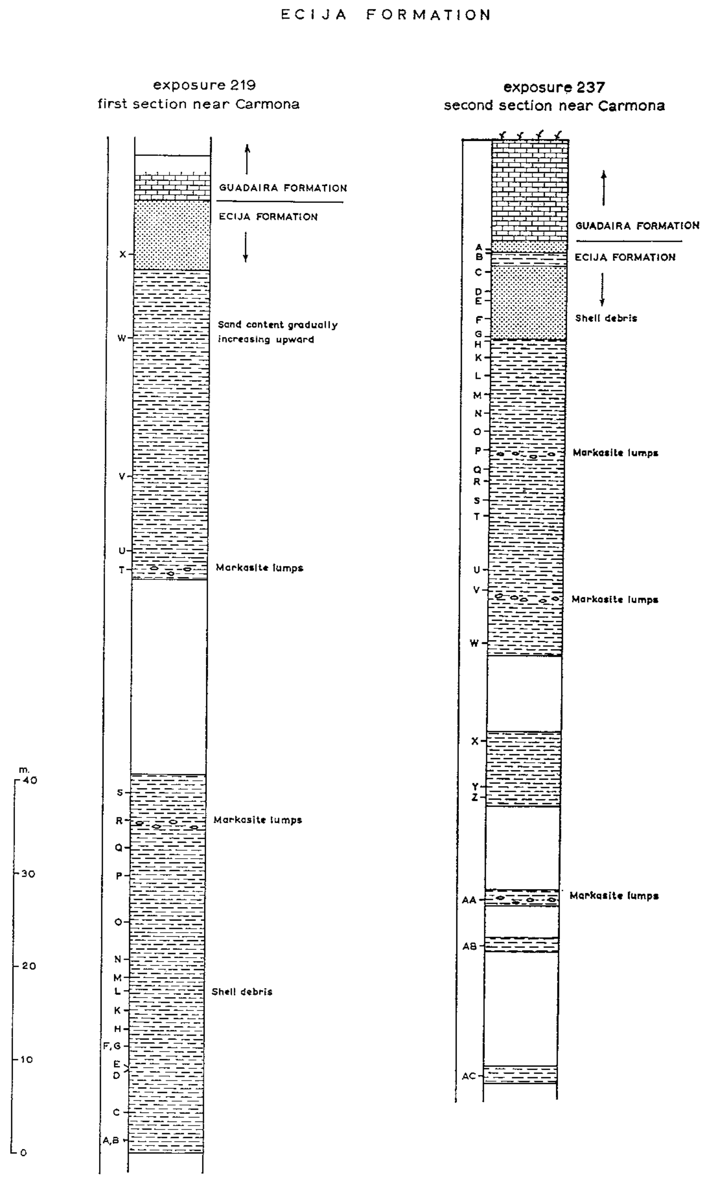


Fig. 3. Stratigraphic columns of the Ecija Formation, Carmona area.

II.2.3. ECIJA FORMATION

Name: After the town of Ecija.
Type locality: Clay pit north of the railway station of Ecija (exp. 67). This exposure can be reached by following the road from Ecija to Cañada Rosal for about 1 km.
Diagnosis: A dark blue-grey plastic clay, locally somewhat sandy.
Type section: The quarry face, only 6 m high, is the actual type section. Higher up on the hillside other exposures are visible indicating a larger thickness. However, they cannot reliably be connected with the quarry exposure, as the clay is very plastic. An exact thickness of the formation cannot be given. Some one hundred meters may be estimated.
Description: In the type locality a homogeneous unlayered clay is exposed. A small quantity of silt is admixed and markasite lumps, not exceeding 1 cm in diameter, are randomly distributed in the clay. No indications of layering are visible. On drying, the dark-blue colour of the clay changes to a very light blue.

Some features not present at the type locality are shown in two sections near Carmona. The first one, exposure 219 (fig. 2B) is situated immediately to the southeast of this town, in the gully south of the national highway IV. The lowermost exposure is near an abandoned railway station. Here we find a blue-grey sticky clay with a very low sand and silt content. This clay is similar to the one near Ecija, in all its properties, except that it shows faint stratification. Following the gully upward, one sees some changes in the sediment type. Thirteen meters above the lowermost exposure, the amount of sand in the clay increases visibly but it remains slight. From 15 to 20 m numerous shells and abundant shell debris are present. From 34 m upward small lumps of a rusty sand are found in the clay. The shell debris, too, mostly occur in discrete masses and not scattered in the clay. From 40 to 60 m no exposures are present. From 60 m to about 80 m the amount of sand continues to increase gradually. At 87 m there is an abrupt change from a sandy clay to an almost pure sand.

The relation between the exposures of the section was established by measurement with a rod and a hand level. The horizontal distance between the lowermost and the uppermost exposure is more than 1 km. Only in these two localities of the section was a stratification visible, showing that the sediments barely deviate from the horizontal, with a slight dip to the northwest. The section is overlain by the Guadaira Formation, with a dip of 2 or 3 degrees to the northwest.

As the indications for the amount of dip are uncertain, no constructions for the real thickness of the section are made, and the samples are placed on their apparent vertical distance in the stratigraphic column.

Another section of the Ecija Formation is to be found one and a half km from

Carmona along the road from Carmona to Alcalá de Guadaira, where between a brick factory and the "Molino de Brenes" a small ravine runs approximately southeast (exp. 237, fig. 2C). Unlike the section beginning at the abandoned railway station the upper part of this one is very well exposed, while the lower part is more discontinuous. Going downward from the detritic limestone of the Guadaira Formation that forms the top of the section, the Ecija Formation is first encountered as a layer of fine sand mixed with blocks of limestone. Immediately below it a layer of about 1 m almost pure clay is found, pervaded with bore-holes filled with sand. Below this layer, 8 m of sand containing some clay are exposed. Sizeable clay-lumps, many thin-walled mollusc shells and much shell debris are present. This sand is underlain by a sandy clay. The boundary is quite well visible in the exposure. Going downward the clay contains sand in ever decreasing quantity. Occasionally one may find mollusc debris or lumps of rusty sand.

The formation is here exposed continuously over a thickness of about 50 m. Three separate exposures downstream add another 30 m to the section. The lowermost is the least reliable, as the sample was taken from the bank of a stream, under water.

On the whole, the first and second section near Carmona do not show great differences. They both present a gradual change in the properties of the Ecija Formation which cannot be seen as clearly in small exposures. The sandy layers at the top of either section form a passage from the clayey Ecija Formation to the coarse clastics of the overlying Guadaira Formation.

Exposures: The best exposures of the Ecija Formation are in the clay pits of brickworks, as long as the exposure is kept fresh by continuous digging. Exposures in water-bearing gullies are often altogether covered by solifluction. Dry exposures weather very soon and get covered by weeds within a short time. Except for the Carmona sections all exposures show only a small portion of the formation. Large expanses underlain by this formation are without actual exposures. However, the presence of the Ecija Formation may be recognized by its gently rolling topography and by the vegetation.

The main crop grown on the Ecija Formation is wheat; trees are very scarce, some may be found near farms.

As most of the Ecija Formation mainly consists of an almost pure clay, no difficulty will arise in differentiating it from the more calcareous formations. Both the Ecija Formation and the Cuesta del Espino Formation consist of sand and clay. However, the latter shows a regular alternation of sand and clay throughout, whereas the major part of the Ecija Formation consists of a homogeneous, rather plastic clay, gradually becoming more sandy toward its top. Moreover, the sedimentary structures typical for the Cuesta del Espino Formation do not occur in the Ecija Formation.

It is much more difficult to differentiate between the Ecija and Chaves Formations, especially when the Chaves Formation contains much clay. From exposures east of Marchena (exp. 118) and near La Puebla de Cazalla (exp. 167) one gets the impression that the two formations, vertically rather than laterally, intergrade in their lithological characters. In separating both formations we used the white to greyish colour and the $CaCO_3$ content of the typical Chaves Formation.

North of the Rio Guadalquivir the Ecija Formation is underlain by the Bembezar Formation, as has been inferred from the relative position of the exposures.

In different parts of the mapped area the Ecija Formation is overlain by various formations. The superposition of the Chaves Formation is concluded from the topographical expression, no contacts being exposed. In the eastern part of the area surveyed the Ecija Formation is overlain by the Cuesta del Espino Formation. This is clearly visible near La Carlota (exp. 207), where the valley bottom consists of Ecija clay, while in the topographically higher places the Cuesta del Espino Formation is exposed.

Between Carmona and Alcalá de Guadaira, the Ecija Formation is overlain by the Guadaira Formation. As mentioned in the description of the sections near Carmona, the Ecija Formation immediately below the contact has a composition different from that in the type locality, as it contains sand and shell debris. The contact between the two formations is clearly visible in the sections near Carmona. Some wells (exp. 221, 222, 238) pierce the whole Guadaira Formation, and the rock brought up last is a blue sandy clay with shell debris. In the field the boundary is traced as the base of the steep escarpment of the Guadaira Formation.

Areal distribution: The Ecija Formation is exposed along either banks of the Rio Guadalquivir between Córdoba and Alcolea del Rio. To the south of the Rio Guadalquivir the formation crops out in the valleys of the tributaries of this river. As mentioned in connection with the Chaves Formation, the Ecija Formation is restricted to the valley floors in the southern part of the mapped area, while the Chaves Formation is found to form the hillsides.

II.2.4. GUADAIRA FORMATION

Name: After the town of Alcalá de Guadaira.

Type locality: In a quarry near Alcalá de Guadaira, two km north of the town of Alcalá de Guadaira and along the bypass in the road from Sevilla to Málaga (exp. 223).

Diagnosis: A yellow to rusty brown clastic skeletal limestone.

Type section: In the type locality a section of about 20 m is exposed.

Description: The limestone consists of mostly unrecognizable mollusc debris. The bulk of these fragments are of a tabular form and have a diameter of some mm and up to 1 cm. Complete shells are restricted to the upper bedding planes of layers, with a preference for the higher part of the section. The lower part of the type section consists of almost horizontal irregular limestone layers. These are overlain by a set of regularly layered horizontal strata, each with a thickness of a few to ten cm. The boundary between this set and the underlying irregular layers is non-erosional.

Over the horizontal strata lies a set of cross-strata, giant foresets that continue in thin bottom-sets, merging in turn into the set of regular horizontal strata mentioned before. The cross-strata are each 10 to 30 cm thick, they have a strike of 210° and a maximum dip of 30°, diminishing to zero at the toe. Vertically they extend over 10 m and horizontally over some tens of meters. At the toe end the thickness diminishes. At some places there is a layer of clay between two cross-strata, with a thickness of some cm and a lateral extension of a few meters.

Other exposures show additional features. Near Carmona (exp. 219 and 237) and in the canyon of the Guadaira river, east of the road from Sevilla to Alcalá de Guadaira (exp. 141), there are cavernous irregular layers, each several meters thick. Occasionally blocks of limestone are lying in a soft matrix of quarz sand and fine calcareous debris. In exposure 241 all features mentioned in describing the type locality are present, with the addition of small cross-strata within some of the giant foresets. This exposure strongly resembles that of the type locality of the Canteras Formation near Osuna.

The Guadaira Formation resembles the Bembezar Formation and Canteras Formation as to its lithology. Differentiation with the Bembezar Formation is made possibly through the absence of metamorphous inclusions and *Heterostegina* in the Guadaira Formation. The differentiation with the Canteras Formation is made through the presence of quartz sand in the Guadaira Formation.

Exposures: Many characteristic exposures of the Guadaira Formation were found, especially near Carmona. In the neighbourhood of Alcalá de Guadaira a section of 49 m is exposed in exposure 141. No lower boundary was found here. Other indications of thickness were obtained from wells that reach into the underlying Ecija Formation. According to local information the wells of exposure 221 are 23 and 29 m deep. Where exposures are lacking, the presence of this formation is easily recognized by the yellowbrown colour of the soil. Citrus fruits are grown there. Large patches are covered with pines and eucalyptus trees. Furthermore, the formation is a good aquifer and contains many wells.

Areal distribution: The Guadaira limestone forms a gently northwest dipping monocline between Carmona and Alcalá de Guadaira over a width of about 5 km. The southeastern boundary is an easily recognizable cuesta, running approximately between the two cities, higher near Carmona than farther southwest. There is no prominent northwestern boundary of the Guadaira Formation. All traces of the limestone disappear at distances of more than 5 km north-northwest of the cuesta. One gets the impression that the formation wedges out in this northwestern direction, but there is no visible proof for the assumption. Toward the northeast some erosion remnants are still visible (not on the map), but there is no more trace of the formation long before one reaches the Guadalquivir. In the southwest toward Dos Hermanas some local sand exposures may indicate a continuation, but because of their being not-calcareous it is considered dubious whether this is really true.

II.2.5. CANTERAS FORMATION

Name: After the Canteras hill, northeast of Osuna.
Type locality: Exposure 272, in a quarry northeast of Osuna.
Diagnosis: A yellow detritic limestone.
Type section: A thickness of about 40 m is exposed, partly in a quarry open to the air, partly in the pillars and the roof of some galleries.
Description: The formation consists of organic debris, very uniform in size, the major part with no greater diameter than 2 mm. On freshly quarried faces only faint traces of layering are seen. These layers are almost horizontal and contain foresets with cut-off tops. The thickness of these layers rarely exceeds 20 cm. Older, weathered faces show the bedding more prominently, but the smaller details are not visible. About 8 m below the top of the exposure there is an abrupt change in the structure of the limestone. A unit of giant foresets is lying over the parallel-layered rock. In some cases the foresets are composed of smaller foresets, dipping either in the same direction as the giant foresets, or in the opposite direction (Plate 2, fig. 1).

The Canteras Formation is easy to distinguish from those that do not contain shell debris, but there is some similarity with the Guadaira and Bembezar Formation, as all three are composed of organogenic debris. Confusion with the Bembezar Formation is not to be expected, as this formation can be distinguished by the presence of *Heterostegina* and pieces of metamorphous rock in the lower part. The lithologic difference between the Canteras and Guadaira Formations is small but they occupy widely separate areas. Especially the sedimentological features of both formations are much alike, for instance the occurrence of giant foresets in the upper part of the type sections of both formations. If a connecting outcrop between the exposure of the two formations were present, with a gradual change in the lithology, one might consider all outcrops and exposures as one formation. In the Guadaira Formation some layers contain sand, whereas the Canteras Formation consists of calcareous debris only.

Near Osuna the Canteras Formation is lying on the Chaves Formation (exp. 91). The contact proper is not exposed. In exposure 93 the Canteras Formation is partly reposing on Mesozoic gypsum, partly on the Chaves Formation.
Areal distribution: The largest exposure of the Canteras Formation is in the type locality. A second exposure is situated to the north of Estepa, where one finds a large abandoned quarry in this rock.

II.2.6. MARCHENA FORMATION

Name: After the town of Marchena.
Type locality: Near the road from Marchena to Morón de la Frontera. About 1 km from Marchena, this road crosses a dry gully with a fountain and the municipal water supply of the town. The banks of this gully on the southeastern side of the road are the type locality (exp. 181).
Diagnosis: A yellow-brown rather soft sandstone, with a variable amount of shell debris.
Type section: The layers of sandstone easily weather to loose sand. A thickness of no more than 7 m is exposed, showing a coset of cross-strata.
Description: The sand is of rather uniform grain size, from 0,1 mm to 1 mm. The grains are loosely cemented. Cosets of cross-strata are characteristic for the formation. The lower boundary of the wedge-shaped or lense-shaped sets of cross-strata is invariably erosional. Trough-shaped cross-stratification is present. The lowermost cross-strata contain most of the shell debris.

Sets of cross-strata vary in thickness from 10 cm to 1 m. In addition to concave cross-strata, straight ones are found.

In the type locality some fine shell debris is present, whereas in exposure 313, near Puente Genil, many pieces of shells and even some unbroken specimens could be collected.

There will be no difficulty in distinguishing the Marchena Formation from the other formations which are more clayey, marly or calcareous. The separation of the Marchena and Cuesta del Espino Formations may present some difficulties, but for the presence of clay layers and conglomerates in the latter.
Exposures: Few exposures of the Marchena Formation were found. It can be mapped over a wide area on the rusty brown soil that originates from this formation. A characteristic vegetation of pines, brushwood, cork-oaks and vineyards indicates the presence of the Marchena Formation where no outcrops are visible.
Areal distribution: The formation forms an almost horizontal plain stretching southeastward from a line connecting El Arahal and Marchena. Another, separate group of outcrops is to the south of the road from Herrera to Puente Genil. To the south the Marchena Formation is bordered by the "Zone of mixed lithology".

In small valleys the boundary of the sandy Marchena Formation over the marly Chaves Formation is easily recognizable, even where no actual outcrops are present. Near Marchena and Paradas exposures of the boundary are found at an elevation of 110 to 130 m above sea level. Near exposure 177, where the road from Marchena to Morón de la Frontera crosses the Sevilla-Málaga road, the boundary is at 140 m. Near La Puebla de Cazalla the boundary is found at about 170 m, and along the road from La Puebla de Cazalla to Morón de la Frontera the boundary lies 190 to 200 m above sea level. No features were found that suggest a primary depositional mechanism for this gradual rise of the boundary between the Marchena and Chaves Formations, when going from north to south. Therefore postdepositional tilt is the reason for these slight differences in altitude.

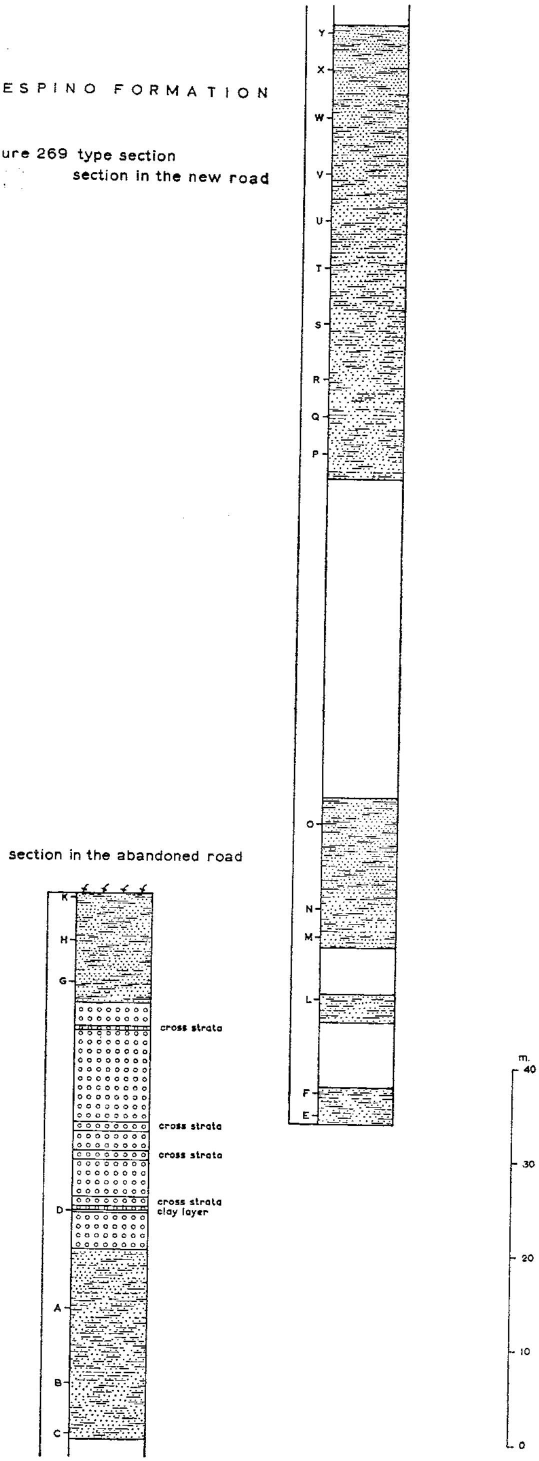
II.2.7. CUESTA DEL ESPINO FORMATION

Name: Derived from the Cuesta del Espino hill range.
Type locality: On the road from Córdoba to Sevilla, about 12 km from Córdoba, where the road ascends the Cuesta del Espino (exp. 269, fig.2D).
Diagnosis: Alternating sand and clay layers, occasionally pebble layers with restricted lateral extension.
Type section: The lower part of the type section is exposed along the abandoned part of the main road where it crosses the Cuesta del Espino. In this place it consists of an alternation of sand and clay layers with an intercalation of conglomerate. The section continues upward in the roadcut of the new highway. All together a thickness of about 150 m is exposed.
Description: The type locality exhibits all features of the Cuesta del Espino Formation, although some may be seen more clearly in other exposures. The lowermost exposed part of the type section is the conglomerate cliff in the abandoned road, that consists of 27 m of alternating pebble-poor and pebble-rich layers with a sand matrix. Most pebbles do not exceed 4 cm in diameter, many being much smaller. About half of them consist of quartzite, the remaining half is almost equally divided over milky quartz and metamorphic and igneous rock. The bigger ones almost all consist of quartzite.

The layers, five to some tens of cm thick, show a dip of about 10° to the south. The bedding-planes are not sharply expressed and do not show erosional features. Tabular pebbles may be arranged parallel to the bedding planes, or imbricated opposite to the dip of the layers (Plate 1, fig. 3). More or less equidimensional pebbles are mostly arranged in a closely-packed fashion, the smaller ones filling the spaces between the bigger ones. Laterally a layer may be recognized by the size of the components and by their shape, orientation and mode of pack-

CUESTA DEL ESPINO FORMATION

exposure 269 type section



ing. In a lateral direction most layers keep their individuality over some meters. A few layers consist of an irregular mass of unoriented pebbles of all sizes.

The shape of the conglomerate mass as a whole could not be ascertained. If the described exposure and some occurrence nearby are considered as parts of the same body, the lateral dimensions will be at least 200 m with a thickness of 27 m.

On top of the conglomerate member, well-exposed layers of sand and clay are found. Each layer has a thickness of 1 to 10 cm. The sand is homogeneous as to grain size, the grains being about 0,1 mm in diameter. Clay layers consist of an almost pure clay. Only few sedimentological features were seen in the Cuesta del Espino section. At one place layers may be arranged as sets of cross-strata, but here it was not possible to get a clear impression of the relations of the various sets. Occasionally very thin, somewhat wavy layers are met with. As far as the exposure permits observation the strata do not augment or diminish in thickness and remain parallel to each other.

In the upper part of the type section, especially in the excavation of the present highway, no continuous detailed observations could be made of the sedimentological properties of the sediment.

The Cuesta del Espino Formation may be recognized everywhere by the alternation of sand and clay layers, sometimes with intercalated conglomerates. In other localities other features than in the type section are met with. In a gravel pit, about 5 km south of La Victoria (exp. 211), an elongate body of sand and gravel is exposed. The diameter of the sand grains is up to 1 mm, the bulk of it being coarse. Most pebbles have a diameter of about 2 cm, but larger ones with a diameter up to 10 cm do occur.

Various cosets of cross-strata of both sand and pebbles are exposed in the sides of the excavation, the single cross-strata being straight or concave, varying in thickness from 0.3 to 3 cm. At their lower end they have a thin, fine-grained continuation over the eroded top of the previous set. Strata may extend over 1 m. The boundary between sets of strata is erosional. Pebbles tend to be accumulated near the lower boundary of the set. Sets of cross-strata ascend in the downstream direction of the single sets of cross-strata. The excavated part of the sand and gravel body has a length of about 200 m and is 20 m wide. The axis of the body is dipping 4° in 170° direction.

Fig. 4. Stratigraphic columns of the Cuesta del Espino Formation.

Sedimentary structures, much resembling channel-fillings in alternating sand and clay layers, are well exposed in exposure 233 to the west of Fuentes de Andalucía. There, the layers are 2 to 10 cm thick. When dry, it may be seen that they are composed of many paper-thin laminae of sand and clay. Sand layers are composed of sets of cross-strata, the latter visible by virtue of colour differences, owing to different grain size or intercalated clayey laminae. Strata are straight or somewhat concave, their length is mostly less than 5 cm. Sets with conspicuous cross-strata alternate with others consisting of more or less parallel strata. Most sets are not more than 5 cm thick and can be followed laterally for some meters.

Generally, there are no difficulties in recognizing the Cuesta del Espino Formation, even in small exposures. Its alternation of sand and clay layers, its sedimentological features, and occasionally its layers of gravel cannot be confused with features of any of the other formations present.

Exposures: The Cuesta del Espino Formation has an easily recognizable surface expression with shallow, rather steep-sided valleys cut into an almost flat plain. Natural exposures are mostly situated in the valley sides, where these form low vertical cliffs. Artificial exposures exist in road-cuts and in pits where clay or gravel are being excavated. Exposures in this sandy formation remain fresh for a longer time than those in the clayey ones, e.g. the Ecija and Chaves Formations.

In exposure 208 a complex of clay layers with very thin sand layers inbetween has been upturned and even overturned so as to form a narrow syncline with sloping axial plane and axial direction of 145° (Plate 2, fig. 2). It is thought possible that this feature arose because the underlying Ecija clay was squeezed out to the valley side (on the right in the figure) under the pressure of the overlying sediment load.

No contacts between the Cuesta del Espino Formation and others were met with in exposures. Nevertheless, there is no doubt about its position overlying the Ecija Formation, as can be seen in the surroundings of the type locality, where northeast of the foot of the Cuesta del Espino range, clay of the Ecija Formation is exposed. In the bottom of the valley running northwest from La Carlota Ecija clay is exposed, below sand and clay layers of the Cuesta del Espino Formation in the valley sides.

To the south of La Luisiana and Ecija the Cuesta del Espino Formation is overlying the Chaves Formation. The easy recognition of the latter's white colour gives some compensation for the scarcity of exposures.

Areal distribution: The Cuesta del Espino Formation is found south of the Rio Guadalquivir. The southern boundary is roughly situated along a line from La Luisiana to Ecija. The valleys of the Arroyo de Madrefuentes, of the Rio Genil and those of the small streams near Santaella and La Carlota have been eroded through the entire Cuesta del Espino Formation, exposing the underlying Ecija

Formation. The east side of the valley of the Rio Corbones is the furthest westward extension of the Cuesta del Espino Formation. To the east, the formation extends beyond the region discussed here.

II.2.8. BEMBEZAR FORMATION

Name: Derived from the Rio Bembezar, a northern tributary of the Rio Guadalquivir.
Type locality: A dry canyon that opens to the Rio Bembezar, immediately west of Hornachuelos. The actual locality is 100 m to the south of the "Fuente de Cano de Hierro" (exp. 260).
Diagnosis: A detritic organogenic limestone with pebbles of crystalline rock.
Type section: Altogether more than 20 m of detritic limestone is exposed. As the canyon side is vertical and partly overhanging, only the lower part of the section can be reached.
Description: In the type locality yellow detritic limestone is exposed. In some places mollusc debris can be recognized, but usually the calcareous components of the rock are beyond recognition. Only little stratification can be seen, but sometimes the bedding can be inferred from an alternation of cavernous indurated layers and softer ones. In exposure 52 gently dipping layers of calcareous sand and gravel are exposed.

Near the road from Estación de Hornachuelos to Hornachuelos, north of the bridge in this road over an irrigation canal, a contact of the Bembezar Formation with the Meseta basement can be seen (exp. 258). Metamorphous schists are covered here by a basal conglomerate composed of elements of the same schists. Going upward, the matrix contains more and more calcareous components and the fragments of metamorphous rock diminish in number and size. At about 1 m above the schists an almost pure organic limestone is found. In a less well indurated detrital layer in this exposure, many complete specimens of *Heterostegina* have been collected. This fossil has been found in other localities of this formation as well, in a more loosely cemented layer or pocket, whereas in hard rock they could be seen but not detached.

The sequence: schists, basal conglomerate and detritic organogenic limestone can be seen in various exposures, for instance 258, 259 and 264. In others the metamorphic schists proper cannot be seen, but the lower part of the limestone does contain pebbles and boulders of them.

The Bembezar Formation differs from both the Canteras and Guadaira Formations by the presence of pieces of metamorphic and crystalline rock in its basal part at least, and by the occurence of *Heterostegina.*
Exposures: Fresh exposures of the Bembezar Formation are mainly found in

quarries and other excavations. Outcrops are easily recognizable as the rock is only partly covered by weathered soil in most places where it occurs. Lower contacts of the Bembezar Formation are all with the metamorphous schists of the Meseta border. Because of the indistinct and frequently irregular contact the base of the formation has not been drawn on the map. The Bembezar Formation is overlain by the Ecija Formation. No exposure of the contact was found, but the conclusion of their superposition can be drawn from the relative position of adjacent exposures of both formations.

Areal distribution: Outcrops of the Bembezar Formation are confined to the northern side of the Rio Guadalquivir. Canyons cutting through the limestone of the Bembezar Formation expose the metamorphous rock of the Meseta proper.

The outcrops of the Bembezar Formation dip a few degrees to the south or southeast. North of Hornachuelos they form the crest of the hills. To the southwest of this town the Bembezar Formation forms a dipslope, as may be seen near the road from Hornachuelos to Palma del Rio, in exposure 48.

PERCONIG (1962) mentions a *Heterostegina*-containing organic limestone, immediately overlying the metamorphic basement, in bore-holes near Villalba del Alcor, Salteras and Castilleja; all northwest and west of Sevilla, outside the mapped area. It may be assumed, therefore, that the Bembezar Formation is more or less continuously overlying the metamorphic basement, not only where this is exposed, but below the cover of younger sediments as well.

Chapter III

BIOSTRATIGRAPHY

III.1. **Planktonic foraminiferal associations**

The planktonic foraminifera in our samples show associations that are known from Eocene to Pliocene deposits elsewhere. Their distribution is shown in fig. 3.

I. *Globigerapsis kugleri / Globorotaloides suteri* association.

The oldest planktonic foraminiferal association, found in one sample (126), contains species that are mentioned from the Eocene Navet Formation of Trinidad by Bolli (1957). Characteristic are *Globigerapsis kugleri, Globigerina boweri* and *Globorotaloides suteri.* The first two species suggest an attribution to the *Globigerapsis kugleri* Zone; the last one to a position in the *Porticulasphaera mexicana* Zone or higher. The possibly mixed association as a whole suggests a Middle Eocene Age for the sediment this sample was taken from. As to its lithology and position on the map the sample is without doubt part of the Chaves Formation.

II. *Globigerinita dissimilis* association.

In fig. 4 the vertical ranges of the planktonic foraminiferal species that are characteristic for this next-younger association are drawn, against some frequently used zonations, based on data from Bolli (1957), Blow (1959), Banner & Blow (1962) and Bolli (1966). The co-occurrence of *Globigerina angustiumbilicata, Globigerinita dissimilis, Globigerinita stainforthi* and *Globigerinoides trilobus altiaperturus* is a feature of the *Globigerinita dissimilis* Zone of Bolli. *Globigerinita dissimilis* and *Globigerinita stainforthi* are both present in the *dissimilis* as well as in the *stainforthi* Zone. Hence, distinction between these two zones has to be based on the presence of other species. Since *Globigerinatella insueta* (*stainforthi* Zone, according to Bolli, 1966) was not found in our samples and because of the presence of *Globigerina angustiumbilicata* our association fits best into the *Globigerinita dissimilis* Zone as defined by Bolli (1957). This association is found in five samples from the type section of the Genil Formation (exp. 218).

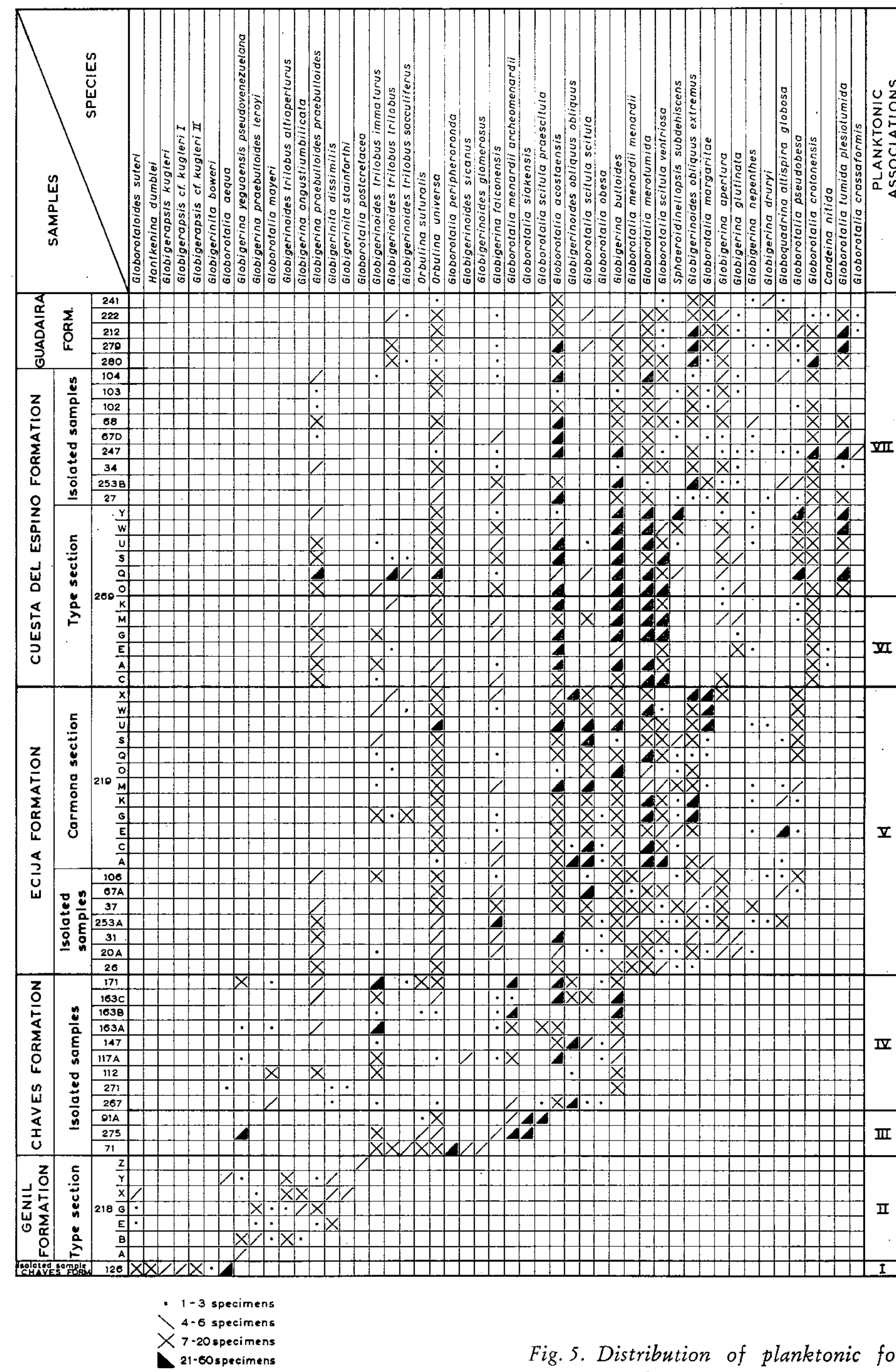


Fig. 5. Distribution of planktonic foraminifera.

III. *Globorotalia peripheroronda / Orbulina suturalis* association.

A third faunal association is characterized by various *Globigerinoides trilobus* variants, together with *Globigerinoides glomerosus, Orbulina suturalis, Orbulina universa* and *Globorotalia peripheroronda.* The latter species occurs in one sample only. *Globorotalia siakensis,* which is restricted to this association, occurs in two samples. *Globorotalia acostaensis* is not yet present. *Globorotalia menardii archeomenardii* is restricted to this and the following zone. BANNER & BLOW (1965) consider *Orbulina suturalis* and *Globorotalia peripheroronda* characteristic for zone N 9 of their Neogene planktonic zonation. The latter species, named *Globorotalia fohsi barisanensis* by BOLLI (1966), is considered by this author to have a wider range than that of the zone with the same name. Samples 71, 91 and 275 that yielded this planktonic foraminiferal association belong to the Chaves Formation.

IV. *Globorotalia acostaensis / Globigerina bulloides* s.str. association.

A fourth planktonic foraminiferal association is characterized by *Globorotalia acostaensis* and *Globigerina bulloides* s.str. with incidental occurrence of *Globorotalia obesa* and *Globigerinoides obliquus obliquus,* and the absence of *Globorotalia merotumida.* An association with these two zonal markers is characteristic for the uppermost member of the Pozón Formation in Venezuela (BLOW, 1959). In their Neogene planktonic zonation BANNER & BLOW (1965) mention a zone N 16: the *Globorotalia acostaensis / Globorotalia merotumida* partial range zone; the latter species, however, is not present in our association. It appears in the next zone.

BOLLI (1966) mentions a *Globorotalia acostaensis* Zone which, according to his views circulated in manuscript, coincides with zone N 16 of BANNER & BLOW. An indirect indication suggesting that our association should be placed in this zone, is the presence of *Globigerinoides obliquus obliquus* while *Globigerinoides obliquus extremus* which is considered by BOLLI as a marker for his next higher zone, is absent. There is no unanimity among authors about the morphology of *Globorotalia acostaensis* and its relations to *Globorotalia dutertrei.*

The data mentioned warrant a tentative correlation of our *Globorotalia acostaensis / Globigerina bulloides* association to the *Globorotalia acostaensis* Zone of BOLLI. More than half of the samples from the Chaves Formation are characterized by this association. No younger associations were found in samples from the Chaves Formation. However, species that are characteristic for older zones are present in all samples.

V. *Globorotalia merotumida / Globorotalia margaritae* association.

In the fifth planktonic foraminiferal association *Globorotalia merotumida, Globorotalia margaritae, Globorotalia scitula ventriosa* and *Globigerinoides obliquus extremus,* make their appearance. *Globorotalia menardii menardii* occurs only in isolated samples of the Ecija Formation but not in samples of this formation of the Carmona section.

Recently, various sections in Italy have been discussed, which contain comparable planktonic foraminiferal associations. BARBIERI (1967) gives a zonation of a long composite section which comprises the stratotype of the Piacenzian Stage as well as a lower unit that is correlated to the Tabianian Stage. IACCARINO (1967) describes the zonation of the stratotype of the Tabianian Stage and the strata immediately overlying this stratotype. BARBIERI & PETRUCCI (1967) present the zonation of a long section along the Crostolo river, Reggio Emilia province, northern Italy. FOLLADOR (1967) published a zonation based on work carried out in central and southern Italy. BIZON (1967) presents a zonation that comprises a large part of the younger Tertiary, based on many sections in western Greece. Figure 5 shows the relevant parts of the zonations of the authors mentioned, with the zones characterized by *Globorotalia margaritae* at the same level. *(Globorotalia hirsuta* in the concept of CONATO & FOLLADOR 1967, FOLLADOR 1967, BARBIERI 1967, IACCARINO 1967 and BARBIERI & PETRUCCI 1967 is considered identical to *Globorotalia margaritae).*

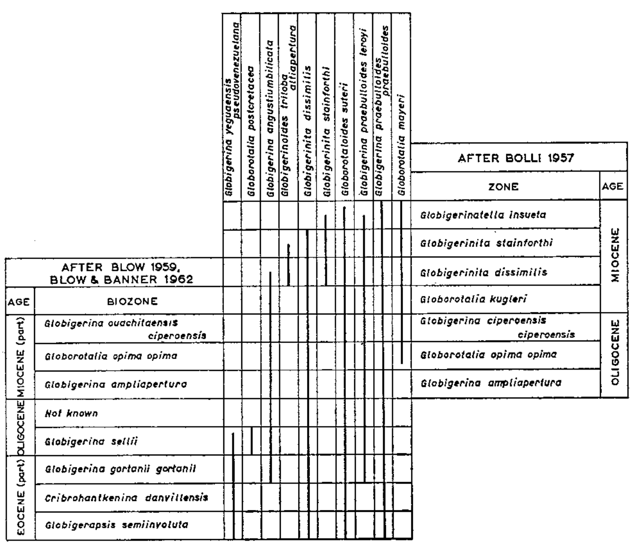


Fig. 6. Ranges of planktonic foraminifera of associations I and II in the Eocene - Miocene interval after BOLLI 1957, BLOW 1959 and BLOW & BANNER 1962.

The presence of *Globorotalia margaritae* in our faunal association seems to point to a correlation with the *margaritae* (=*hirsuta* auct.) Zone of the basal Pliocene and possibly somewhat lower (top Messinian?) of the Mediterranean area.

A comparison of the foraminiferal faunal associations of the authors mentioned to that found by Cita, Premoli Silva & Rossi (1965) in the Tortonian stratotype and its topmost tobacco-coloured marls, attributed to the Messinian by these authors, gives the impression of a completely different fauna.

Species that are restricted to Tortonian strata in Italy, however, are present in our samples together with species considered characteristic for the *margaritae* (= *hirsuta* auct.) Zone of the Italian authors, giving our association a mixed character.

In the planktonic foraminiferal zonation presented by Bolli (1966) the only zone that can accomodate the association under discussion is again the *Globorotalia margaritae* Zone which overlies his *acostaensis* Zone. Bolli considers this zone to embrace the entire range of the marker.

Comparing our foraminiferal association with the markers used by Banner & Blow (1965) for their Neogene planktonic zonation, the best fit is again with the *Globorotalia acostaensis* / *Globorotalia merotumida* partial range zone or N 16.

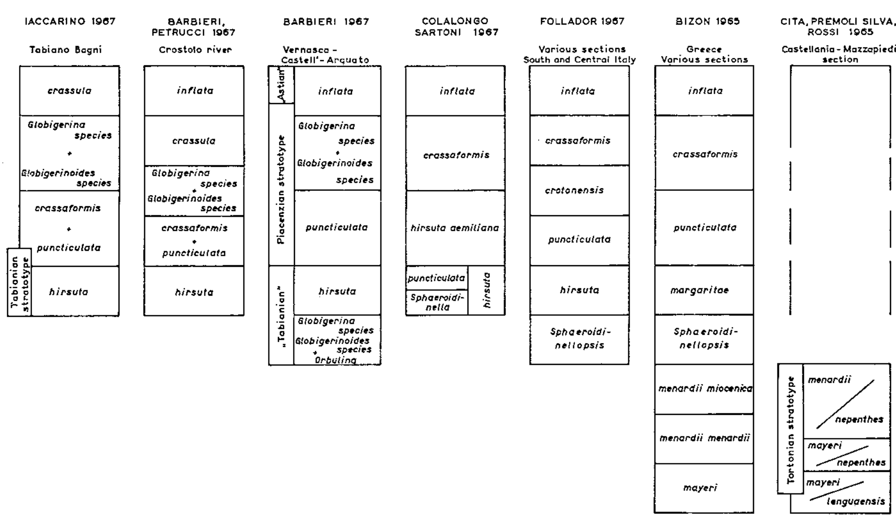


Fig. 7. Neogene (mainly Pliocene) zonations in the Mediterranean area according to various authors. The margaritae (= hirsuta) Zones have been placed at the same level. No correlation is implied by the position of the other zones.

Evidently the zonations of BOLLI and of BANNER & BLOW are not in good harmony. Both our associations IV en V would point to zone N 16 of the latter authors, though possibly to different parts. In BOLLI's zonation our associations fall well apart in different superposed zones, with a *G. dutertrei* Zone in between. The presence of mainly *Globorotalia margaritae* is reason to consider association V equivalent to that of the *Globorotalia margaritae* Zone, as represented in the lower part of the Tabianian stratotype.

Samples containing this planktonic foraminiferal association are all from the Ecija Formation (see fig. 3).

VI. *Globorotalia merotumida / Globorotalia crotonensis* association.

The main differences of the sixth planktonic foraminiferal association with the preceding one is the presence of *Globorotalia crotonensis*. When trying to compare this association with established zonations, one encounters a number of serious difficulties. The zonations of IACCARINO (1967), BARBIERI & PETRUCCI (1967), BARBIERI (1967), COLALONGO & SARTONI (1967) and FOLLADOR(1967), all based on Italian material, and of BIZON (1967), based on Greek successions, show but little agreement in the species considered to be characteristic for the interval between their *Globorotalia margaritae* (=*hirsuta* auct.) Zone and their *Globorotalia inflata* Zone.

From the comparison of the few figures and the faunal lists of these authors and the material available in Utrecht laboratory, it would appear that between the *Globorotalia margaritae* (=*hirsuta* auct.) Zone at the base and the *Globorotalia inflata* Zone at the top, only one association, characterized by *Globorotalia puncticulata, Globorotalia crassaformis, Globorotalia hirsuta aemiliana* (=*Globorotalia crotonensis* CONATO & FOLLADOR) can be distinguished. It is impossible to decide from the sum of data in the literature whether there is any fixed order of appearance of these species.

The presence of *Globorotalia crotonensis* in our *Globorotalia merotumida / Globorotalia crotonensis* association is a point of similarity to the zone overlying the *Globorotalia margaritae* Zone of the previously mentioned authors. This zone, indicated with different names by these authors, is represented in the lower part of the Piacenzian stratotype.

All samples containing this planktonic foraminiferal association are from the lower part of the type section of the Cuesta del Espino Formation. This association was not found in any of the other samples of this formation from scattered localities.

VII. *Globorotalia crotonensis / Globorotalia tumida plesiotumida* association.

The occurrence of *Globorotalia tumida plesiotumida* in addition to the species present in the preceding association is the main characteristic feature of this planktonic foraminiferal association.

Its presence would suggest a possible correlation with zone N 17 of the planktonic zonation by BANNER & BLOW (1965), which these authors place, without offering clear arguments, in the Upper Tortonian. It seems, however, that arguments for a correlation of this association with the Piacenzian are stronger.

This association was found in the upper part of the Cuesta del Espino type, in all scattered surface samples of this formation, and in the samples from clayey intercalations in the Guadaira Formation.

III.2. Biozonation by means of Uvigerina lineages

MEULENKAMP (1969) describes two lineages in the genus *Uvigerina* that show a change in morphology with geologic time. Parameters were chosen that enabled him to express these morphological changes in counts and measurements. By means of a statistical evaluation of the counted and measured values the significance of the morphological changes is checked.

In the Tertiary strata from the Guadalquivir Basin, representatives of the *Uvigerina cretensis* group were found. From our section 219, which includes part of the stratotype of the Andalusian Stage, three samples were studied by MEULENKAMP. He concludes that the specimens from 219A (Ecija Formation, Upper Tortonian according to PERCONIG) are transitional between *Uvigerina lucasi* and *Uvigerina arquatensis*, the penultimate and ultimate species of the *Uvigerina cretensis* lineage, whereas the specimens from 219E (same formation, same age according to PERCONIG), and 219Q (Ecija Formation, Andalusian according to PERCONIG) belong to *U. arquatensis*. The same species was found in clayey deposits of exposure 280 (Guadaira Formation), which would belong to the Lower Pliocene of PERCONIG.

If we consider the ranges of these species given bij MEULENKAMP against the background of the Italian stages, it is apparent that the Andalusian would be of Pliocene Age.

III.3 The occurrence of Lepidocyclina

From exp. 271 (Chaves Formation) a number of specimens of *Lepidocyclina*

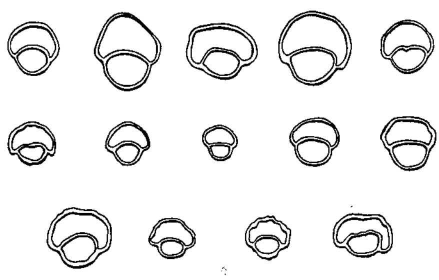
(Nephrolepidina) morgani LEMOINE & R. DOUVILLE have been collected. In the application of biometry various parameters are used to characterize a population. According to VAN DER VLERK (1963) the optimal biostratigraphic solution, however, is attained by the grade of embracement (factor A), e.g. the percentual expression of the part of the protoconch that is surrounded by the deuteroconch. The bad preservation of our material hampers observation of other parameters.

By grinding away one side of lateral layers, equatorial sections were prepared. The proto- and deuteroconch of 14 megalospheric specimens (fig. 6) were drawn with a camera lucida. Circumferences of the protoconch and its embraced part have been measured in the drawings with a curvimeter.

In the literature there is some disagreement whether measurements should be carried out along the outer or the inner surface of the protoconch wall (VAN DER VLERK 1964, DROOGER & FREUDENTHAL 1964). Both techniques have been applied to my material; it will be appreciated that practically the same values are obtained here. DROOGER & FREUDENTHAL (1964) prefer to measure the outer circumference of the protoconch. From their data, those concerning A 71 (Escornebéou) and Fr. 475 (Sausset) are chosen for a comparison with those from sample 271.

The means of A of neither A 71, nor Fr. 475 differ significantly from those of sample 271 (fig. 5). All samples thus belong to *L. morgani*.

The deposits of Escornebéou, where A 71 originates, are placed in the stages immediately below and above the Oligocene - Miocene boundary by different



DEGREE OF EMBRACEMENT				
		RANGE	M	σM
A 71	(OUTER)	42-63	49	2.0
FR 475	(OUTER)	39-62	47	1.2
JE 271	INNER	32-64	47	1.9
	OUTER	40-64	48	1.5

Fig. 8 Camera lucida drawings of protoconch and deuteroconch in median section of 14 specimens of Lepidocyclina morgani from exposure 271. The mean values for the degree of embracement (M_a) are discussed in the text.

authors. Those of Sausset, Fr. 475, are commonly considered to be of Aquitanian Age. Difference in age is concluded from the *Miogypsina* species found in the same exposures (DROOGER & FREUDENTHAL 1964). However, on the analysis of a large number of samples, these authors argue that only one species of *Lepidocyclina* can be recognized in the Late Oligocene and Early Miocene. Consequently this is the narrowest age determination to be attained for the *Lepidocyclina* specimens of sample 271. Planktonic foraminifera in the overlying marl have been attributed, with some reserve, to the *Globorotalia acostaensis* association, mixed with elements of older associations such as *Globigerinita stainforthi.* This gives the idea that the Lepidocyclinids and some of the planktonics have been reworked from older deposits.

Chapter IV

ECOLOGY

IV.1. Introduction

Thanatocoenoses of fossil foraminifera can provide much information about the circumstances of sedimentation of the strata they are found in. Their study inevitably departs from a comparison with the distribution of recent foraminiferal faunae. While basing their assumptions on a large body of circumstantial evidence, most authors publishing on foraminiferal ecology agree that the qualities of certain foraminiferal taxa remain the same during the existence of the taxon, at least during the Neogene.

The most conspicuous distribution patterns of benthonic foraminifera commonly mentioned in the literature are connected with depth (PARKER 1954, PHLEGER 1960, PHLEGER 1964). There are indications that it is not depth as such that is of decisive importance, but that it in turn controls a complex of ecological factors that are little known separately, e.g. salinity, oxygen, p_H, etc. Very little is known about the influence of these factors in the ecology of recent foraminifera, with the exception of some generalities (tolerance for salinity changes in *Ammonia*, etc.).

Comparatively little attention has been given to the correlation of foraminiferal ecology and bottom sediments.

General ideas about foraminifera that live attached to seaweed and bottom-dwelling organisms are found in many authors, but there are no qualitative data or specific information about this issue. Some of the genera reputed to have an attached mode of life are *Cibicides*, *Hanzawaia* and *Discorbis*, but many other genera that are commonly present immediately on the bottom, will be found attached to seaweed as well.

IV.2. The distribution of foraminifera applied to ecology

IV.2.1. PREPARATION OF THE SAMPLES AND ECOLOGICAL APPLICATIONS.

From all samples containing a reasonable extensive foraminiferal fauna, 100 specimens of planktonic foraminifera were determined and counted, together with the accompanying benthonic foraminifera, which were counted as well. Figure 7

	CHAVES FORMATION — Isolated samples										ECIJA FORMATION — Carmona section 210											CUESTA DEL ESPINO FORMATION — Type section 260											
SAMPLES / SPECIES	147	275	126	117A	71	91A	171	163A	163B	163C	A	C	E	G	K	M	O	Q	S	U	W	C	A	E	G	M	K	O	Q	S	U	W	Y
Dorothia brevis		·				·																											
Martinottiella communis	·									X	·	·	·		·	\			\	·	\												
Eggerella bradyi						·																											
Vulvulina pennatula																										·	·		·	·			
Pyrgo bulloides											·																						
Pyrgo depressa							·			·				·			·																
Sigmoilopsis schlumbergeri	·	·			\						·																						
Quinqueloculina seminula																						·				·		·	·				
Nodosaria longiscata								·																									
Nodosaria catenulata											·																			·			
Nodosaria hispida											·	·				·																	
Lenticulina (L.) orbicularis											·	·					·	·	·	·										·			
Lenticulina (L.) calcar											X	\	X	\	·	X	X	·	X		·					·		·	X	\	\	\	\
Lenticulina (L.) cultrata											·				·	·	·			·									·	·		·	
Lenticulina (L.) peregrina											·		·					·															·
Lenticulina (L.) convergens	·	·			·	·	·																										
Lenticulina (L.) cf. costata											·			·	·						·												
Lenticulina (Saracenaria) italica											·																						·
Lenticulina (Vaginulinopsis) decorata											·																		·				
Amphicoryna scalaris	\									·	X	·	·	·	·	\	·	·		·	·											·	
Chrysalogonium globiferum					·		·			·	·																						
Chrysalogonium obliquatum		·			·					·																							
Chrysalogonium lanceolum					\					\																							
Chrysalogonium cf. lamellatum	·	·		·				·	·	·																							
Chrysalogonium sp.					·																												
Marginulina costata											·		·			·	·		·	·	·												
Marginulina hirsuta											\	·																					
Dentalina inornata				·					·																						·		
Lagena acuticosta																								·							·		
Lagena sulcata laevigata	·																																
Glandulina laevigata	·					·																											
Guttulina problema			·																														
Bulimina aculeata											X	\	X		X	X	\	X	X	\													
Bulimina striata	\	·				X	·		·	·															·								
Bulimina ovata						\				\	X	·	\	·	\	\	·	·		·													
Bulimina acanthia																						X	X	X	X	X	X	X	X	◣	X	·	
Bulimina costata																						·	·	·		·	·	\	·			·	X
Globobulimina pacifica							·			·	X	·	X	\	X	X	\	◣	·	·	·				·		·	·	·	\	X	·	·
Bolivina antiqua											·	·	·	·	\		·	·	·		·	·	·		·		·	\			·		\
Bolivina alata							·			X	·						\	·			·	·	·	·		·	·				·		
Bolivina dilatata											·		·			·		·	·			·			·			·			\	·	·
Bolivina dohmi										·												\											
Bolivina byramensis						·					X	·	·	·	·	·		·	·	·	·					·	·	X	X		\		·
Bolivina cf. byramensis											X	\				X	·	·	·	\	X											·	
Bolivina cf. robusta													X		\			\	·													·	
Bolivina cf. midwayensis											·				·			·		·	·	\	·		·				·	·			
Bolivina cf. jacksonensis					·																												
Uvigerina hispidocostata											\	·	◣		◣	X	X	X	\	·	·	X	\	·	X	·	X	·	\	·	X	◣	◣
Uvigerina rustica							\			\																							
Uvigerina canariensis									·																								
Uvigerina rutila											\	·	·	·					·		\												
Uvigerina arquatensis											X	\	\	\	X	X	◣	◣	\	\	\					·	·		·	·	·		
Hopkinsina bononiensis											X	X	\	\	X	·	·	X	·	·		·			·								
Stilostomella subspinosa	·					·																											
Stilostomella advena								·		·																							
Stilostomella gracilis			·	·				·																		·							
Stilostomella nuttalli	\						·			\																							
Stilostomella cf. paucistriata										·																							
Stilostomella challengeriana	·																																
Trifarina bradyi											·		·			·		·	·	·		·	·	·			·	·		·	·		
Trifarina carinata											·			·	·		·	·	X	◣	X										·		
Reussella spinulosa											\	\	X	X	·	\		\	·	X	X												
Oolina longispina																													·	·			
Oolina apiculata																						·											
Fissurina submarginata						·		·																									
Plectofrondicularia semicosta								·	\		X																	·		·			·
Virgulina schreibersiana									·		·						·		·			·					\	·	·	·		·	·
Sphaeroidina bulloides												X	◣	X	X	◣	X	X	X	X	X		·			◣	◣		X		X	◣	◣
Cassidulina crassa											·	·	·			·	·	·												·			
Cassidulina laevigata											X										·		·		·					·		·	·
Cassidulina cf. laevigata											·				\		·																
Cassidulina subglobosa	·		·				·				·		\	\	·		·	·	\				·	\	·	◣	\	·	X	X	\	·	·
Cassidulina subglobosa horizontalis							·												·														
Nonion pompilioides	X			\		X	·	X	\	\	\	·					·			X	\		·		·		·	X	X	\	X	X	X
Nonion boueanum											\	X	X	X	\	\	◣	X	\	\	\	\	X	·	\	\	\	\	X	◣	X	X	X
Nonion tuberculatum																												·					
Astrononion italicum																												·	·	·	·	·	
Pullenia bulloides	X			\							·	·	X	X	X	X	X	\	X	·			·	X					·	·	\	·	\
Pullenia subcarinata		·								·																							
Cibicides ungerianus											·	·	\	\	X		X	·		·	\						·		\	\		\	·
Cibicides dutemplei praecinctus											X	X	◣	◣	◣	X	◣	◣	◣	X	X	·	X	·	\	X	◣	·	X	X	X	\	
Cibicides pseudoungerianus	X	\	·	·	·	·	·		X	X												X	·	·	\		X	·	\	\	·	·	X
Hanzawaia producta											·	X	X	X	X	X	·	◣	◣	◣	◣	\	·	·		·	·	X	·			·	·
Gyroidina soldanii	\					\	·	X		·	·	·	X		·		\	·	·	\	·							·	·			\	\
Gyroidina parva																						·	·						·	\	\	\	·
Laticarinina pauperata		·			\																												
Rosalina globularis											·										·								·				
Cancris auriculus											·			·			·	·	·	·	·												
Planulina ariminensis		·									X	X	X	·	X	\	\	X	X	X	·	·		·	·	·		·			·		
Planulina marialana	·	·	\		X	\			\																								
Siphonina planoconvexa				\																		·	·	·	·						·	·	
Valvulineria araucana malagaensis																						\	X	·	X	◣	X	◣	◣	◣	■	◣	◣
Eponides umbonatus	\		·		·		\	·	\	X												·			·						·	·	
Epistomina elegans											·		·		·					·													
Pleurostomella alternans					·																												
Pleurostomella brevis	·				·	·	·																										
Asterigerina planorbis												\	·	X	\	\	\	·	X	◣	◣			·	·	·		·				·	
Elphidium fichtellianum											·	·		\	·						X	·			·	·		·		·		·	
Elphidium crispum																						·	·	·	·	·			·			·	
Elphidium subumbilicatum	\		·	·	·	·																											
Elphidium excavatum																						·	X	·	·	·	X	·		·		·	
Ammonia beccarii													·			X	X	\	·	·		X	X	X	X	X	\	·	X	X	\	X	\
Planorbulina mediterranensis											·	·	\	·	·	·	·		·	\													

· 1-3 specimens
\ 4-6 specimens
X 7-20 specimens
◣ 21-60 specimens
■ > 60 specimens

shows the distribution of the benthonic foraminifera in the most important sample series of three of the formations. One may object that the results for the benthonic forms are not comparable because their total numbers per sample are different. Theoretically this is correct, but in practice this disadvantage is slight because the plankton/benthos ratios are comparable in value for the formations to be discussed primarily: the Cuesta del Espino and Ecija Formations.

For a better insight, figure 8 shows the distribution of those benthonic foraminifera that occur in great numbers in the major sections of these two formations.

The number of genera and species represented in the samples is mentioned likewise, as well as the plankton/benthos ratios. Based on these data, the foraminiferal populations in these samples can be interpreted ecologically with various techniques.

A simple method for obtaining ecological information from a foraminiferal association without going as far as an actual determination of the species is the application of the plankton/benthos ratio, the quotient of the numbers of planktonic and benthonic foraminifera in the sample. GRIMSDALE & VAN MORKHOVEN (1955) prepared a graph of the plankton/benthos ratio as a function of bottom depth. The general increase in the ratio with increasing depth is plainly visible, although there is a large variation in ratio for samples of the same depth, especially between 100 and 1000 m.

The faunal diversity is the number of species and that of genera present in a

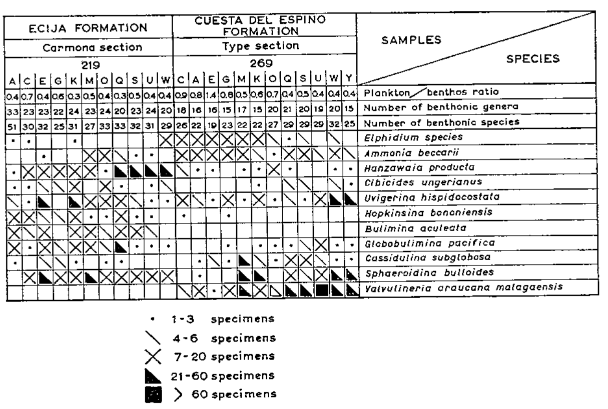


Fig. 10. Non-specific faunal characteristics and frequent foraminifera of ecological importance in the Ecija and Cuesta del Espino Formations.

Fig. 9. Distribution of the benthonic foraminifera in the Chaves, Ecija and Cuesta del Espino Formations.

sample. Empirically this non-specific faunal characteristic was found to be correlated to the environment of deposition. In fig. 9, data tabulated after PHLEGER (1960) about non-specific faunal characters in different environments, are given.

IV.2.2. DOMINANT BENTHONIC FORAMINIFERAL GROUPS.

The taxa that show a marked predominance in figure 8, the distribution chart of common species in the Ecija and Cuesta del Espino sections, are mentioned below with their ecological implications as mentioned in the literature.

I. The *Elphidium-Ammonia* association. According to WALTON (1964) and many others these genera are characteristic for marginal-marine environment. In the northeastern Gulf of Mexico the ten-fathom-depth contour is almost wholly situated within the area where *Ammonia beccarii* makes up more than 10% of the total benthonic foraminiferal fauna; the 20-fathom contour lies in the area where this species comes below 5% of the benthonic fauna. DROOGER & KAASSCHIETER (1958) mention a comparable distribution from the Orinoco shelf, especially in front of river mouths. The same authors mention a tendency of some *Elphidium* species to avoid areas with pelitic sediment. KRASHENINNIKOV (quoted by BOLTOVSKOY 1965) suggests that *Elphidium macellum*, *Elphidium crispum*, and *Elphidium fichtelianum* are euryfacial, i.e. will be found in a wide range of different facies types.

II. The *Hanzawaia producta* - *Cibicides* species association. It is commonly thought, without much argument, that specimens of these species are often attached to seaweed during life. An attached mode of life would lead to a preponderant occurrence in the area of distribution of the host and scattered occurrences outside this area if the host organism is easily transported by currents. For organisms depending on photosynthesis the maximum depth of growing is about 70 m; the presence of clay in suspension in the sea water will diminish its permeability for sunlight, thereby reducing this maximum depth considerably.

III. The *Uvigerina* - *Hopkinsina* association. DROOGER & KAASSCHIETER (1958) distinguish a preferential distributional pattern of striated Uvigerinids of the *Uvigerina peregrina* group in areas with a substratum of clay or very clayey sediments.

IV.3. Occurrence of associations in formations and sections and their ecological meaning

IV.3.1. FORMATIONS WITH POOR FORAMINIFERAL FAUNAE OR NONE.

In the Canteras Formation no foraminifera were found at all. However, the sedimentological features of this formation and its nearly uniform mineralogical composition of organic calcareous debris suggest that this formation was formed in very shallow water from material derived of a rich fauna of lime-secreting organisms. No traces of a reef were discovered.

The sole foraminifera found in the Bembezar Formation are locally abundant specimens of *Heterostegina;* together with the texture of the rocks of this formation they make its origin probable in a shallow high energy environment.

In the Marchena Formation no foraminifera were found at all, possibly due to partial decalcification. The sedimentological features and the presence of shell debris which is locally abundant, suggest an origin in shallow water with intensive current action.

An accurate ecological analysis of the benthonic foraminiferal fauna of a turbidite succession is of no use because of the mixing of faunae from different environments. Consequently no ecological information can be gathered from the contents of the Genil Formation.

IV.3.2. CHAVES FORMATION.

The plankton-benthos ratio of the Chaves Formation which invariably is $\geqslant 10$ is characteristic for the lower slope- or deepsea deposit of figure 9, which implies a sea depth greater than 1000 meters. This fully agrees with the occurrence of numerous radiolarians and diatoms and the clayey-marly sediment type.

Benthonic foraminifera are relatively scarce. They belong to a great number of species, but none of them is predominant. Additional specimens were picked to get data for figure 7. Therefore these data can only be seen as qualitative. Some of the regularly occurring species, such as *Bulimina striata, Nonion pompilioides, Cibicides pseudoungerianus, Gyroidina soldanii, Planulina marialana* and *Eponides umbonatus,* give no clue to a definite depth. Individuals may have been transported to greater depth as may be concluded from the presence of *Lepidocyclina* at some localities.

IV.3.3. ECIJA FORMATION, CARMONA SECTION

In the lower part of the Carmona section the *Uvigerina / Hopkinsina* association is preponderant up to sample Q. This agrees well with the mainly clayey sediment in this part of the section. A sea depth of about 100 m can be concluded. Because of the frequent occurrences of *Nonion boueanum* a greater depth is thought unlikely. The sea probably was not shallower because of the common presence of *Sphaeroidina bulloides* and *Bulimina aculeata.*

In sample Q and higher *Hanzawaia producta* is abundant, whereas it occurs

ENVIRONMENT	DEPTH RANGE	PLANKTON / BENTHOS RATIO	NO. OF GENERA	NO. OF SPECIES
Nearshore turbulent zone	0-20 m.	-	-	-
Inner continental shelf	20-60 m.	<0.1	5-15	10-25
Outer continental shelf	60-100m.	0.1-1+	20-30	30-40
Upper continental slope	100-1000m.	1-5+	20-30	30-40
Lower continental slope; deep-sea	>1000m.	±10	5-15	10-25

Fig. 11. Non-specific faunal characteristics related to sea depth after Phleger 1960.

less frequently in the lower samples. A sea depth of less than 70 m is suggested for sample Q and the higher samples.

Asterigerina planorbis, Trifarina carinata and *Hanzawaia producta* become more abundant in the samples U and W, from the upper few meters of the section, whereas the *Uvigerina / Hopkinsina* association strongly decreases in number. Together with the marked change from clayey strata to sand this faunal association suggests a shallow but fully marine environment. The virtual absence of *Elphidium* species, the high diversity of the benthonic fauna as a whole and the persistence of a plankton/benthos ratio between 0,4 and 0,6 throughout the whole section indicate a fully marine sedimentary environment.

IV.3.4. CUESTA DEL ESPINO FORMATION, TYPE SECTION.

The samples with foraminiferal fauna are all taken from the clayey intervals in the section, as the sandy interval proved to be usually barren.

In the lower part of the Cuesta del Espino section, from sample C to sample K an *Ammonia beccarii / Elphidium* association is distinctly present, suggesting a marginal marine environment, with sea depths probably not exceeding 60 m. The sand layers are thicker than the clay layers in this part of the section; the gravel intercalation exhibits a pebble arrangement similar to that of braided rivers, suggesting a wholly continental origin of this interval. Lateral equivalents of the gravel layers, however, consist of sand and clay layers not unlike those found immediately below and on top of the gravel layers. Presumably the gravel intercalation reflects a local sea-ward extension of a braided river system during a short interval of time and not a general regression that affected the entire depositional area.

The interval of strata, samples O to U were taken from, has no preponderant foraminiferal faunal elements. The reduction in number of *Elphidium* species suggests a change to a more open marine environment which is supported by the frequent presence of *Sphaeroidina bulloides* from sample M onward. This development is concurrent with the increase in number and thickness of the clay layers in this part of the section. In accordance with this we see that *Uvigerina hispidocostata, Sphaeroidina bulloides* and *Valvulineria araucana malagaensis* become predominant in the higher samples, whereas *Ammonia beccarii* shows a reduction in number. These lithologic and faunistic characteristics indicate a change to a more open-marine and clayey environment.

The alternation of sand and clay layers, the intercalation of pebble-lenses, and the presence of certain sedimentological features in the sand layers suggest a deposition of these sediments under the influence of intermittent, rather strong currents. The foraminiferal association which is similar all over the investigated area and the sedimentological features of the Cuesta del Espino Formation give no precise information about the exact depth of deposition, which probably was always less than 100 meters. The presence in relative abundance of planktonic foraminifera in all samples except those near the gravel intercalation and the rather high diversity of the benthonic foraminiferal fauna are strong indications for a free entrance of sea water into the area of deposition of the Cuesta del Espino Formation.

IV.3.5. GUADAIRA FORMATION.

The clayey intercalations of the Guadaira Formation mainly yielded planktonic foraminifera. The benthonic forms are ill preserved with especially representatives of *Cibicides dutemplei, Hanzawaia producta, Asterigerina planorbis, Ammonia beccarii* and several other forms known already from the other formations. In the coarser sediments mainly *Asterigerina planorbis* and some *Elphidium* were encountered.

Chapter V

STRATIGRAPHIC INTERRELATION OF THE FORMATIONS; HISTORY OF THE BASIN

With the field data and subsurface data from PERCONIG (1962 and 1964) and SAAVEDRA (1964) a schematic section over the Guadalquivir Basin has been drawn. The figure 10 shows the relative position of the most important Neogene formations but the horizontal and vertical dimensions are not to scale. Units that presumably have been transported horizontally are shaded.

The Bembezar Formation discordantly overlies the Paleozoic and older rocks along the northern boundary of the basin. A distinct basal conglomerate is present where the contact between both units is exposed. More towards the centre of the basin rocks are present that evidently closely resemble the Bembezar Formation, and again immediately overlie a basement that may be seen as the buried continuation of the Meseta. This conclusion may be drawn from the information from bore-holes at various places (PERCONIG 1962).

From evidence of macrofossils, found also outside the area (*Pecten beudanti, P. besseri, P. gigas, Clypeaster altus, C. pyramidalis*) a Miocene Age of the Bembezar Formation has been concluded (R. DOUVILLE 1911), but apart from frequent *Heterostegina* specimens no microfauna could be found to offer a more exact age determination. Further study of the Heterosteginids was not attempted, not only because of their moderate state of preservation, but also because of the disappointing results FREUDENTHAL (1969) had in unravelling the phylogenetic development of Miocene European representatives of the genus.

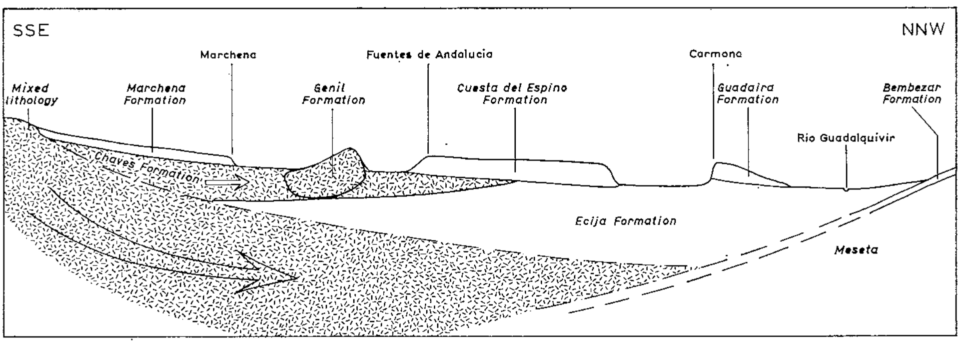


Fig. 12. Rough schematic northnorthwest - southsoutheast section over the Guadalquivir Basin showing the relative position of most of the formations. Dimensions not to scale. Subsurface conclusions from the literature below dashed lines. Not-autochthonous strata shaded.

Toward the south the shallow water deposits of the Bembezar Formation are overlain by the Ecija Formation along the whole length of the investigated part of the basin. This relation may be inferred from the position of both formations in the field.

The clays of the Ecija Formation with their fully marine microfauna are witness of increased sea depth during deposition, probably not exceeding a hundred meters. Only in their upper portion coarser clastics of sand size (Carmona section) make their appearance again. As far as visible very slight and regular dips of the strata demonstrate that we are dealing with autochthonous sediments which probably were deposited in an area much greater than that of today's outcrops. The age of these sediments corresponds with that of the *Globorotalia margaritae* Zone of Italian authors. This zone, which is found in the lower part of the classical Italian Pliocene (type deposits of the Tabianian), probably started outside the Mediterranean before Pliocene time already. As a consequence it is reasonable to suppose that in a chronostratigraphic sense the Ecija Formation straddles the Miocene-Pliocene boundary.

Farther south the Ecija Formation comes in contact with the Chaves Formation. This lithological unit corresponds with the "Moronitas" of the literature. These marls with abundant and predominant planktonic microfauna indicate depositional depths much greater than that concluded for the Ecija Formation. If we take the plankton/benthos ratio as a reliable criterion for an estimate, a bathyal depth cannot be precluded for the majority of the sediments of the Chaves Formation.

The field relations of the Ecija and Chaves Formations must be inferred from evidence of a secondary character, as no contacts are exposed. When both formations occur close together the Chaves Formation is found in the hillsides, whereas the valley floor consists of the Ecija Formation. Near Marchena, La Puebla de Cazalla and Puente Genil sediments with characteristics intermediate between the sediment types of the two formations are present. In most cases the vertical relation between both formations is maintained, with the Chaves Formation topmost. Nevertheless, the relation of the two formations must be of a more intricate nature than a simple sedimentary superposition.

First of all the planktonic association of most of the Chaves samples, corresponding to that of Bolli's *Globorotalia acostaensis* Zone, appears to be distinctly, though not much, older than that found in the Ecija Formation. Evidently we have the older formation overlying the younger one. This is possible only if we assume postdepositional lateral movements of the Chaves sediments. It is logical to think that their source area was in the south. Evidently a rapid and considerable rise in Late Miocene to Early Pliocene time caused these sediments to slide in northern direction over clays of the Ecija Formation. The assumption of such mass movements make the frequently observed chaotic character of the Chaves sediments, and their occasional high dips without preferential strike direction more understandable. Possibly these movements took place while farther north the higher part of the Ecija Formation was being laid down under quiet circumstances in a shallower and more stable part of the basin.

If the majority of the Chaves sediments indicate some Late Miocene Age (no good comparison with the type deposits of Tortonian and/or Messinian) the formation contains older associations as well which show that deposition of this formation started earlier in the Miocene. Derived elements are frequent, such as *Lepidocyclina morgani* and several planktonic species. The single sample with a Middle Eocene fauna (exp. 126) does not necessarily mean that the Chaves Formation reaches back in time that far. We may be dealing with masses of older sediment slipped into the basin in Miocene time from a more southern source area. Proof of such olistostromes has been forwarded by other authors before (PERCONIG 1962).

Evidence of enormous slip masses may be seen in the Genil Formation. In itself they show evidence of mass transport because of the sole presence of turbidites laid down in Early Miocene time (*Globigerinita dissimilis* association). Furthermore, we are evidently dealing with enormous allochthonous blocks which as a whole moved into their present position in Late Miocene time. This time may be concluded from the largest block along the Rio Genil which is in contact and possibly overlying both the Chaves and Ecija Formations.

The main planes of movement of the Chaves sediments probably occurred at their base where they were in contact with the Triassic sediments. Thorough mixing during the displacement along this contact zone and later diapiric movements of the gypsum caused the elongated strip in the south indicated on the map as "Zone of mixed lithology".

After the Chaves sediments reached their present position at the latest in Early Pliocene time, the entire basin remained a stable area.

From place to place, different formations are overlying the Ecija and Chaves Formations. They have in common that they all show evidence of deposition in shallow water.

The Cuesta del Espino Formation is found overlying the Ecija Formation in the central and northern part of the mapped area and the Chaves Formation in the eastern part. In the southern part, near Puente Genil and near Marchena, the Marchena Formation covers the Chaves Formation. Whereas the Cuesta del Espino Formation consists of alternating sand and clay layers, the Marchena Formation is composed of sand only. Both formations are rich in sedimentological features common for shallow, moving water. The superposition of the relevant formations is visible in some exposures, and can be inferred, in the absence of outcrops, from differences in the topographic expression of the lithological units.

In the west near Carmona the Guadaira Formation regularly overlies the Ecija Formation, and in the area of Osuna and Estepa we find some isolated outcrops of the Canteras Formation. Both formations show calcareous detritic limestones with strong foreset bedding.

It is remarkable that the outcrop areas of these four near-horizontal younger formations are nowhere in lateral contact with one another. Unfortunately the two southern ones, the Marchena and Canteras Formations, yielded no microfaunae for age determination or ecological interpretation.

The plane of contact between the Ecija and Cuesta del Espino Formations is almost horizontal, with a very slight dip to the north, as can be concluded from exposures along the Arroyo de Guadalmazán and the Rio Genil between Ecija and Palma del Rio. The plane of contact between the Chaves Formation and the Marchena Formation is also dipping north. Going southward from Marchena to Morón de la Frontera, the amount of dip of this plane increases gradually. However, this observation is entirely based on the contour of the contact on the map. The actual dip is too slight to be directly measurable in the field. It could not be decided whether the planes of lower contact of both subhorizontal formations are continuous or not.

As to the northwestern part of the investigated area there seems to be no reason to follow the suggestion of PERCONIG (1966) that the Guadaira Formation, as part of his "Formazione marnoso-arenacea", should disappear below a higher formation and reappear near the Rio Guadalquivir, thus forming a shallow syncline with a northeast-southwest axial direction. No formation comparable to the Guadaira Formation was found near the Guadalquivir river, where it should be present according to PERCONIG. Although the area is shown on the map as not exposed there are occasional outcrops which invariably yield clay of the Ecija Formation.

The overlying "Pliocene" mentioned by PERCONIG in the same and other publications, could not be recognized in the field. However, between the layers of detritic limestone of the Guadaira Formation, thin clay layers can be found and it seems likely that they correspond to PERCONIG's "Pliocene". Their foraminiferal fauna is different from that of the Ecija Formation.

The type section of the Cuesta del Espino Formation contains two successive Pliocene planktonic associations, the *Globorotalia merotumida - Globorotalia crotonensis* association and the *Globorotalia tumida plesiotumida* association, which seem to follow that of the Ecija Formation without interruption. The younger of both associations was found in various outcrops of the Cuesta del Espino Formation throughout the basin and also in the clayey intercalations of the Guadaira Formation. Unless the clayey layer with lumps of detritic limestone and burrows at the base of the Guadaira Formation at Carmona is considered as such, there is no evidence or a considerable break in the Ecija-Guadaira sequence. So the absence of the lower Cuesta del Espino planktonic association in the Carmona section might be due to unfavourable environmental circumstances at the place where the coarser sediments of the lower part of the Guadaira Formation were deposited. Evidently the Cuesta del Espino and Guadaira Formations are roughly contemporaneous of Middle (-Late?) Pliocene time. Possibly the Marchena Formation is a southern sandy time-equivalent rock unit if we might accept the dubious sandy deposits near Dos Hermanas, in the southeastern continuation of the Guadaira Formation outside the mapped area, as some kind of intermediate between this formation and the Marchena Formation. The local presence of much calcareous debris in the latter formation may be another indication in this direction. Whether the Canteras Formation fits into this picture or not is still more uncertain.

PERCONIG's hypothesis (1966) that the strip of the Guadaira Formation with its northwestward trending foresets was formed along the southeastern margin of a Pliocene bay lying northwest in the area of Sevilla cannot be substantiated. Primarily these Guadaira sediments show fully marine, though shallow water microfaunae, in their clayey intercalations. The foresets being practically free of fluviatile influence, their direction only indicates that of the strongest currents. The complete sets rather indicate tidal currents over shoals in between the open ocean to the west and a far reaching and fully marine bay eastward, at least as far as the Córdoba area. At the Cuesta del Espino the formation of this name still consists predominantly of shallow marine sediments with hardly any fresh-water influence. The conglomerates in this formation are only evidence of local transport of terrigenic material from the north into this basin.

Chapter VI

DISCUSSION OF THE ANDALUSIAN STRATOTYPE AND STAGE.

VI.1. **Introduction**

In the sediment series of Carmona comprising the Ecija and Guadaira Formations the type section for the Andalusian Stage was chosen by PERCONIG (1966 and 1968). This stage was proposed by him as a fully marine equivalent and substitute for the Messinian, which is based on a section characterized by sediments from an environment with aberrant salinities. An extensive list of the foraminiferal fauna of the Andalusian was presented at the Congress of the Committee on Mediterranean Neogene Stratigraphy (Berne 1964), without, however, mentioning the exact location of the samples.

While he proposed in his 1966 publication the stratotype for the Andalusian Stage somewhat vaguely ("designando como stratotipo la serie marnoso-arenacea di Carmona - Dos Hermanas"), PERCONIG gave a more exact indication of its whereabouts in 1968: "The type section of the proposed stage is located in the north-eastern part of this outcrop (i.e. the "serie marnoso-arenacea di Carmona - Dos Hermanas") and consists of the exposures along the Madrid-Cadiz road". An approximate thickness of 300 m is mentioned both in the 1966 and in the 1968 publications.

In a paper on the biostratigraphy of the Carmona section, based on planktonic foraminifera (PERCONIG 1968 a), a geological map and a section of the stratotype are presented. A comparison of this section with the section described in this paper (exposure 219, fig. 2B), which was studied at the same locality as PERCONIG's, indicates that a distinct lower lithological boundary of the Andalusian type section (the transition from the "Marne azzurre" to the "Formazione marnoso-arenacea" within our Ecija Formation) is poorly documented. Instead, the sand content very gradually increases in upward direction. The major lithological change observed by me is that between the Ecija and Guadaira Formations, corresponding with a level somewhere within PERCONIG's "Formazione marnoso-arenacea", the Andalusian stratotype. This quite striking lithological change is not mentioned at all in PERCONIG's description of the "Formazione marnoso-arenacea" in the 1968 publication. Although a schematic column, suggesting a number of marked lithological changes within the "Formazione marnoso-arenacea" is given in the 1966 publication, it is not discussed in the text. Moreover, the exact location of this column is not mentioned. Comparison of this column with the observed

Carmona section is meaningless, as the length of the column of the Andalusian (300 m) is a multiple of the corresponding section measured by myself (90 m). Finally, the presence of the greenish-gray clay ("marne grigio-verdi") that is supposed to overlie the "Formazione marnoso-arenacea" is not adequately supported by field evidence.

Small exposures of clayey sediment were found intercalated in the Guadaira Formation (samples 212, 242, 279, 280) but there is no evidence for a continuous cover of a separate unit of clayey strata.

Before considering the applicability of the Andalusian Stage, the stratigraphy of the Neogene will have to be discussed, with special attention to the position of the Messinian.

VI.2. The stages close to the Miocene-Pliocene boundary

VI.2.1. THE TORTONIAN STAGE.

The Tortonian Stage was erected by MAYER-EYMAR in 1858. The Rio Mazzapiedi - Castellania section was chosen as the stratotype by GIANOTTI in 1953. Its upper part, with a thickness of about 70 m, was attributed to the Messinian by CITA, PREMOLI SILVA & ROSSI (1965), who described the planktonic foraminiferal faunas of the entire section. The stratigraphical use of some *Uvigerina* species from this section with the application of biometrical and statistical techniques was described by MEULENKAMP (1969). Both the lithostratigraphical and biostratigraphical position of the Tortonian are well defined. The Tortonian Stage, based on this stratotype, is unanimously accepted as a (Middle-Upper) Miocene stage.

VI.2.2. THE MESSINIAN STAGE.

The Messinian Stage was proposed by MAYER-EYMAR in 1868 with the intention to prove his thesis that a distinction between "Miocene" and "Pliocene" is useless. The stage was to occupy the place in-between these series, and to represent a complete transgressive-regressive cycle. While mentioning the strata he proposes to include in the Messinian, MAYER-EYMAR does show an astonishing aquaintance with details of Tertiary strata all over Europe, but he offers no reason whatever for incorporating a number of them into his proposed stage. He mentions a succession of strata near Messina as the most important lithological representatives of the three substages he distinguishes in the Messinian. Owing to their stratigraphical, sedimentological and tectonical properties, however, these strata were considered unfit to serve as a stratotype by SELLI (1960), who proposed the Pasquasia-Capodarso sequence (central Sicily) as a neostratotype for the Messinian Stage. By micropaleontological means D'ONOFRIO correlates the formations below and above this type section with the Tortonian and the Lower Pliocene respectively. The central, gypsiferous, part is considered to represent the Messinian Stage. The paleontological merits of the Messinian neostratotype are perhaps best expressed by her when she states "Il Messiniano, com'è noto si può definire con sicurezza, in Italia e nel Mediterraneo occidentale, solo de un punto di vista litostratigrafico e paleoambientale (SELLI 1960) essendo le microfaune saltuarie e per lo più distrofiche e spesso assenti". All correlations in Italy with the Messinian stratotype proper are based on lithological similarities, e.g. the presence of gypsum. A Messinian Age, attributed on biostratigraphical evidence, is always based on evidence of second order, e.g. the superposition on clearly Tortonian strata or position below clearly Pliocene strata or both. If carried out correctly, there would be no objection against the expression of such an age relationship in relative terms.

VI.2.3. THE TABIANIAN STAGE.

This stage has been erected by MAYER-EYMAR in 1868. A stratotype has been designated by IACCARINO (1967), who gave a survey of the foraminiferal content of this stratotype.

MEULENKAMP (1969), in a biometrical study of some *Uvigerina* species from this section, indicates its position over the Tortonian and close to the Piacenzian stratotype. The Tabianian Stage has not been widely used in stratigraphy; however, because of its clear lithological position and its rich associations of marine fossils from various groups, it may prove a useful addition to Neogene stratigraphy.

VI.2.4. THE PIACENZIAN STAGE.

The Piacenzian Stage was erected by MAYER-EYMAR (1857), without indicating a stratotype. PARETO (1865) considered the marls between Lugagnano and Castell'Arquato as the most typical of this stage; therefore, the section between these places is unanimously considered as its stratotype. Various publications about its fossil content appeared; the foraminifera were dealt with by BARBIERI (1967). *Uvigerina* species from two samples below the Piacenzian stratotype and from one sample near the top of this stratotype were included by MEULENKAMP (1969) in his biometrical studies.

There is not much discussion about the stratotype of the Piacenzian Stage.

Moreover, this stratotype offers excellent possibilities for biostratigraphy with various groups of marine fossils.

VI.2.5. INTERRELATION OF UPPER NEOGENE STAGES.

On account of their lithostratigraphic field interrelations as well as of their planktonic and benthonic foraminiferal faunae, the stratotypes of the Tortonian, Tabianian and Piacenzian Stages can be placed in an approximate relative position. There is no controversy that the stratigraphical position of the Tabianian stratotype should be somewhere above the Tortonian, but the very details of the succession are unclear.

Below the Tabianian and over the Tortonian stratotype, strata are present that testify of aberrant salinity, commonly attributed to the "crise de salinité", the event that is expressed in geochronology by the Messinian Age. In Mediterranean biostratigraphy this event ought to be expressed as a hiatus. Between the planktonic foraminiferal faunae of the Tortonian and of the Tabianian there is a marked change; it is not possible to decide whether or not this indicates a biostratigraphical hiatus. MEULENKAMP (1969) concludes that in the *Uvigerina* development the hiatus between the Tortonian (in the sense of GIANOTTI) and Tabianian stratotypes is very small compared to the morphological change occurring in earlier stages; the necessity of a separate stage for this hiatus is doubted by this author. Moreover, in the Cretan Neogene, marine sedimentation locally continued during the "Messinian" interval, which throws grave doubts on the assumption of an ubiquitous and synchronous "crise de salinité" in the entire Mediterranean area.

VI.3. Biostratigraphical relations of the Andalusian to the Neogene stratotypes in Italy

In arguing the introduction of the Andalusian Stage as a substitute for the Messinian Stage, PERCONIG claims that of the three units recognized by him in the section at Carmona, the lowermost can be correlated with the Tortonian stratotype and the uppermost with "Lower Pliocene" strata; it thus follows that the central unit can be correlated to Italian sections of Messinian Age.

To support his argumentation, PERCONIG quotes data from some of the recent publications on Neogene stratigraphy of the Mediterranean area, using foraminifera as the main stratigraphic tool. Unfortunately very few of these publications give any reasonably useful information at all. Only papers by CITA, PREMOLI SILVA & ROSSI (1965) on the Tortonian stratotype and by D'ONOFRIO (1964) on the Messinian neostratotype contain pertinent data. Nevertheless, PERCONIG uses published data about other sections in order to have a larger number of species names designated by others to the Tortonian and Messinian Stages. This would have been a correct procedure if the primary relation of these sections with the stratotypes of stages on the basis of stratigraphical and paleontological data would have been beyond reproach. However, this cannot be claimed for all the publications mentioned. When critically perusing the literature he quoted in support, one cannot fail to notice that in some papers the faunal data are scanty and poorly documented, see DECIMA (1962), IACCARINO (1963), BARBIERI & PETRUCCI (1963), LAZZAROTTO, MAZZANTI & SALVATORINI (1964), and VEZZANI (1966); in other publications, e.g. PERCONIG (1955), MISTRETTA (1962) and PEZZANI (1963) the age of the sediments is a priori stated without mentioning the means of correlation. CRESCENTI (1966), while nicely illustrating his fauna, is unclear as to the stratigraphic position of his samples. In the Agip atlas (1957) the stratigraphical background is not documented.

PERCONIG compares each section from the Italian Neogene with the unit in the Carmona section of supposedly the same age. The number of planktonic foraminiferal species occurring in the sections in Italy as well as in the unit of the Carmona section is counted. Based on the number of planktonic species in the Carmona unit, the number of common species is expressed as a percentage. The results of these counts and computations are used to compare the degree of similarity of the various sections in Italy to the units in the Carmona section.

Some serious objections can be made against this biostratigraphical technique. It leads to the wilful suppression of specific information considered essential in the application of planktonic foraminifera in biostratigraphy. Moreover, the number of planktonic foraminiferal species is next to useless as a stratigraphic tool, as the very typological species concept may lead to considerable differences in the number of recognized species, even between two authors working on the same material. On the other hand, the identity of a large part of the planktonic foraminiferal fauna is of no consequence if a few characteristic species are present in one unit and lacking in the other.

The correlations suggested by PERCONIG are considered unproved because of the inadequacies in the correlating techniques. His data about the distribution of planktonic foraminifera in the Carmona section, however, are well suited for a comparison with the planktonic foraminiferal faunae from the Neogene stratotypes in Italy. Moreover, they are nearly the same as those mentioned in this paper for the same section and some exposures in its vicinity. Any seeming incompatibility is almost wholly due to slightly different species concepts of the respective authors. The planktonic associations of the Andalusian have to be correlated to those of the Tabianian and Piacenzian stratotypes. There is no reason to correlate the lowermost part of the Carmona section to the Tortonian stratotype, as was suggested by PERCONIG for the "Marne azzurre".

VI.4. Conclusions

The existence of a correlation of the strata below the Andalusian stratotype to the Tortonian stratotype and of those over the Andalusian stratotype to the "Lower Pliocene" - thereby placing the Andalusian Stage in the supposed or real interval between the Tortonian and "Lower Pliocene" - cannot be proved.

Because of its planktonic foraminifera and of its Uvigerinids from the stratotype, the Andalusian Stage should be considered partly equivalent to the Tabianian, partly to the Piacenzian Stage. Hence, the Andalusian cannot be used as a substitute of the Messinian, meant in the recent literature to be the topmost Miocene stage.

Chapter VII

FAUNAL REFERENCE LIST
(References to illustrations in this paper between brackets)

VII.1. Benthonic foraminifera

Dorothia brevis CUSHMAN & STAINFORTH 1945, Cushm. Lab. For. Res., Spec. Publ.; 14, p. 18, pl. 2, 5. (plate 3, fig. 1).
Martinottiella communis (D'ORBIGNY) = *Clavulina communis* D'ORBIGNY 1846, For. Foss. Vienne; p. 196, pl. 12, 1-2 (plate 3, fig. 10).
Eggerella bradyi (CUSHMAN) = *Verneuilina pygmaea* (EGGER), BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 385, pl. 47, 4-5.
Vulvulina pennatula (BATSCH) = *Bigenerina capreolus* (D'ORBIGNY), BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 372, pl. 45, 1-4.
Pyrgo bulloides (D'ORBIGNY), KAASSCHIETER 1961, Kon. Belg. Inst. Natw., Verh.; 147, p. 167, pl. 5, 18.
Pyrgo depressa (D'ORBIGNY), CUSHMAN 1929, U.S. Nat. Mus., Bull.; 104, p. 71, pl. 19, 4-5 (plate 3, fig. 2).
Sigmoilopsis schlumbergeri (SILVESTRI) = *Sigmoilina schlumbergeri* SILVESTRI 1904, Mem. Pont. Acc. N. Lincei; 22, p. 267. (plate 3, fig. 3).
Quinqueloculina seminula (LINNAEUS), CUSHMAN 1945, Cushm. Lab. For. Res., Spec. Publ.; 13, p. 17, pl. 2, 16.
Nodosaria longiscata D'ORBIGNY 1846, For. Foss. Vienne; p. 32, pl. 1, 10-12.
Nodosaria catenulata BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 515, pl. 63, 32-33. (plate 3, fig. 11).
Nodosaria hispida D'ORBIGNY 1846, For. Foss. Vienne; p. 35, pl. 1, 24-25 (plate 3, fig. 4).
Lenticulina (L) orbicularis (D'ORBIGNY) = *Cristellaria orbicularis* (D'ORBIGNY), BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 549, pl. 69, 17 (plate 4, fig. 3).
Lenticulina (L) calcar (LINNAEUS) = *Cristellaria calcar* (LINNAEUS), BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 551, pl. 70, 9-12. (plate 4, fig. 2).
Lenticulina (L) cultrata (MONTFORT) = *Robulina cultrata* (MONTFORT), D'ORBIGNY 1846, For. Foss. Vienne; p. 96, pl. 4, 10-13.
Lenticulina (L) peregrina (SCHWAGER) = *Cristellaria peregrina* SCHWAGER 1866, Novara Exp.; 2, p. 245, pl. 7, 89 (plate 4, fig. 1).
Lenticulina (L) convergens (BORNEMANN) = *Cristellaria convergens* BORNEMANN 1855, Zeitschr. Deut. Geol. Ges.; 7, p. 327, pl. 13, 16-17 (plate 4, fig 4).
Lenticulina (L) cf. *Lenticulina costata* (D'ORBIGNY) = *Lenticulina* sp. cf. *L.*

costata (D'ORBIGNY), KAASSCHIETER 1961, Kon. Belg. Inst. Natw., Verh.; 147, p. 172, pl. 7, 3 (plate 4, fig. 5).

Lenticulina (Saracenaria) italica (DEFRANCE) = *Saracenaria italica* DEFRANCE 1824, Dict. Sci. Nat.; 32, p. 176; Atlas Conch., pl. 13, 6 (plate 4, fig. 6).

Lenticulina (Vaginulinopsis) decorata (REUSS) = *Cristellaria decorata* REUSS 1855, Zeitschr. Deut. Geol. Ges.; 7, p. 269, pl. 8, 16; pl. 9, 1-2.

Amphicoryna scalaris (BATSCH) = *Nodosaria scalaris* (BATSCH), BUCHNER 1940, Nova Acta Leopoldina; 9, 62, p. 404, pl. 1, 11-15.

Chrysalogonium obliquatum (BATSCH) = *Nodosaria obliquata* (BATSCH), CUSHMAN 1931, Cushm. Lab. For. Res., Contr.; 7, p. 65, pl. 8, 15-19. (plate 3, fig. 12).

Chrysalogonium lanceolum CUSHMAN & JARVIS 1934, Cushm. Lab. For. Res., Contr.; 10, p. 75, pl. 10, 16 (plate 3, fig 15).

Chrysalogonium cf. *Chrysalogonium lamellatum* BERMUDEZ = *Chrysalogonium lamellatum* BERMUDEZ 1949, Cushm. Lab. For. Res., Spec. Publ.; 25, p. 150, pl. 10, 4.

Chrysalogonium globiferum (BATSCH) = *Nodosaria globifera* (BATSCH), CUSHMAN 1931, Cushm. Lab. For. Res., Contr.; 7, p. 68, pl. 9, 1-4 (plate 3, fig. 14).

Chrysalogonium sp. Possibly a microspheric form of *Chrysalogonium obliquatum* (BATSCH) (plate 3, fig. 13).

Marginulina costata (BATSCH), CUSHMAN 1931, Cushm. Lab. For. Res., Contr.; 7, p. 64, pl. 8, 2-5 (plate 3, fig. 6).

Marginulina hirsuta D'ORBIGNY 1846, For. Foss. Vienne; p. 69, pl. 3, 17-18 (plate 3, fig. 5).

Dentalina inornata D'ORBIGNY *bradyensis* (DERVIEUX) = *Nodosaria inornata* (D'ORBIGNY) var. *bradyensis* DERVIEUX 1894, Boll. Soc. Geol. It.; 12, p. 610, pl. 5, fig. 30-31 (plate 3, fig. 16).

Lagena acuticosta REUSS 1862, Kon. Akad. Wiss., Wien, Math.-Natw. Cl.; 44, 1, p. 305, pl. 1,4.

Lagena sulcata (WALKER & JACOB) var. *laevigata* CUSHMAN & GRAY 1946, Cushm. Lab. For. Res., Contr.; 22, p. 68, pl. 12, 13-14 (plate 3, fig. 9).

Glandulina laevigata D'ORBIGNY 1846, For. Foss. Vienne; p. 29, pl. 1, 4-5.

Guttulina problema D'ORBIGNY 1846, For. Foss. Vienne; p. 224, pl. 12, 26-28.

Bulimina aculeata D'ORBIGNY, CUSHMAN & TODD 1945, Cushm. Lab. For. Res., Spec. Publ.; 15, p. 39, pl. 6, 11 (plate 4, fig. 17).

Bulimina striata D'ORBIGNY, CUSHMAN & PARKER 1938, Cushm. Lab. For. Res., Contr.; 14, p. 90, pl. 16, 1-3. (plate 4, fig. 15).

Bulimina ovata D'ORBIGNY 1846. For. Foss. Vienne; p. 185, pl. 11, 13-14 (plate 5, fig. 1).

Bulimina acanthia COSTA 1856, Atti Acc. Pont.; 7, 2, p. 335, pl. 13, 35-36 (plate 4, fig. 18).
Bulimina costata D'ORBIGNY, CUSHMAN 1947, U.S. Geol. Surv., Prof. Paper; 210 D, p. 115, pl. 27, 2-3.
Globobulimina pacifica CUSHMAN 1927, Cushm. Lab. For. Res., Contr.; 3, p. 67, pl. 14, 12 (plate 4, fig. 14).
Bolivina antiqua D'ORBIGNY 1846, For. Foss. Vienne; p. 240, pl. 14, 11-13. (plate 4, fig. 8).
Bolivina alata (SEGUENZA) = *Vulvulina alata* SEGUENZA 1862, Atti Acc. Gioenia Sci. Nat. (2); 18, p. 115, pl. 2, 5 (plate 4, fig 10).
Bolivina dilatata REUSS 1850, Denkschr. Kon. Akad. Wiss., Wien; 1, p. 381, pl. 48, 15 (plate 4, fig. 12).
Bolivina dohmi BERMUDEZ 1949, Cushm. Lab. For. Res., Spec. Publ.; 25, p. 189, pl. 12, 28.
Bolivina byramensis CUSHMAN & TODD 1945, Cushm. Lab. For. Res., Spec. Publ.; 15, p. 47, pl. 7, 20 (plate 4, fig. 9).
Bolivina cf. *Bolivina byramensis* CUSHMAN & TODD 1945, Cushm. Lab. For. Res., Spec. Publ.; 15, p. 47, pl. 7, 20 (plate 4, fig. 13).
Bolivina cf. *Bolivina robusta* BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 421, pl. 53, 7-9 (plate 4, fig. 16).
Bolivina cf. *Bolivina midwayensis* CUSHMAN 1936, Cushm. Lab. For. Res., Spec. Publ.; 6, p. 50, pl. 7, 12 (plate 4, fig. 7).
Bolivina cf. *Bolivina jacksonensis* CUSHMAN & APPLIN 1926, Bull. A.A.P.G.; 10, p. 167, pl. 7, 3-4 (plate 4, fig. 11).
Uvigerina hispido-costata CUSHMAN & Todd 1945, Cushm. Lab. For. Res., Spec. Publ.; 15, p. 51, pl. 7; 27, 31.
Uvigerina rustica CUSHMAN & EDWARDS 1938, Cushm. Lab. For. Res., Contr.; 14, p. 83, pl. 14, 6 (plate 5, fig. 4).
Uvigerina canariensis D'ORBIGNY 1839, Foram. iles Canaries; p. 138, pl. 1, 25-27.
Uvigerina rutila CUSHMAN & TODD 1941, Cushm. Lab. For. Res., Contr.; 17, p. 78, pl. 20, 16-22 (plate 5, fig. 2).
Uvigerina arquatensis PAPP, MEULENKAMP 1969, Utrecht Micropal. Bull.; 2, p. 143, pl. 16, 12-15, 19 = *Uvigerina gaudryinoides* LIPPARINI *arquatensis* PAPP, PAPP 1963, Mitt. Geol. Ges., Wien; 56, p. 253, pl. 6, 11-13.
Hopkinsina bononiensis (FORNASINI) 1888, Boll. Soc. Geol. It.; 7, 1, p. 48, pl. 3, 12 (plate 5, fig. 3).
Stilostomella subspinosa (CUSHMAN) = *Ellipsonodosaria subspinosa* CUSHMAN 1943, Cushm. Lab. For. Res., Contr.; 19, p. 92, pl. 16, 6-7.
Stilostomella advena (CUSHMAN & LAIMING) = *Nodogenerina advena* CUSHMAN & LAIMING 1931, Journ. Paleont.; 5, p. 106, pl. 11, 19.

Stilostomella gracilis (PALMER & BERMUDEZ) = *Ellipsonodosaria gracilis* PALMER & BERMUDEZ 1936, Mem. Soc. Cub. Hist. Nat.; 10, p. 296, pl. 18, 8-9 (plate 3, fig. 8).
Stilostomella nuttalli (CUSHMAN & JARVIS) = *Ellipsonodosaria nuttalli* CUSHMAN & JARVIS 1934, Cushm. Lab. For. Res., Contr.; 10, p. 72, pl. 10, 6.
Stilostomella cf. *Stilostomella paucistriata* (GALLOWAY & MORREY) = *Nodosarella paucistriata* GALLOWAY & MORREY 1929, Bull. Amer. Pal.; 15, p. 42, pl. 6, 12.
Stilostomella challengeriana (THALMANN) = *Nodosaria perversa* (SCHWAGER), BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 512, pl. 64, 26 (plate 3, fig 7).
Trifarina bradyi CUSHMAN 1923, U.S. Nat. Mus., Bull.; 104, 4, p. 99, pl. 22, 3-9.
Trifarina carinata CUSHMAN = *Angulogerina carinata* CUSHMAN var. *bradyana* CUSHMAN 1932, Cushm. Lab. For. Res., Contr.; 8, p. 45, pl. 6, 9-10 (plate 5, fig. 6).
Reussella spinulosa (REUSS) = *Verneuilina spinulosa* REUSS 1850, Denkschr. Kon. Akad. Wiss., Wien; 1, p. 374, pl. 47, 12.
Oolina longispina (BRADY) = *Lagena longispina* BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 454, pl. 56, 36.
Oolina apiculata REUSS 1851, Natw. Abh., Wien; 4, p. 22, pl. 2, 1.
Fissurina submarginata (BOOMGAART) = *Entosolenia submarginata* BOOMGAART 1949, Smaller For. Bodjonegoro (Java). Thesis, Utrecht, p. 107, pl. 9, 7.
Plectofrondicularia semicosta (KARRER) = *Frondicularia semicosta* KARRER 1877, Geol. Reichsanst., Abh., Wien; 9, p. 380, pl. 16b, 26 (plate 5, fig. 7).
Virgulina schreibersiana CZJZEK 1848, Natw. Abh., Wien; 2, p. 147, pl. 13, 18-21 (plate 5, fig. 5).
Sphaeroidina bulloides D'ORBIGNY, BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 620, pl. 84, 12-16 (plate 5, fig. 15).
Cassidulina crassa D'ORBIGNY 1846, For. Foss. Vienne; p. 213, pl. 21, 42-43 (plate 5, fig. 10).
Cassidulina laevigata D'ORBIGNY, BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 428, pl. 54, 1-3 (plate 5, fig. 8).
Cassidulina cf. *Cassidulina leavigata* D'ORBIGNY, SAAVEDRA 1961, Bol. Inst. Geol. Min. Esp.; 72, pl. 7, 4, 37 (plate 5, fig. 9).
Cassidulina subglobosa BRADY 1884, Rep. Voy. Challenger, Zool.; 9 p. 430, pl. 54, 17 (plate 5, fig. 12).
Cassidulina subglobosa BRADY *horizontalis* CUSHMAN & RENZ 1941, Cushm. Lab. For. Res., Contr.; 17, p. 26, pl. 4, 8 (plate 5, fig. 11).
Nonion pompilioides (FICHTEL & MOLL), BATJES 1958, Kon. Belg. Inst. Natw., Verh.; 143, p. 141, pl. 6, 14.

Nonion boueanum (D'ORBIGNY) = *Nonionina boueana* D'ORBIGNY 1846, For. Foss. Vienne; p. 108, pl. 5, 11-12 (plate 5, fig. 14).
Nonion tuberculatum (D'ORBIGNY) = *Nonionina tuberculata* D'ORBIGNY 1846, For. Foss. Vienne; p. 108, pl. 5, 13-14.
Astrononion italicum CUSHMAN & EDWARDS 1937, Cushm. Lab. For. Res., Contr.; 13, p. 35, pl. 3, 19-20 (plate 5, fig. 13).
Pullenia bulloides (D'ORBIGNY) = *Nonionina bulloides* D'ORBIGNY 1846, For. Foss. Vienne; p. 107, pl. 5, 9-10.
Pullenia subcarinata (D'ORBIGNY) = *Nonionina subcarinata* D'ORBIGNY 1839, Voy. Amer. Merid.; 5, p. 28, pl. 5, 23-24.
Cibicides ungerianus (D'ORBIGNY) = *Rotalina ungeriana* D'ORBIGNY 1846, For. Foss. Vienne; p. 157, pl. 8, 16-18 (plate 6, fig. 1).
Cibicides dutemplei (D'ORBIGNY) *praecinctus* (KARRER), KAASSCHIETER 1955, Kon. Ned. Akad. Wet., Nat. (1); 21, 2, p. 94, pl. 11, 3. (plate 6, fig. 4, 5).
Cibicides pseudoungerianus (CUSHMAN) = *Truncatulina pseudoungeriana* CUSHMAN 1922, U.S. Geol. Surv., Prof. Paper; 129E, p. 97, pl. 20, 9. (plate 6, fig. 3).
Hanzawaia producta (TERQUEM) = *Truncatulina producta* TERQUEM 1882, Mem. Soc. Geol. France, (3); 2, p. 92, pl. 9, 20-21 (plate 6, fig. 2).
Gyroidina soldanii (D'ORBIGNY) = *Rotalina soldanii* D'ORBIGNY 1846, For. Foss. Vienne; p. 155, pl. 8, 10-12 (plate 5, fig. 18).
Gyroidina parva CUSHMAN & RENZ 1941, Cushm. Lab. For. Res., Contr.; 17, p. 23, pl. 4, 2 (plate 5, fig. 17).
Laticarinina pauperata (PARKER & JONES) = *Pulvinulina repanda* FICHTEL & MOLL var. *menardii* D'ORBIGNY subvar. *pauperata* PARKER & JONES 1865, Phil. Trans., London; 155, p. 395, pl. 16, 50-51 (plate 5, fig. 16).
Rosalina globularis D'ORBIGNY 1826, Ann. Sci. Nat., Paris; 1, 7, p. 271, pl. 13, 1-4.
Cancris auriculus (FICHTEL & MOLL), CUSHMAN & TODD 1942, Cushm. Lab. For. Res., Contr.; 18, p. 74, pl. 18, 5 (plate 7, fig. 2).
Planulina ariminensis D'ORBIGNY 1826, Ann. Sci. Nat., Paris, (1); 7, p. 280, pl. 14, 1-3 (plate 7, fig. 1).
Planulina marialana HADLEY 1934, Bull. Amer. Pal.; 20, p. 27, pl. 4, 4-6 (plate 6, fig. 6).
Siphonina planoconvexa (SILVESTRI) = *Truncatulina reticulata* (CZJZEK) var. *planoconvexa* SILVESTRI 1898, Acc. Pont. N. Lincei, Mem.; 15, p. 300, pl. 11, 12 (plate 7, fig. 6).
Valvulineria araucana (D'ORBIGNY) *malagaensis* KLEINPELL 1938, Mioc. Strat. California; p. 308, pl. 22, 10-12 (plate 7, fig. 10).
Eponides umbonatus (REUSS) = *Rotalia umbonata* REUSS 1851, Zeitschr. Deut. Geol. Ges.; 3, p. 75, pl. 5, 35.

Epistomina elegans (D'ORBIGNY), MARKS 1951, Cushm. Found, For. Res., Contr.; 2, p. 65 (plate 7, fig. 3).
Pleurostomella alternans SCHWAGER 1866, Novara exp., Geol.; 2, p. 238, pl. 6, 79-80.
Pleurostomella brevis SCHWAGER 1866, Novara Exp., Geol.; 2, p. 239, pl. 6, 81 (plate 7, fig. 4).
Asterigerina planorbis D'ORBIGNY 1846, For. Foss. Vienne; p. 205, pl. 11, 1-3 (plate 7, fig. 11).
Elphidium fichtellianum (D'ORBIGNY) = *Polystomella fichtelliana* D'ORBIGNY 1846, For. Foss. Vienne; p. 125, pl. 6, 7-8 (plate 7, fig. 9).
Elphidium crispum (LINNAEUS), CUSHMAN 1939, U.S. Geol. Surv., Prof. Paper; 191, p. 50, pl. 13, 19-21 (plate 7, fig. 7).
Elphidium subumbilicatum (CZJZEK) = *Polystomella subumbilicata* CZJZEK 1848, Natw. Abh., Wien; 2, p. 143, pl. 12, 32-33.
Elphidium excavatum (TERQUEM) CUSHMAN 1939, U.S. Geol. Surv., Prof. Paper; 191, p. 58, pl. 16, 7-12 (plate 7, fig. 8).
Ammonia beccarii (LINNAEUS) = *Nautilus beccarii* LINNAEUS 1758, Syst. Nat.; 10, p. 710, pl. 1, 1 (plate 7, fig. 13).
Planorbulina mediterranensis D'ORBIGNY 1846, For. Foss. Vienne; p. 166, pl. 9, 15-17 (plate 7, fig. 5).

VII.2. **Planktonic foraminifera**

Candeina nitida D'ORBIGNY 1839, Hist. Phys. Nat. Cuba; p. 108, vol. 8, pl. 2, 27-28.
Globigerapsis kugleri, BOLLI, LOEBLICH & TAPPAN 1957, U.S. Nat. Mus., Bull.; 215, p. 34, pl. 6, 6 (plate 9, fig. 5).
Globigerapsis cf. *Globigerapsis kugleri* BOLLI, LOEBLICH & TAPPAN var. I.
These specimens are similar to *Globigerapsis kugleri* in all respects, except that the last-formed chamber does not cover the entire umbilicus.
Globigerapsis cf. *Globigerapsis kugleri* BOLLI, LOEBLICH & TAPPAN var. II.
In these specimens the last-formed chamber does not extend over the umbilicus. A small bulla is present over the umbilicus provided with two or three rather large, arched accessory apertures, which are situated over the intercameral sutures.
Globigerina apertura CUSHMAN 1918, U.S. Geol. Surv., Bull.; 676, p. 57, pl. 12, 8.
Globigerina angustiumbilicata BOLLI = *Globigerina ciperoensis angustiumbilicata* BOLLI 1957, U.S. Nat. Mus., Bull.; 215, p. 109, pl. 22, 12-13.
Globigerina boweri BOLLI 1957, U.S. Nat. Mus., Bull.; 215, p. 163, pl. 36, 1.

Globigerina bulloides D'ORBIGNY, BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 593, pl. 79, 7 (plate 7, fig. 12).
Globigerina druryi AKERS 1955, Journ. Paleont.; 29, p. 654, pl. 65, 1.
Globigerina falconensis BLOW 1959, Bull. Amer. Pal.; 178, p. 177, pl. 9, 40-41.
Globigerina glutinata EGGER = *Globigerinita glutinata* (EGGER), PARKER 1962, Micropaleontology; 8, p. 246, pl. 9, 1-16.
Globigerina nepenthes TODD 1957, U.S. Geol. Surv., Prof. Paper; 280 H, p. 301, pl. 78, 7.
Globigerina praebulloides leroyi BLOW & BANNER 1962, Fund. Mid- Tert. Strat. Corr.; p. 93, pl. 9, R-T (plate 7, fig 15).
Globigerina praebulloides praebulloides BLOW & BANNER 1962, Fund. Mid-Tert. Strat. Corr.; p. 92, pl. 9, O-Q (plate 7, fig. 14).
Globigerina yeguaensis WEINZIERL & APPLIN *pseudovenezuelana* BLOW & BANNER = *Globigerina yeguaensis pseudovenezuelana* BLOW & BANNER 1962, Fund. Mid-Tert. Strat. Corr.; p. 100, pl. 11, N, O.
Globigerinita dissimilis (CUSHMAN & BERMUDEZ) = *Globigerina dissimilis* CUSHMAN & BERMUDEZ 1937, Cushm. Lab. For. Res., Contr.; 13, p. 25, pl. 3, 4-6.
Globigerinita stainforthi (BOLLI, LOEBLICH & TAPPAN) = *Catapsydrax stainforthi* BOLLI, LOEBLICH & TAPPAN 1957, U.S. Nat. Mus., Bull.; 215, p. 37, pl. 7, 11.
Globigerinoides sicanus DE STEFANI = *Globigerinoides bispherica* TODD 1954, Amer. Jour. Sci.; 252, p. 681, pl. 1, 1.
Globigerinoides glomerosus BLOW 1956, Micropaleontology; 2, p. 64, textfig. 1, 9-19; textfig. 2, 1-4; textfig. 3, stage 3-5.
Globigerinoides obliquus BOLLI *extremus* BOLLI & BERMUDEZ = *Globigerinoides obliquus extremus* BOLLI & BERMUDEZ 1965, Bol. Inform. Asoc. Venez. Geol. Min. Petr.; 8, p. 139. pl. 1, 10-12.
Globigerinoides obliquus obliquus BOLLI = *Globigerinoides obliqua* BOLLI 1957, U.S. Nat. Mus., Bull.; 215, p. 113, pl. 25, 9-10.
Globigerinoides trilobus (REUSS) *altiaperturus* BOLLI = *Globigerinoides triloba altiapertura* BOLLI 1957, U.S. Nat. Mus., Bull.; 215, p. 113, pl. 25, 7-8.
Globigerinoides trilobus (REUSS) *immaturus* LEROY = *Globigerinoides sacculiferus* (BRADY) var. *immatura* LEROY 1939, Natuurk. Tijdschr. Ned. Indië; 99, p. 263, pl. 3, 19-21.
Globigerinoides trilobus trilobus (REUSS) = *Globigerina triloba* REUSS 1850, Denkschr. Kon. Akad. Wiss., Wien, Math. Natw. Cl.; 1, p. 374, pl. 47, 11.
Globigerinoides trilobus sacculiferus (BRADY) = *Globigerina sacculifera* BRADY 1877, Geol. Mag., London, n.s., decade 2, 4, 12, p. 535 = *Globigerina sacculifera* BRADY, BRADY 1884, Rep. Voy. Challenger, Zool.; 9, p. 604, pl. 80, 11-17; pl. 82, 4.

Globorotalia acostaensis BLOW 1959, Bull. Amer. Pal.; 178, p. 208, pl. 17, 106-107 (plate 9, fig. 1).
Globorotalia aequa CUSHMAN & RENZ = *Globorotalia crassata* (CUSHMAN) var. *aequa* CUSHMAN & RENZ 1942, Cushm. Lab. For. Res., Contr.; 18, p 12, pl. 3, 3.
Globorotalia archeomenardii BOLLI 1957, U.S. Nat. Mus., Bull.; 215, p. 119, pl. 28, 11.
Globorotalia crassaformis (GALLOWAY & WISSLER) = *Globigerina crassaformis* GALLOWAY & WISSLER 1927, Journ. Paleont., 1, p. 41, pl. 7, 12.
Globorotalia crotonensis CONATO & FOLLADOR 1967, Boll. Soc. Geol. It.; 86, p. 556, textfig. 1; textfig. 4, 1-2 = *Globorotalia hirsuta* CUSHMAN (non D'ORBIGNY) *aemiliana* COLALONGO & SARTONI 1967, Giorn. Geol., Bologna (2); 34, p. 3, textfig. 2, pl. 30, 2, 5; pl. 31, 4 (plate 9, fig 3).
CONATO & FOLLADOR have rightly mentioned that the material figured by COLALONGO & SARTONI is far from homogeneous. They attributed the low-spired specimens, which were included by the latter authors in *Globorotalia hirsuta aemiliana,* to their new species *Globorotalia crotonensis.* The introduction of a new name *Globorotalia crassacrotonensis* for the remaining high-spired specimens of *Globorotalia hirsuta aemiliana* is not necessary. Since CONATO & FOLLADOR included the holotype of *Globorotalia hirsuta aemiliana in* their species *Globorotalia crassacrotonensis,* they were simply reducing their new name to the status of a junior synonym. Topotype material of *Globorotalia miozea* FINLAY at my disposal suggests affinities of some specimens of FINLAY's species to *Globorotalia margaritae, Globorotalia crotonensis* and *Globorotalia hirsuta aemiliana.*
Globorotalia margaritae BOLLI & BERMUDEZ 1965, Bol. Inform. Venez. Geol. Min. Petr.; 8, p. 139, pl. 1, 16-18 = *Pulvinulina canariensis* BRADY (non D'ORBIGNY) 1884, Rep. Voy. Challenger, Zool., 9, p. 692, pl. 103, 8-9 (non 10) = *Globorotalia hirsuta* CUSHMAN (non D'ORBIGNY) 1931, U.S. Nat. Mus., Bull.; 104, 8, p. 99, pl. 7, 6 = *Globorotalia hirsuta* CUSHMAN (non D'ORBIGNY), CONATO & FOLLADOR 1967, Boll. Soc. Geol. It.; 86, p. 562, textfig. 6 = *Globorotalia hirsuta* CUSHMAN (non D'ORBIGNY), COLALONGO & SARTONI 1967, Giorn. Geol., Bologna (2); 34, p. 3, pl. 31, 5. (plate 9, fig. 4).
The attribution of the name "*canariensis*" to this species by BRADY (1884) is clearly a mistake. However, as the work of BRADY was much easier to consult than that of D'ORBIGNY, one has used that term in this sense extensively.
In 1931, CUSHMAN rightly focused attention on this mistake; his emendation, consisting of designating the name "*hirsuta*" to this species seems not correct, however, when we consult the original figure of D'ORBIGNY. The concept of *Globorotalia hirsuta* in CONATO & FOLLADOR and in COLALONGO & SARTONI is in agreement with CUSHMAN (1931). The same is supposed to be true for *G. hirsuta*

of some other authors (BARBIERI 1967, IACCARINO 1967, BARBIERI & PETRUCCI 1967).

Globorotalia mayeri CUSHMAN & ELLISOR 1939, Cushm. Lab. For. Res., Contr.; 15, p. 11, pl. 2, 4.

Globorotalia menardii menardii (D'ORBIGNY), BLOW 1959, Bull. Amer. Pal.; 178, p. 215, pl. 18, 119.

Globorotalia menardii (D'ORBIGNY) *archeomenardii* BOLLI = *Globorotalia archeomenardii* BOLLI 1957, U.S. Nat. Mus. Bull.; 215, p. 119, pl. 28, 11.

Globorotalia merotumida BLOW & BANNER 1965, Nature; 207, p. 1352, textfig. 1 (plate 8, fig 1-3).

Globorotalia obesa BOLLI 1957, U.S. Nat. Mus. Bull.; 215, p. 119, pl. 29, 2-3.

Globorotalia pseudobesa (SALVATORINI) = *Turborotalia pseudobesa* SALVATORINI 1966, Atti Soc. Tosc. Sc. Nat.; 73, (A), p. 10, pl. 2, 6-15. (plate 9, fig. 6).

Globorotalia scitula (BRADY) *praescitula* BLOW = *Globorotalia scitula praescitula* BLOW 1959, Bull. Amer. Pal.; 178, p. 221, pl. 19, 128.

Globorotalia scitula scitula (BRADY) = *Pulvinulina scitula* BRADY 1882, Roy. Soc. Edinburgh; 11, p. 716.

Globorotalia scitula (BRADY) *ventriosa* OGNIBEN = *Globorotalia scitula ventriosa* OGNIBEN 1958, Riv. Ital. Paleont.; 64, p. 246, pl. 15, 4-5 (plate 9, fig 2).

Globorotalia siakensis (LEROY) = *Globigerina siakensis* LEROY, LEROY 1944, Colorado School of Mines, Quart.; 39, 3, p. 39, pl. 6, 39-40.

Globorotalia tumida (BRADY) *plesiotumida* BLOW & BANNER = *Globorotalia (G.) tumida* (BRADY) *plesiotumida* BLOW & BANNER 1965, Nature; 207, p. 1353, textfig. 2 (plate 8, fig. 4-6).

Globorotalia peripheroronda BLOW & BANNER = *Globorotalia (Turborotalia) peripheroronda* BLOW & BANNER 1966, Micropaleontology; 12, p. 294, pl. 1, 1, pl. 2, 1-3 (plate 9, fig. 7).

Globorotalia postcretacea (MYATLIUK), BANNER & BLOW 1962, Fund. Mid-Tert. Strat. Corr.; p. 120, pl. 12, G-J.

Globoquadrina altispira (CUSHMAN & JARVIS) *globosa* BOLLI = *Globoquadrina altispira globosa* BOLLI 1957, U.S. Nat. Mus., Bull.; 215, p. 111, pl. 24, 9-10.

Globorotaloides suteri BOLLI 1957, U.S. Nat. Mus., Bull.; 215, p. 117, pl. 27, 9; 11.

Hantkenina dumblei WEINZIERL & APPLIN 1929, Journ. Paleont.; 3, p. 402, pl. 43, 5.

Orbulina universa D'ORBIGNY, BLOW 1956, Micropaleontology; 2, p. 66, textfig. 2, 8-9; textfig. 3, stage 7.

Sphaeroidinellopsis subdehiscens (BLOW) = *Sphaeroidinella dehiscens subdehiscens* BLOW 1959, Bull. Amer. Pal.; 178, p. 195, pl. 12, 71-72.

PLATE 1

1

0 5 10 cm

2

3

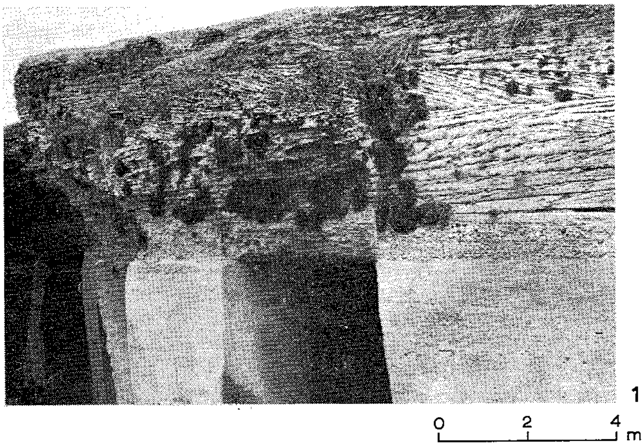
Plate 1

Fig. 1 Genil Formation, exposure 218.
Contorted set of cross strata.

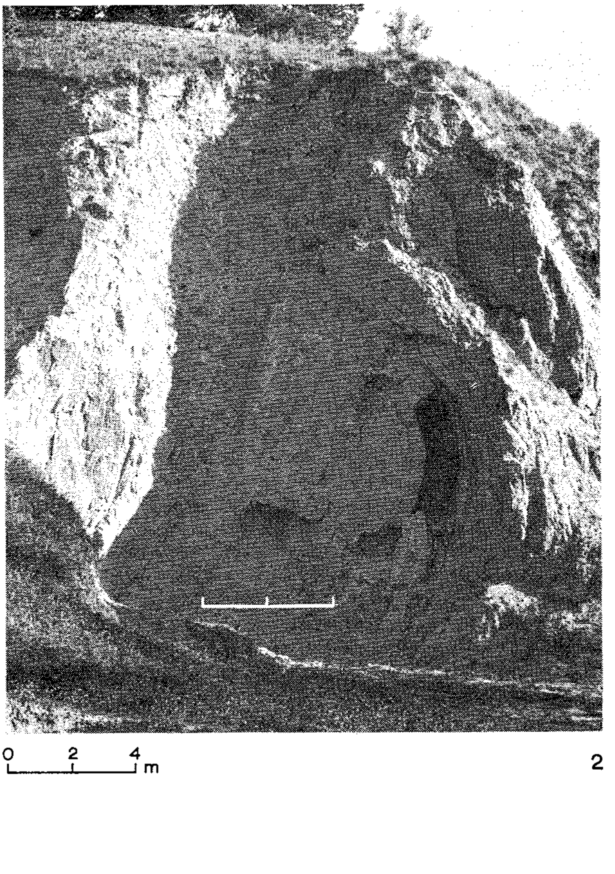
Fig. 2 Genil Formation, exposure 218.
A coset of cross strata in the lower part of a graded sandstone layer, disturbed by a small reverse fault. Diameter of lens hood 5 cm.

Fig. 3 Cuesta del Espino Formation, exposure 269.
Pebble arrangement in the Cuesta del Espino cliff; alternating layers of mainly coarse sand and mainly pebbles. Length of ruler 25 cm.

PLATE 2



1



2

Plate 2

Fig. 1 Canteras Formation, exposures 272.
Giant foresets dipping to the southwest (to the left and to the observer). Many of the sets of cross strata within the giant foresets dip in another direction than the giant foresets they from part of.

Fig. 2 Cuesta del Espino Formation, exposure 208.
Upturned and overturned clay layers in a steep valley side.

PLATE 3

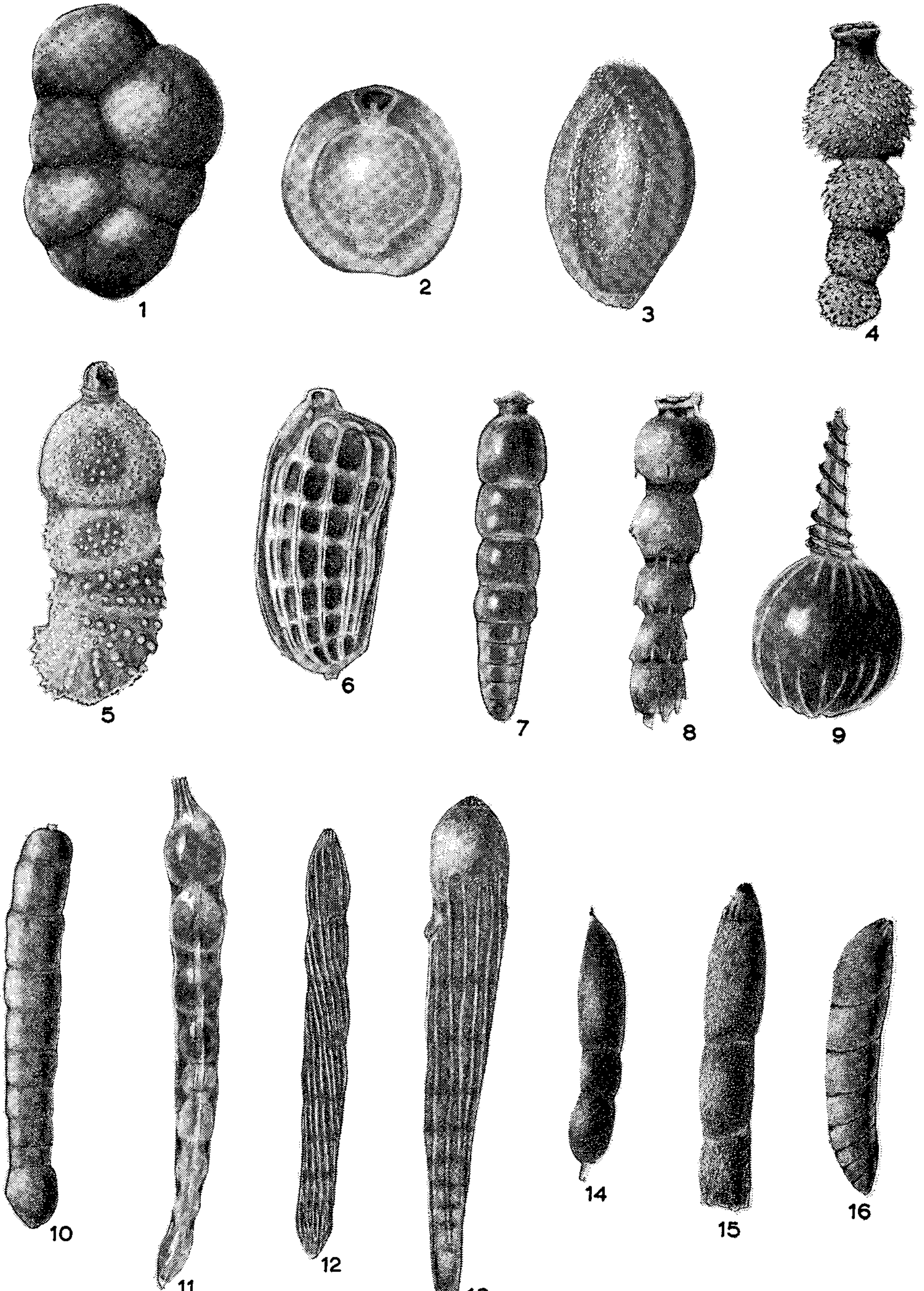


Plate 3

1. *Dorothia brevis* CUSHMAN & STAINFORTH, sample 275; x 70.
2. *Pyrgo depressa* D'ORBIGNY, sample 171; x 70.
3. *Sigmoilopsis schlumbergeri* (SILVESTRI), sample 71; x 50.
4. *Nodosaria hispida* D'ORBIGNY, sample 219 a; x 50.
5. *Marginulina hirsuta* D'ORBIGNY, sample 219 a; x 50.
6. *Marginulina costata* (BATSCH), sample 219 m; x 30.
7. *Stilostomella challengeriana* (THALMANN), sample 147; x 70.
8. *Stilostomella gracilis* (PALMER & BERMUDEZ), sample 163 a; x 70.
9. *Lagena sulcata* (WALKER & JACOB) *laevigata* CUSHMAN & GRAY, sample 147; x 50.
10. *Martinottiella communis* (D'ORBIGNY), sample 163 c; x 32.
11. *Nodosaria catenulata* BRADY, sample 219 a; x 50.
12. *Chrysalogonium obliquatum* (BATSCH), sample 71; x 16.
13. *Chrysalogonium* sp., sample 163 a; x 50.
14. *Chrysalogonium globigerum* (BATSCH), sample 163 c; x 70.
15. *Chrysalogonium lanceolum* CUSHMAN & JARVIS, sample 71; x 70.
16. *Dentalina inornata* D'ORBIGNY *bradyensis* (DERVIEUX), sample 117 a; x 50.

PLATE 4

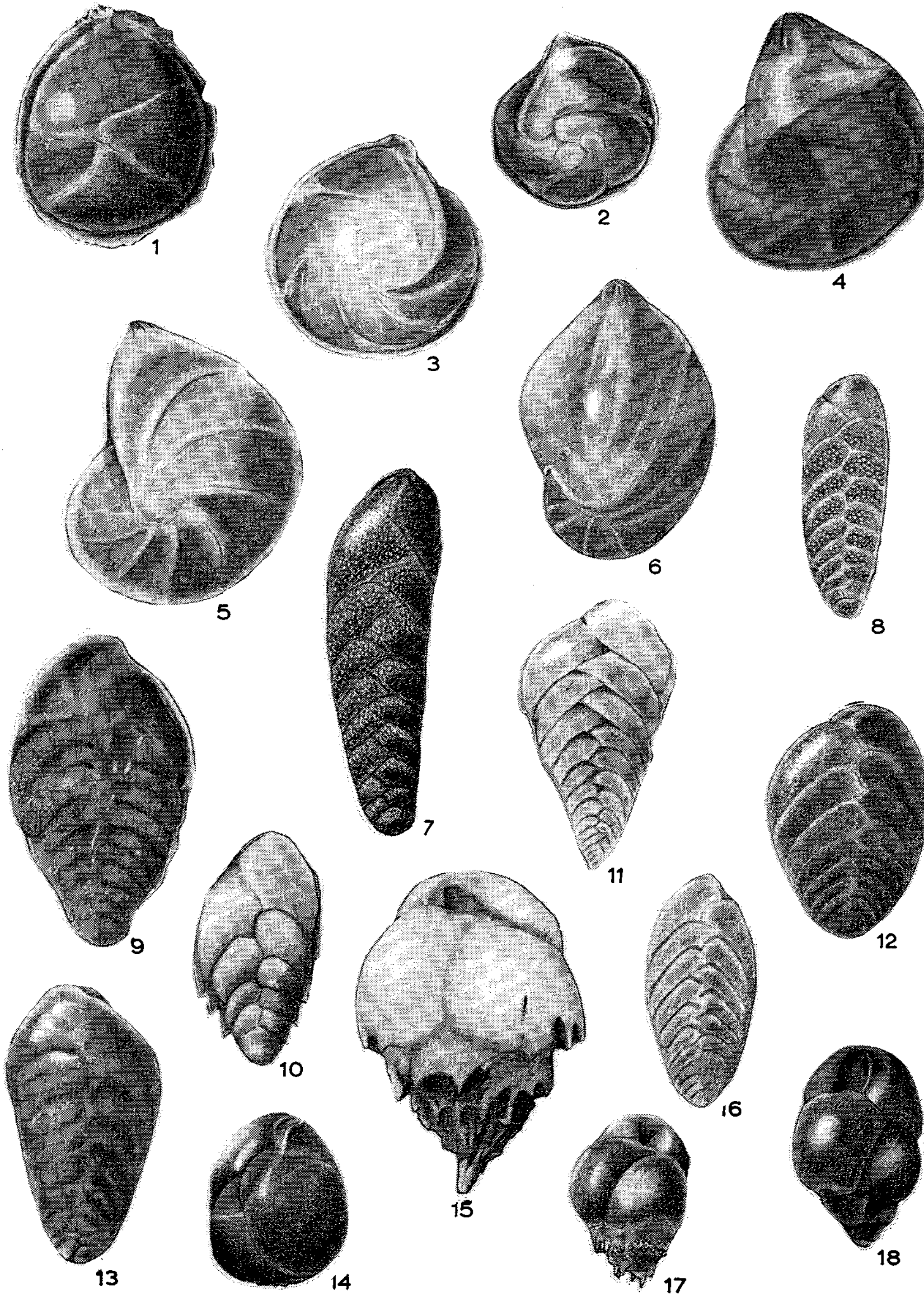


Plate 4

1. *Lenticulina (L) peregrina* (SCHWAGER), sample 219 a; x 70.
2. *Lenticulina (L) calcar* (LINNAEUS), sample 219 m; x 70.
3. *Lenticulina (L) orbicularis* (D'ORBIGNY), sample 219 a; x 70.
4. *Lenticulina (L) convergens* (BORNEMANN), sample 91 a; x 70.
5. *Lenticulina (L)* cf. *Lenticulina costata* (D'ORBIGNY), sample 219 a; x 70.
6. *Lenticulina (Saracenaria) italica* (DEFRANCE), sample 219 a; x 70.
7. *Bolivina* cf. *Bolivina midwayensis* CUSHMAN, sample 219 a; x 100.
8. *Bolivina antiqua* D'ORBIGNY, sample 219 k; x 70.
9. *Bolivina byramensis* CUSHMAN, sample 219 a; x 100.
10. *Bolivina alata* (SEGUENZA), sample 163 c; x 70.
11. *Bolivina* cf. *Bolivina jacksonensis* CUSHMAN & APPLIN, sample 71; x 100.
12. *Bolivina dilatata* REUSS, sample 219 a; x 100.
13. *Bolivina* cf. *Bolivina byramensis* CUSHMAN, sample 219 a; x 100.
14. *Globobulimina pacifica* CUSHMAN, sample 219 q; x 50.
15. *Bulimina striata* D'ORBIGNY, sample 91 a; x 100.
16. *Bolivina* cf. *Bolivina robusta* BRADY, sample 219 a; x 70.
17. *Bulimina aculeata* D'ORBIGNY, sample 219 a; x 70.
18. *Bulimina acanthia* COSTA, sample 269 c; x 100.

PLATE 5

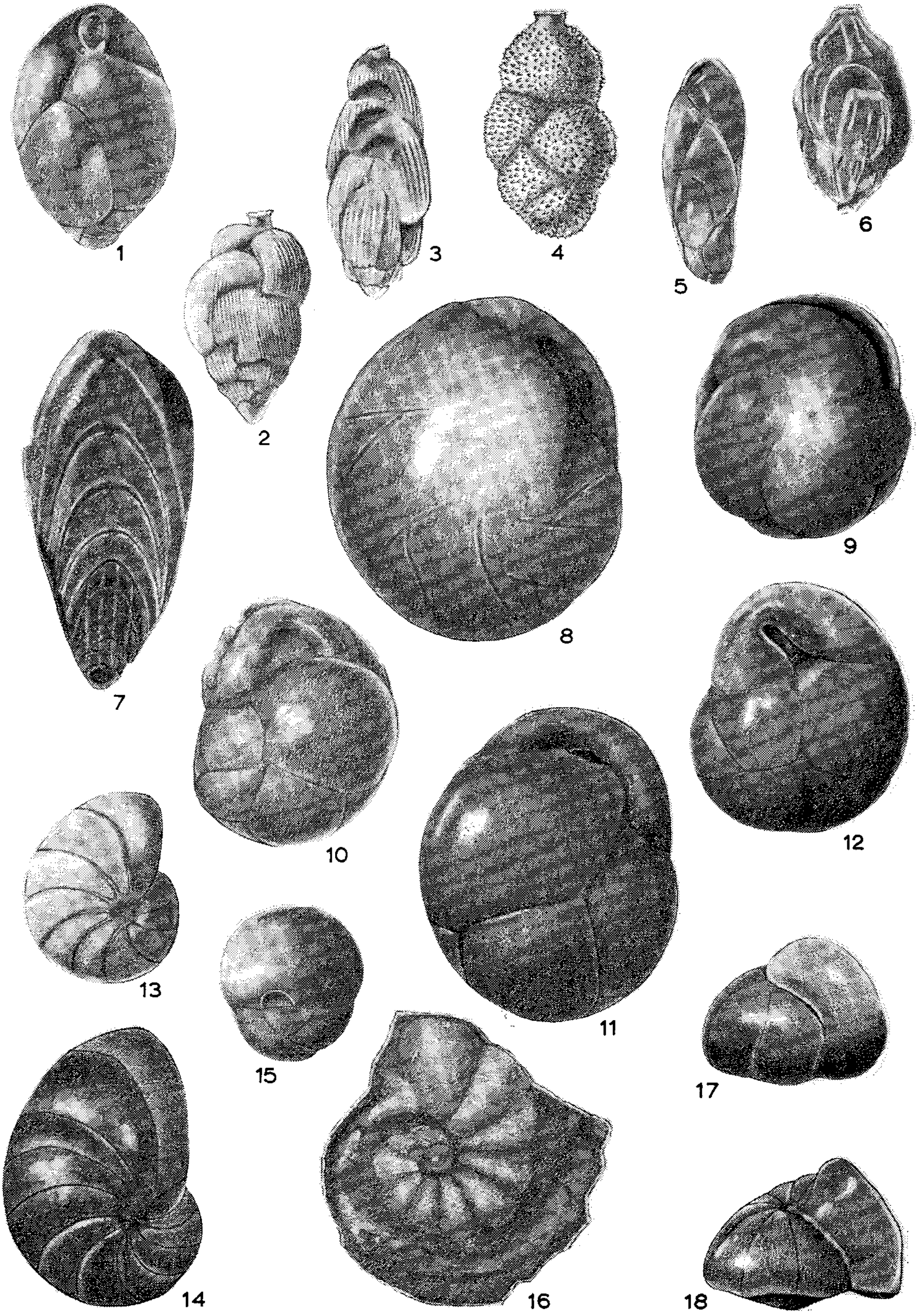


Plate 5

1. *Bulimina ovata* D'ORBIGNY, sample 219 a; x 100.
2. *Uvigerina rutila* CUSHMAN & TODD, sample 219 a; x 50.
3. *Hopkinsina bononiensis* (FORNASINI), sample 219 a; x 70.
4. *Uvigerina rustica* CUSHMAN & EDWARDS, sample 163 c; x 32.
5. *Virgulina schreibersiana* CZJZEK, sample 219 d; x 70.
6. *Trifarina carinata* CUSHMAN, sample 219 w; x 100.
7. *Plectofrondicularia semicosta* (KARRER), sample 219 a; x 100.
8. *Cassidulina laevigata* D'ORBIGNY, sample 219 a; x 100.
9. *Cassidulina* cf. *Cassidulina laevigata* D'ORBIGNY, sample 219 a; x 150.
10. *Cassidulina crassa* D'ORBIGNY, sample 219 e; x 150.
11. *Cassidulina subglobosa* BRADY *horizontalis* CUSHMAN & RENZ, sample 219 a; x 150.
12. *Cassidulina subglobosa* BRADY, sample 219 s; x 100.
13. *Astrononion italicum* CUSHMAN & EDWARDS, sample 219 k; x 100.
14. *Nonion boueanum* (D'ORBIGNY), sample 219 o; x 100.
15. *Sphaeroidina bulloides* D'ORBIGNY, sample 219 e; x 100.
16. *Laticarinina pauperata* (PARKER & JONES), sample 71; x 50.
17. *Gyroidina parva* CUSHMAN & RENZ, sample 219 o; x 100, apertural view.
18. *Gyroidina soldanii* (D'ORBIGNY), sample 163 c; x 70, apertural view.

PLATE 6

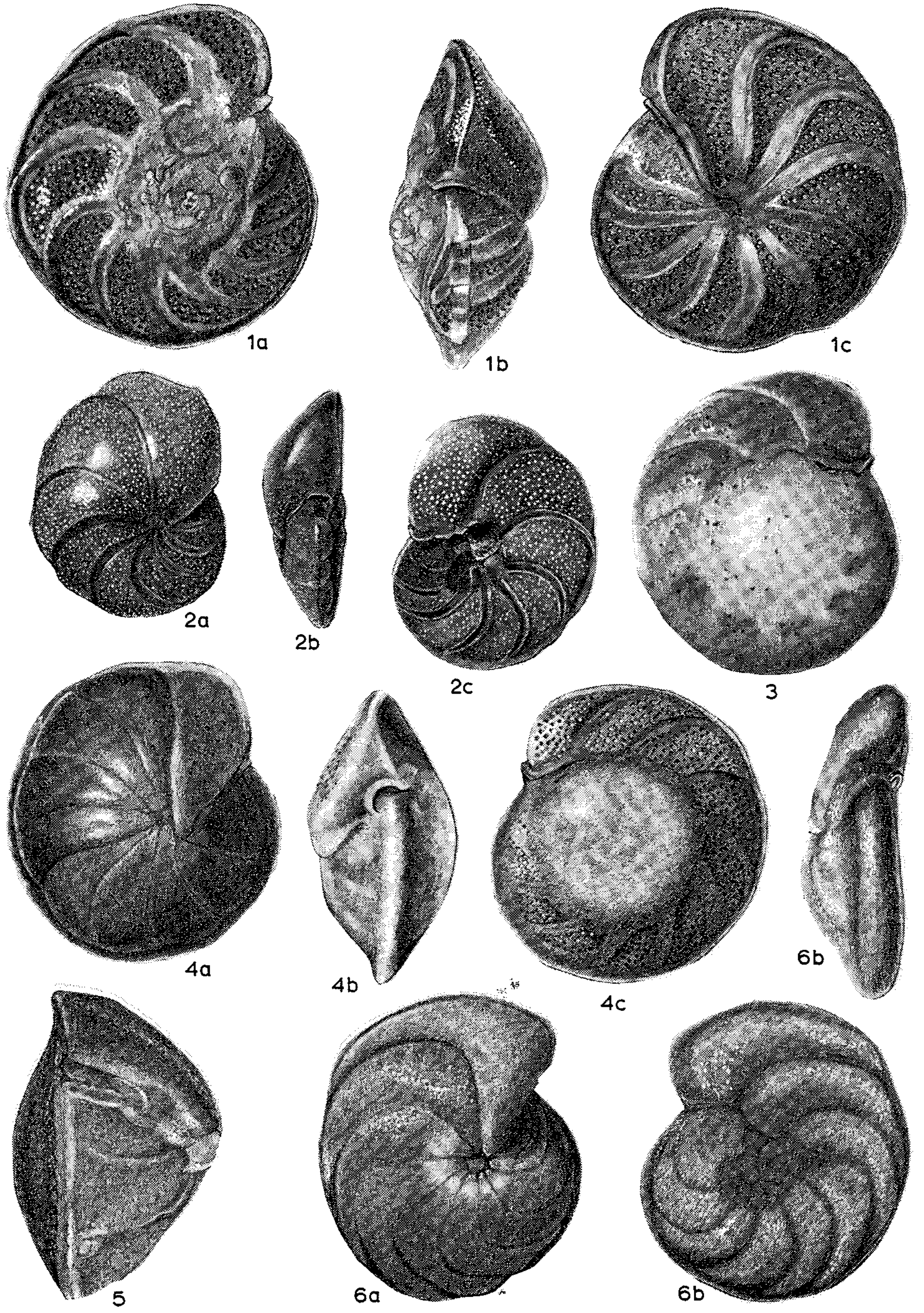


Plate 6

1. *Cibicides ungerianus* (D'ORBIGNY), sample 219 k; x 100.
   a) spiral view, b) apertural view, c) umbilical view.
2. *Hanzawaia producta* (TERQUEM), sample 219 w; x 100.
   a) umbilical view, b) apertural view, c) spiral view.
3. *Cibicides pseudoungerianus* (CUSHMAN), sample 171; x 100.
   spiral view.
4. *Cibicides dutemplei* (D'ORBIGNY) *praecinctus* (KARRER), sample 219 o; x 100.
   a) umbilical view, b) apertural view, c) spiral view.
5. *Cibicides dutemplei* (D'ORBIGNY) *praecinctus* (KARRER), sample 219 o; x 100.
   apertural view of high-spired variant.
6. *Planulina marialana* HADLEY, sample 71; x 70.
   a) umbilical view, b) apertural view, c) spiral view.

PLATE 7

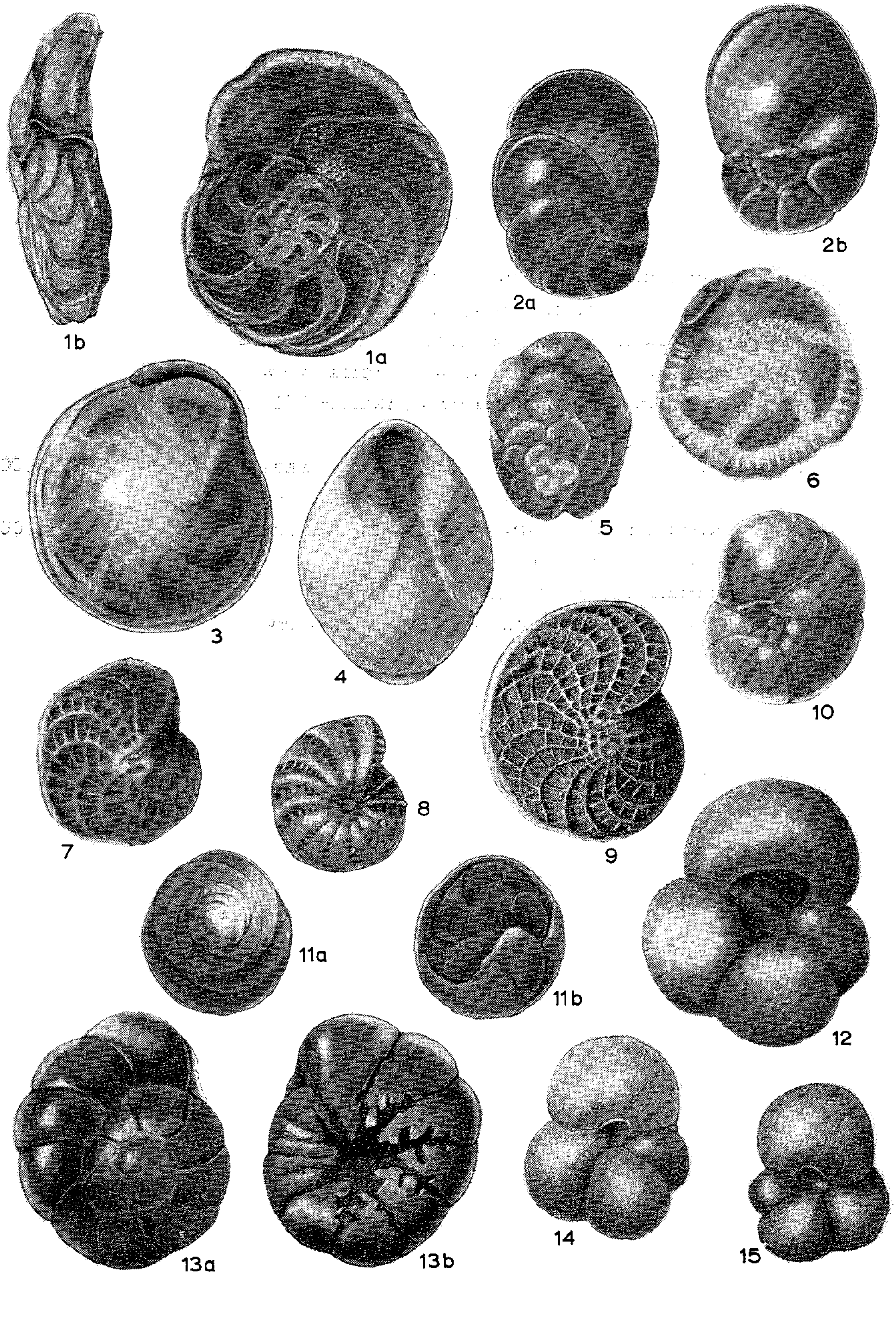


Plate 7

1. *Planulina ariminensis* D'ORBIGNY, sample 219 q; x 70.
   a) spiral view, b) apertural view.
2. *Cancris auriculus* (FICHTEL & MOLL), sample 219 a; x 50.
   a) spiral view, b) umbilical view.
3. *Epistomina elegans* (D'ORBIGNY), sample 219 k; x 70.
   umbical view.
4. *Pleurostomella brevis* SCHWAGER, sample 91 a; x 50.
5. *Planorbulina mediterranensis* D'ORBIGNY, sample 219 k; x 100.
6. *Siphonina planoconvexa* (SILVESTRI), sample 117 a; x 70.
7. *Elphidium crispum* (LINNAEUS), sample 269 c; x 70.
8. *Elphidium excavatum* (TERQUEM), sample 269 c; x 70.
9. *Elphidium fichtellianum* (D'ORBIGNY), sample 219 a; x 70.
10. *Valvulineria araucana* (D'ORBIGNY) *malagaensis* KLEINPELL, sample 269 u; x 70.
11. *Asterigerina planorbis* D'ORBIGNY, sample 219 w; x 70.
    a) spiral view, b) umbilical view.
12. *Globigerina bulloides* D'ORBIGNY, sample 163 c; x 100.
13. *Ammonia beccarii* (LINNAEUS), sample 269 s; x 70.
    a) spiral view, b) umbilical view.
14. *Globigerina praebulloides praebulloides* BLOW, sample 269 q; x 100.
15. *Globigerina praebulloides* BLOW *leroyi* BLOW & BANNER, sample 218 g ;x 100.

PLATE 8

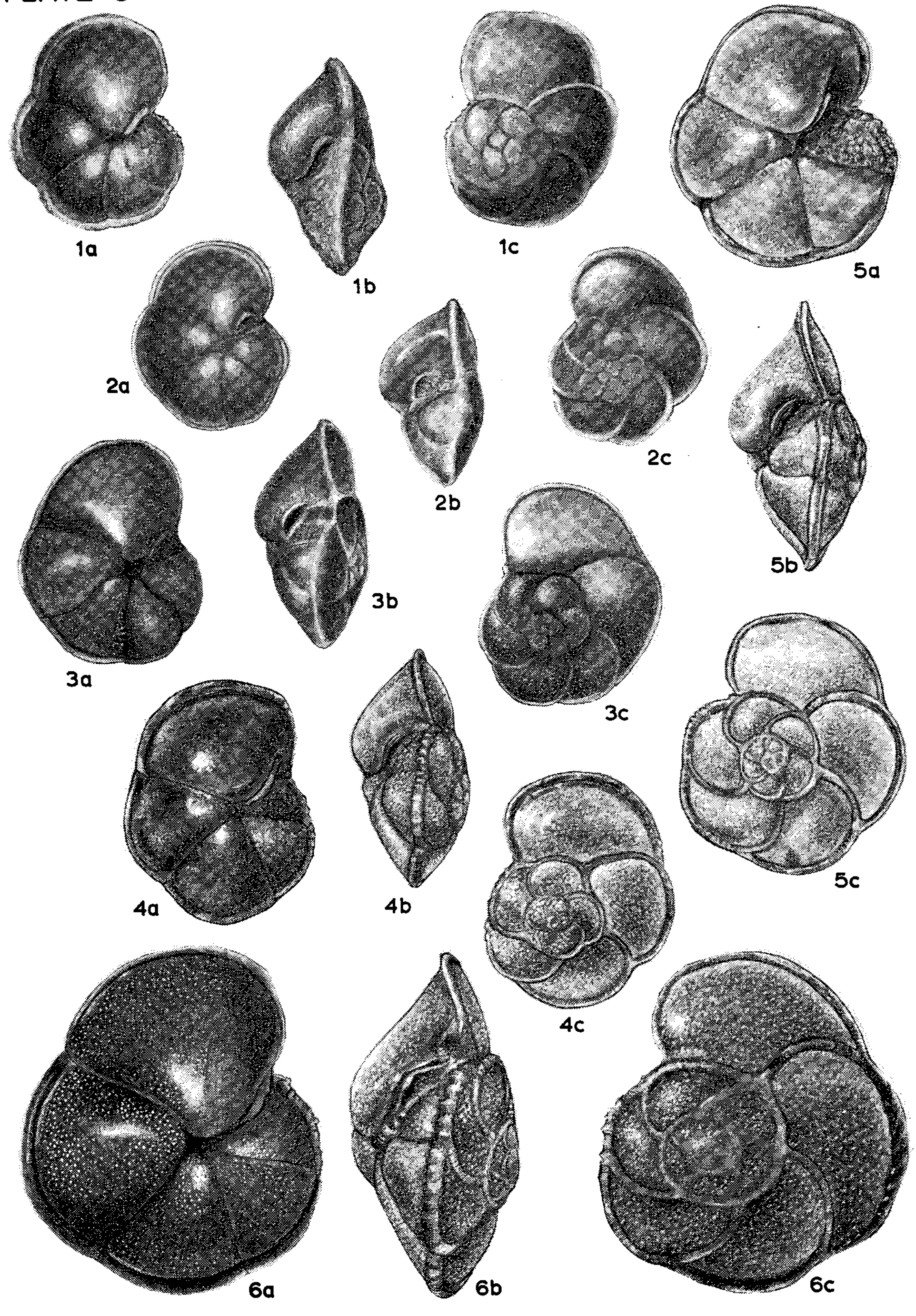


Plate 8

1. *Globorotalia merotumida* Blow & Banner, sample 219 g; x 100.
   a) umbilical view, b) apertural view, c) spiral view.
2. *Globorotalia merotumida* Blow & Banner, sample 219 q; x 100.
   a) umbilical view, b) apertural view, c) spiral view.
3. *Globorotalia merotumida* Blow & Banner, sample 20 b, x 100.
   a) umbilical view, b) apertural view, c) spiral view.
4. *Globorotalia tumida* (Brady) *plesiotumida* Blow & Banner, sample 269 y; x 100.
   a) umbilical view, b) apertural view, c) spiral view.
5. *Globorotalia tumida* (Brady) *plesiotumida* Blow & Banner, sample 212; x 100.
   a) umbilical view, b) apertural view, c) spiral view.
6. *Globorotalia tumida* (Brady) *plesiotumida* Blow & Banner, sample 269 u; x 100.
   a) umbilical view, b) apertural view, c) spiral view.

PLATE 9

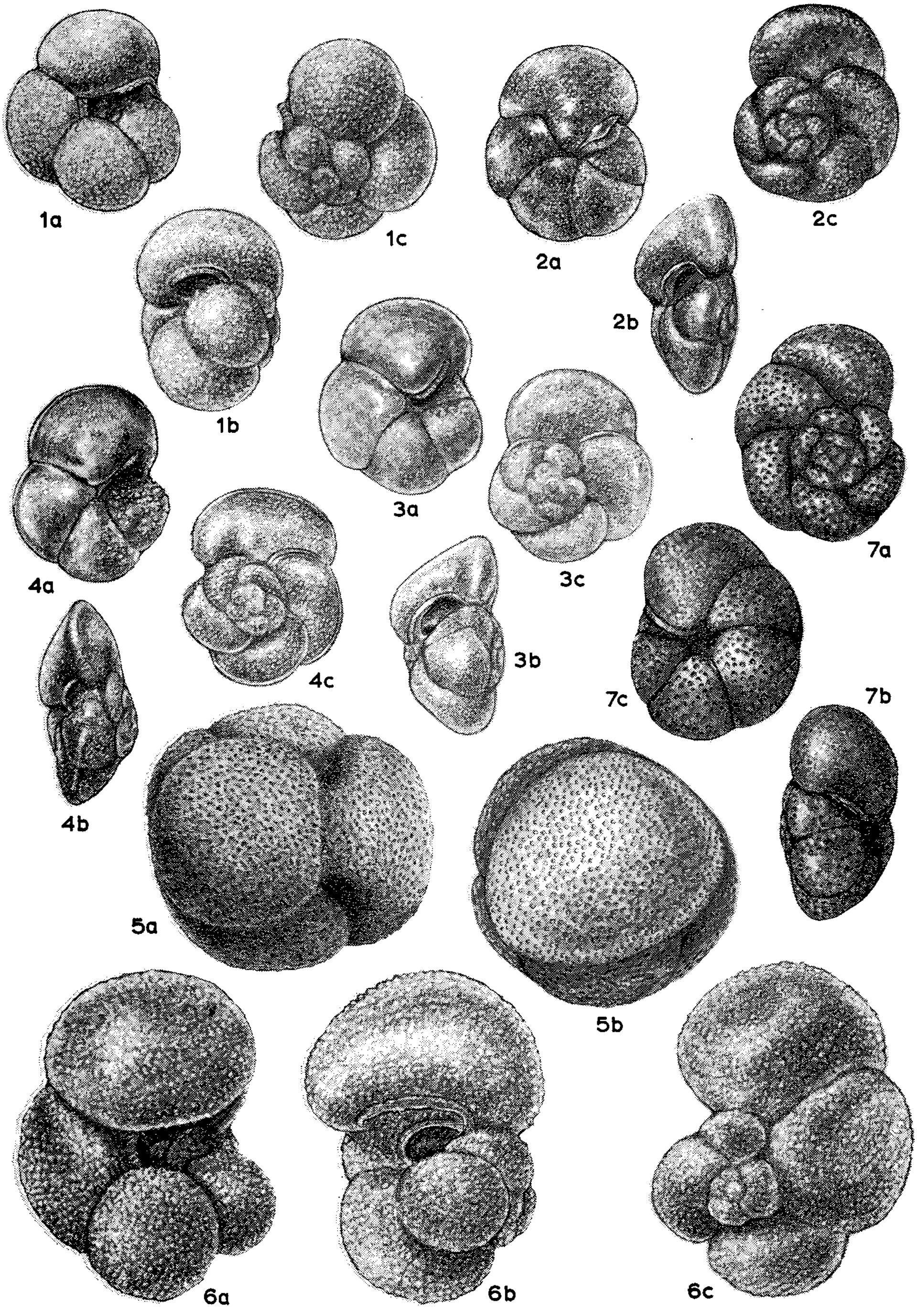


Plate 9

1. *Globorotalia acostaensis* BLOW, sample 219 m; x 100.
   a) umbilical view, b) apertural view, c) spiral view.
2. *Globorotalia scitula* (BRADY) *ventriosa* OGNIBEN, sample 219 c; x 100.
   a) umbilical view, b) apertural view, c) spiral view.
3. *Globorotalia crotonensis* CONATO & FOLLADOR, sample 280; x 100.
   a) umbilical view, b) apertural view, c) spiral view.
4. *Globorotalia margaritae* BOLLI & BERMUDEZ, sample 219 w; x 100.
   a) umbilical view, b) apertural view, c) spiral view.
5. *Globigerapsis kugleri* BOLLI, sample 126; x 100.
   a) lateral view, b) umbilical view.
6. *Globorotalia pseudobesa* (SALVATORINI), sample 219 w; x 100.
   a) umbilical view, b) apertural view, c) spiral view.
7. *Globorotalia peripheroronda* BLOW & BANNER, sample 71, x 100.
   a) spiral view, b) apertural view, c) umbilical view.

REFERENCES

AGIP MINERARIA (1957) Foraminiferi Padani (Terz.e Quatern.). "Atlante iconografico e distribuzione stratigrafica", Milano. 52 pls.

ALASTRUE, E. (1949) Las unidades estructurales de las Cordilleras Béticas según los estudios del Dr. Blumenthal. Bol. Inst. Geol. Min. Esp.; *62:* 205-271.

——— & PRIETO, I. (1954) Reconocimiento geologico de la Sierra de Montellano (Sevilla). Notas y Com. Inst. Geol. Min Esp.; *35:* 5-12.

AUCT. VAR. (1935) Explicación del nuevo mapa geológico de España en escala 1 : 1.000.000. Mem. Inst. Geol. Min. Esp.; *41:* 528 pp.

BANNER, F. T. & BLOW, W. H. (1959) The classification and stratigraphical distribution of the Globigerinaceae. Palaeontology; *2:* 1-27.

——— ———(1960) Some primary types of species belonging to the superfamily Globigerinaceae. Cushm. Found. For. Res., Contr.; *11:* 1-41.

——— ——— (1962) The type specimens of *Globigerina quadrilobata* D'ORBIGNY, *Globigerina sacculifera* BRADY, *Rotalina cultrata* D'ORBIGNY and *Rotalia menardii* PARKER, JONES AND BRADY. Cushm. Found. For. Res., Contr.; *13:* 98-99.

——— ——— (1965) *Globigerinoides quadrilobatus* (D'ORBIGNY) and related forms: their taxonomy, nomenclature and stratigraphy. Cushm. Found. For. Res., Contr.; *16:* 105-115.

——— ———(1965) Two new taxa of the Globorotaliinae (Globigerinacea, Foraminifera) assisting determination of the Late Miocene / Middle Miocene boundary. Nature; *207,* 5004: 1351-1354.

——— ——— (1965) Progress in the planktonic foraminiferal biostratigraphy of the Neogene. Nature; *208,* 5016: 1164-1166.

BARBIERI, F. (1967) The foraminifera in the Pliocene section Vernasca-Castell'Arquato, including the "Piacenzian stratotype" (Piacenza prov.). Mem. Soc. Ital. Sci. Nat. e Mus. Civ. Stor. Nat., Milano; *15,* 3: 145-163.

——— & PETRUCCI, F. (1963) I Foraminiferi del Tortoniano di Casatico (Parma). Boll. Soc. Geol. It.; *82,* 3: 119-180.

——— ——— (1967) La série stratigraphique du Messinien au Calabrien dans la vallée du T. Crostolo (Reggio Emilia, Italie sept.). Mem. Soc. Ital. Sci. Nat. e Mus. Civ. Stor. Nat., Milano; *15,* 3: 181-188.

BIZON, G. (1967) Contribution à la connaissance des foraminifères planctoniques d'Epire et des îles ioniennes (Grèce occidentale) depuis le Paléogène supérieur jusqu'au Pliocène. Thèse, Paris.

BLOW, W. H. (1959) Age, correlation and biostratigraphy of the Upper Tocuyo and Pozón Formations, eastern Falcón, Venezuela. Bull. Amer. Pal.; *39,* 178: 59-252.

BOLLI, H. M. (1957) Planktonic foraminifera from the Oligocene-Miocene Cipero and Lengua Formations of Trinidad, B.W.I. U.S. Nat. Mus., Bull.; *215:* 97-123.

——— (1964) Observations on the stratigraphic distribution of some warm water planktonic foraminifera in the young Miocene to Recent. Eclogae Geol. Helv.; *57:* 541-552.

——— (1966) Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera. Bol. Inform. Asoc. Venez. Geol. Min. Petr.; *9,* 1: 3-32.

CABANAS, R. (1964) Notas estratigráficas de la provincia de Córdoba. Notas y Com. Inst. Geol. Min. Esp.; *74:* 69-73.

CALA Y SANCHEZ, M. (1897) Geologia del Termino de Morón y descriptión de su yacimiento diatomífero. An.R. Soc. Esp. Hist. Nat.; *26:* 83-175.

CALDERON, S. (1888) Foraminíferos fóssiles de Andalucia. Act. R. Soc. Esp. Hist. Nat.; *17:* 52-57.

——— (1893) Movimientos Pliocenicos y postpliocenicos en la valle del Guadalquivir. An. R. Soc. Esp. Hist. Nat.; *22:* 1-18.

——— (1893) Estructura del terreno terciario del Guadalquivir en la provincia de Sevilla. Bol. Com. Mapa Geol. Esp.; *20:* 313-318.

——— (1896) Fossiles contenidos en unas muestras de arenisca de Bollullos de Condado (Huelva). An. R. Soc. Esp. Hist. Nat.; *25:* 69-70.

——— (1898) Mas diatomeas de Morón y noticias sobre este yacimiento según el botanico Sr. Coincy. An. R. Soc. Esp. Hist. Nat.; *27:* 30.

——— & PAUL, M. (1886) La Moronita y los yacimientos diatomíferos de Morón. An. R. Soc. Esp. Hist. Nat.; *15:* 477-493.

CANTOS FIGUEROLA, J. (1955) Investigación gravimétrica en Carmona (Sevilla). Notas y Com. Inst. Geol. Min. Esp.; *38:* 97-120.

CARBONELL, A. (1926) Linea tectonica de Guadalquivir. 14 Congreso Geológico International, Madrid 1926, Guia A - 4.

——— (1926) Notas explicativas de la Geología de la immediaciones de Córdoba. Bol. Real. Acad. Sci., Let. y Arte, Córdoba.

——— (1926) Nota sobre los depósitos de foraminíferos Terciarios de Córdoba. Bol. Inst. Geol. Min. Esp.; *47:* 281-288.

CITA, M. B., PREMOLI SILVA, I. & ROSSI, R. (1965) Foraminiferi planctonici del Tortoniano-tipo. Riv. Ital. Paleont.; *71:* 217-308.

COLALONGO, M. L. & SARTONI, S. (1967) *Globorotalia hirsuta aemiliana,* nuova sottospecie cronologica del Pliocene in Italia. Giorn. Geol., Bologna, (2); *34,* 1 : 1-15.

COLOM, G. (1952) Aquitanian-Burdigalian diatom deposits of the North Betic Strait, Spain. Journ. Paleont., *26:* 867-885.

——— (1954) Estudio de las biozonas con foraminíferos del Terciario de Alicante. Bol. Inst. Geol. Min. Esp.; *66:* 101-451.

——— & GAMUNDI, J. (1951) Sobre la extensión e importancia de las "Moronitas" a lo largo de las formaciones aquitano-burdigalienses del estrecho nort-bético. Estudios Geológicos, Inst. Invest. Geol. "Lucas Mallada"; *7:* 331-385.

CONATO, V. & FOLLADOR, U. (1967) *Globorotalia crotonensis* e *Globorotalia crassacrotonensis* nuove specie del Pliocene italiano. Boll. Soc. Geol. It.; *86,* 3: 555-563.

CRESCENTI, U. (1966) Sulla biostratigrafia del Miocene affiorante al confine Marchigiano-Abruzzese. Geol. Rom; *5:* 1-54.

CRUSAFONT PAIRO, M. & TRUYOLS SANTONJA, J. (1959) Sobre el nuevo proyecto de estructuración y nomenclatura del Miocene mediterráneo. Notas y Com. Inst. Geol. Min. Esp.; *56:* 33-53.

DECIMA, A. (1962) Osservazioni sulle argille ritenute Plioceniche del versante meridionale delle Madonie (Sicilia centro-settentrionale). Riv. Ital. Paleont.; *68:* 389-428.

DONDI, L. & PAPETTI, I. (1966) Studio paleoecologico e stratigrafico sul passaggio Pliocene-Quaternario nella bassa valle del Santerno (Emilia). Riv. Ital. Paleont.; *72:* 231-244.

D'ONOFRIO, S. (1964) I Foraminiferi del neostratotipo del Messiniano. Giorn. Geol., Bologna, (2); *32,* 2: 409-461.

DOUVILLE, R. (1906) Esquisse géologique des Préalpes subbétiques (Partie centrale). Thèse, Paris. Impr. H. Bouillant.

——— (1911) La peninsule Ibérique. A. Espagne. Handbuch der regionalen Geologie; *3*, 3.

DROOGER, C. W. & FREUDENTHAL, T. (1965) Associations of *Miogypsina* and *Lepidocyclina* at some European localities. Eclogae Geol. Helv.; *57* (1964): 509-528.

——— & KAASSCHIETER, J. P. H. (1958) Foraminifera of the Orinoco-Trinidad-Paria shelf. Kon. Ned. Akad. Wet., Amsterdam, Verh. (1); *22*.

——— & SOCIN, C. (1959) Miocene Foraminifera from Rosignano, Northern Italy. Micropaleontology; *5:* 415-426.

FALLOT, P. (1931) Essais sur la répartition des terrains secondaires et tertiaires dans le domaine des Alpides espagnoles. Introduction. Geol. Médit. Occid.; *4*, (2) 1: 1-8.

——— (1931) Essais sur la répartition des terrains secondaires et tertiaires dans le domaine des Alpides espagnoles. Le Trias, Geol. Médit. Occid.; *4* (2), 1: 9-28.

——— (1932) Essais sur la répartition des terrains secondaires et tertiaires dans le domaine des Alpides espagnoles. Le Lias, Geol. Médit. Occid.; *4*, (2), 1 : 29-64.

——— (1933) Essais sur la répartition des terrains secondaires et tertiaires dans le domaine des Alpides espagnoles. Le Dogger, Geol. Médit. Occid.; *4*, (2), 1: 65-72.

——— (1934)Essais sur la répartition des terrains secondaires et tertiaires dans le domaine des Alpides espagnoles. Le Jurassique sup., Geol. Médit. Occid.; *4*, (2), 1: 73-118.

——— (1948) Les Cordillères Bétiques. Estudios Geologicos, Inst. de Invest. Geol. "Lucas Mallada"; *8:* 83-172.

FOLLADOR, U. (1967) Il Pliocene ed il Pleistocene dell'Italia centro-meridionale, versante adriatico. Biostratigrafia. Boll. Soc. Geol. It.; *86*, 3: 565-584.

FREUDENTHAL, T. (1969) Stratigraphy of Neogene deposits in the Khania Province, Crete, with special reference to Foraminifera of the family Planorbulinidae and the genus *Heterostegina*. Utrecht Micropal. Bull.; *1*. Schotanus & Jens, Utrecht.

GRIMSDALE, T. F. & MORKHOVEN, F. P. C. M. VAN (1955) The ratio between pelagic and benthonic foraminifera as a means of estimating depth of deposition of sedimentary rocks. Proc. fourth world petroleum Congr., Rome 1955.

HERNANDEZ-PACHECO, F. (1926) La Sierra Morena y la llanura Betica. 14 Congreso Geológico Internacional, Madrid 1926. Guia x - 1.

HERNANDEZ-SAMPELAYO, P. (1942) Explicación del nuevo Mapa Geológico de España, esc. 1: 1.000.000: Sistema Siluriano. Mém. Inst. Geol. Min. Esp.; *45*, 2, 1.

IACCARINO, S. (1963) Il Pliocene inferiore del rio Lombasino (S. Andrea Bagni - Parma). Riv. Ital. Paleont.; *69:* 261-284.

KILIAN, W. (1889) Etudes paléontologiques sur les terrains secondaires et tertiaires de l'Andalousie. Mem. Ac. Sc.; *30:* 582-751.

KOCKEL, F. (1967) Fazies und Tektonik im Miozän am S-Rand der Sierra Morena zwischen Lora del Rio (Sevilla) und Posadas (Córdoba). Geol. Rundschau; *56:* 784-791.

LAZZAROTTO, A., MAZZANTI, R. & SALVATORINI, G. (1964) Stratigrafia Neogenica Toscana: Esame geologico e micropaleontologico di alcune sezioni del complesso neoautoctono delle Valli di Cornia e di Milia (Province di Pisa e Grosseto). Boll. Soc. Geol. It.; *83*, 4: 401-460.

LOPEZ DE AZCONA, J. M. (1962) Bibliografía de Mineria, Metalurgia, Geología y ciencias afines. Mem. Inst. Geol. Min. Esp.; *63*.

MALLADA, L. (1880) Reconocimiento geológico de la Provincia de Córdoba. Bol. Com. Mapa Geol. Esp.; *7*.

——— (1884) Reconocimiento geologico de la Provincia de Jaén. Bol. Com. Mapa Geol. Esp.; *11:* 1-55.

——— (1896) Explicación del mapa geológico de España. Mem. Com. Map. Geol. Esp.; 2, Sistemas Cambriano y Siluriano.

——— (1902) Explicación del mapa geológico de España. Mem. Com. Map. Geol. Esp.; *4,* Sistemas Permiano, Triásico, Liásico y Jurásico.

McKee, E. D. & Weir, G. W. (1953) Terminology for stratification and cross-stratification in sedimentary rocks. Bull. Geol. Soc. Amer.; *64:* 381-390.

McPherson, J. (1879) Estudio geológico y petrográfico del Norte de la provincia de Sevilla. Bol. Com. Mapa Geol. Esp.; *6:* 97.

Meulenkamp, J. E. (1969) Stratigraphy of Neogene deposits in the Rethymnon Province, Crete, with special reference to the phylogeny of uniserial *Uvigerina* from the Mediterranean region. Utrecht Micropal. Bull.; *2.* Schotanus & Jens, Utrecht.

Mistretta, F. (1962) Foraminiferi planctonici del Pliocene inferiore di Altavilla Milicia (Palermo, Sicilia). Riv. Ital. Paleont.; *68:* 97-114.

Novo, P., Carbonell, A., Carandell, J. & Gomez Llueca, F. (1926) De Sierra Morena a Sierra Nevada (Reconocimiento orogenético de la región Bética). 14 Congreso Geológico Internacional, Madrid 1926. Guia A - 5.

Ogniben, L. (1958) Stratigrafia e microfaune del Terziario della zona di Caiazzo (Caserta). Riv. Ital. Paleont.; *64:* 199-286.

Pan Arana, T. (1952) Contribución al estudio de los microforaminíferos del Mioceno de Sevilla. Bol. R.Soc. Esp. Hist. Nat.; *50:* 121-130.

——— (1953) Algunos géneros y especies de foraminíferos de La Pañoleta (Sevilla). Bol. R. Soc. Esp. Hist. Nat.; *51:* 107-130.

Perconig, E. (1955) Ricerche stratigrafiche e micropaleontologiche nella regione marchigiana (Foglio Fermo). Boll. Serv. Geol. Ital.; *77,* 2-3: 199-269.

——— (1962) Sur la constitution géologique de l'Andalousie occidentale en particulier du bassin du Guadalquivir (Espagne méridionale). Livre à la mémoire du Prof. Fallot; *1:* 231-256.

——— (1964) La estratigrafiá del Mioceno en Andalucia occidental (Esp.). El limite Oligoceno - Mioceno y la fase terminal marina del Mioceno. Atti 2a Riun. Comm. Médit. Néog. Strat., Sabadell - Madrid 1961. Cursillos y Conferencias Inst. "Lucas Mallada"; *9:* 219-228.

——— (1966) Sull'esistenza del Miocene superiore in facies marina nella Spagna meridionale. Proc. 3rd Sess. Comm. Medit. Neog. Strat., Berne 1964: 288-302. Brill, Leiden.

——— (1968a) Biostratigrafia della sezione di Carmona (Andalusia, Spagna) in base ai foraminiferi planctonici. Proc. 4th Sess. Comm. Medit. Neog. Strat., Bologna 1967. Giorn. Geol., Bologna, (2); *35,* 3: 191-218.

——— (1968b) Nuevo specie di Foraminiferi planctonici della sezione di Carmona (Andalusia, Spagna). Proc. 4th Sess. Comm. Medit. Neog. Strat., Bologna 1967. Giorn. Geol., Bologna, (2); *35,* 3: 219-232.

Peyre, Y. (1958) Premières observations sur le Crétacé de la région d'Estepa (Andalousie). C.R. S. Ac. Sci., Paris; *246:* 2137-2139.

——— (1962) El Subbético con Jurásico margoso o "Subbético Meridional" como unidad paleogeográfica y tectónica de las cordilleras Béticas. Notas y Com. Inst. Geol. Min. Esp.; *67:* 133-144.

Pezzani, F. (1963) Studio micropaleontologico di un campione della serie Messiniana di Tabiano Bagni (Parma). Riv. Ital. Paleont.; *69:* 559-662 .

PHLEGER, F. B. (1960) Ecology and distribution of recent foraminifera. John Hopkins Press, Baltimore, Maryland.

——— (1964) Foraminiferal ecology and marine geology. Marine Geol.; *1:* 16-43.

RIOS, J. M. (1958) Relación de los principales sondeos para investigación de petróleos llevados a cabo en España desde 1939. Notas y Com. Inst. Geol. Min. Esp.; *50:* 47-74.

SAAVEDRA, J. L. (1961) Los foraminíferos del Terciario superior y Cuaternario del valle del Guadalquivir. Bol. Inst. Geol. Min. Esp.; *72:* 349-468.

——— (1963) Datos sobre micropaleontología de las hojas de Lucena, Baena, Puente Genil y Montilla. Notas y Com. Inst. Geol. Min. Esp.; *72:* 81-103.

——— (1964) Datos para la interpretación de la estratigrafía del Terciario y Secundario de Andalucía. Notas y Com. Inst. Geol. Min. Esp.; *73:* 5-50.

SCHMIDT, H. (1953) Ökologische Beobachtungen an den Foraminiferen des Golfes von Neapel. Paläont. Z.; *27:* 123-128.

SELLI, R. (1957) Sulla trasgressione del Miocene nell'Italia meridionale. Giorn. Geol., Bologna, (2); *26:* 1-54.

——— (1960) Il Messiniano Mayer - Eymar 1897. Proposta di un neostratotipo. Giorn. Geol., Bologna, (2); *28:* 1-33.

SWINCHATT, J. P. (1967) Formation of large-scale cross-bedding in a carbonate unit. Sedimentology; *8:* 93-120.

VEZZANI, L. (1966) La sezione Tortoniana di Perosa sul Fiume Sinni presso Episcopía (Potenza). Geol. Rom.; *5:* 263-290.

VLERK, I. M. VAN DER (1963) Biometric research on *Lepidocyclina.* Micropaleontology; *9:* 425-426.

——— (1964) Biometric research on European *Lepidocyclinas.* Kon. Ned. Akad. Wet., Amsterdam, Proc. (B); *67,* 5: 2-10.

WALTERS, R. (1965) The *Globorotalia zealandica* and *G. miozea* lineages. N.Z. Jl. Geol. Geophys.; *8:* 109-127.

WALTON, W. R. (1964) Recent foraminiferal ecology and paleoecology. Approaches to Paleoecology, New York: 151-237.

Subscribers to the entire series will have the benefit of a 20% reduction.

Subscriptions can be made to:

Messrs Schotanus & Jens
Lange Nieuwstraat 20
Utrecht
The Netherlands

GEOLOGICAL MAP OF THE CARMONA - ECIJA AREA
GUADALQUIVIR BASIN