# Biostratigraphy and Paleoecology of the Upper Miocene (Messinian) and Lower Pliocene(?) Cerro de Almendral Section, Almería Basin, Southern Spain

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GEOLOGICAL SURVEY PROFESSIONAL PAPER 774-F

*Prepared in cooperation with the*
*Empresa Nacional de Investigaciones Mineras of Spain*

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

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*By* RICHARD Z. POORE *and* SEAN MURPHY STONE

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

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By RICHARD Z. POORE and SEAN MURPHY STONE

## ABSTRACT

Planktic foraminifers from the Cerro de Almendral section in the Almería Basin of southern Spain show that sedimentary rocks below a 20-m-thick gypsum deposit are referable to the Messinian *Globorotalia conomiozea* Zone and suggest that sedimentary deposits above the gypsum are lower Pliocene. Benthic foraminifer assemblages indicate that the Messinian sedimentary rocks were deposited in middle bathyal (800-1,000 m) water depths and show no evidence for shallowing upsection to the gypsum. We therefore conclude that the gypsum was deposited in a basin having about 800-1,000 m of relief.

## INTRODUCTION

During a reconnaissance study of the paleontology and stratigraphy of the Almería Basin, southern Spain (Addicott and others, 1978), a 130-m upper Miocene (Messinian) and lower Pliocene(?) section containing 20 m of massively bedded gypsum was found at Cerro de Almendral, approximately 16 km northeast of the village of Nijar (figs. 1 and 2). This sequence provides a record of the terminal Miocene event—the Messinian salinity crisis—in the northeastern Almería Basin.

A major controversy concerning the latest Miocene history of the Mediterranean area revolves around whether the evaporites were deposited in shallow basins (on the order of a few hundred meters deep) that later underwent substantial subsidence or in preexisting deep basins of 1,000 m or more (Drogger, 1973). The results of Deep Sea Drilling Project Legs 13 and 42A (Ryan and others, 1973; Hsu and others, 1978) clearly indicate the existence of deep basins (>1,000 m) in the Mediterranean Sea during Messinian evaporite deposition.

Moreover, a growing body of data shows that the Mediterranean Sea was linked to the Atlantic Ocean by a series of interconnected marine basins across southern Spain—the Betic Straits—and that some of these basins were relatively deep during much of the Messinian. These basins are thought to have provided the last communication between the Atlantic Ocean and the Mediterranean Sea at the end of the Miocene (Adams and others, 1977) (fig. 3).

At the end of the Miocene, the Almería Basin was one of a number of basins forming the east end of the Betic Straits. In this study we use foraminifers to document the occurrence of deep-water (800-1,000 m) preevaporite Messinian sedimentary deposits in the northeastern Almería Basin and thus the existence of a relatively deep basin within the Betic Straits during the Messinian.

This study is a part of a cooperative program between the U.S. Geological Survey and the Empresa Nacional de Investigaciones Mineras of Spain.

*Acknowledgments.*—We thank W.O. Addicott and A.K. Armstrong for providing us with samples from the Cerro de Almendral section. We also thank Kristin McDougall for discussions on the benthic foraminifers and W.O. Addicott and John Barron for constructive criticism of this manuscript.

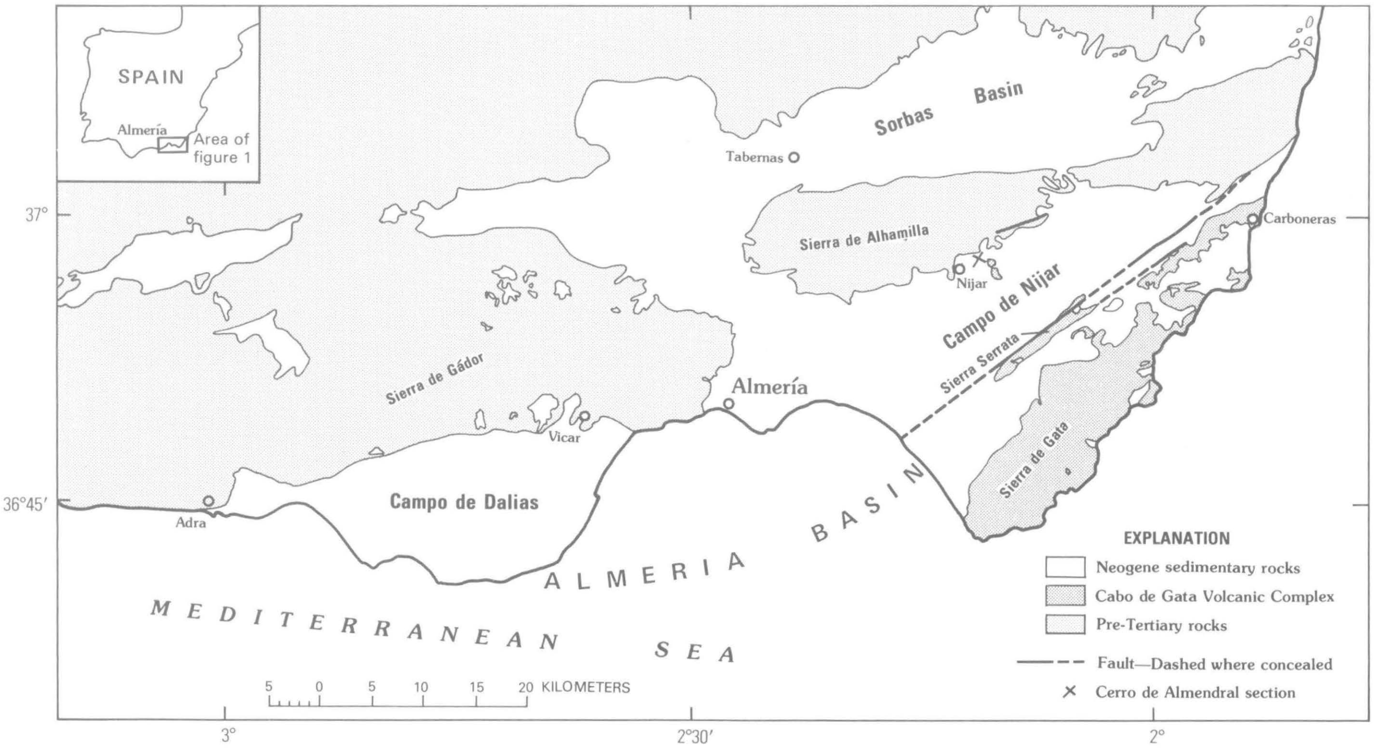

FIGURE 1.—Generalized geologic map of southern Almería Province, southeastern Spain, showing location of Cerro de Almendral section (from Addicott and others, 1978).

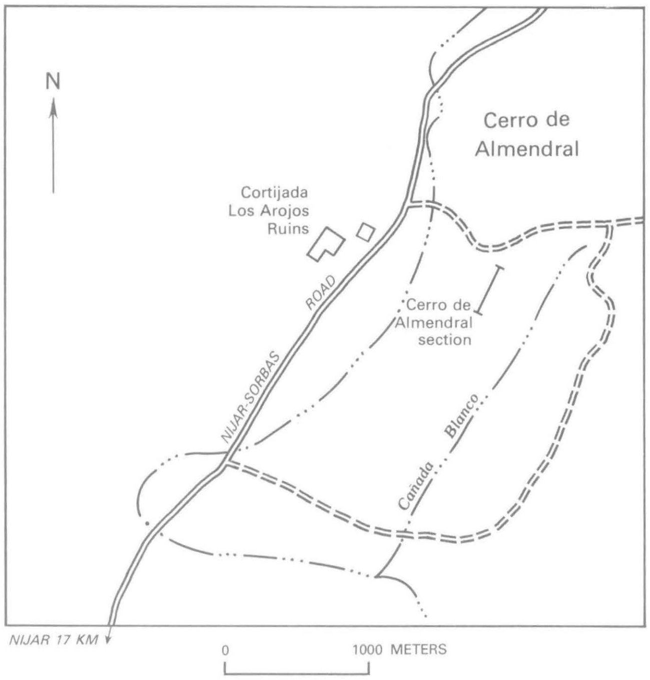

FIGURE 2.—Location of the Cerro de Almendral section on the south side of Cerro de Almendral between the Nijar-Sorbas Road and Cañada Blanco (loc. Mf3331, section G-76-2 of Addicott and others, 1978).

## THE CERRO DE ALMENDRAL SECTION AND ITS GEOLOGIC SETTING

Neogene rocks deposited in the Almería Basin crop out in Almería Province, southeastern Spain (fig. 1). The Almería Basin, one of several late Neogene basins that occur in the northeast-trending Betic Cordilleras of southern Spain, is bounded to the north by the Sierra de Gádor and the Sierra de Almendral and to the south by the Mediterranean Sea and the Sierra de Gádor.

The late Neogene stratigraphy of the northeastern part of the Almería Basin (Campo de Nijar) is summarized by Addicott and others (1978), whose stratigraphic nomenclature is followed in this report. Briefly, upper Miocene rocks consist of interfingering shallow- and deep-water carbonate rocks with minor amounts of clastic rocks; these rocks unconformably overlie the middle Miocene Cabo de Gata Volcanic Complex or pre-Tertiary rocks. The most widespread upper Miocene units are the shallow-water Vicar Formation and the predominantly deep-water Nijar formation. The Pliocene sequence consists of marly sandstone and siltstone (Cuevas Viejas formation) and coarser clastic rocks (Morales formation). The base of the Pliocene is usually marked by a distinct unconformity.

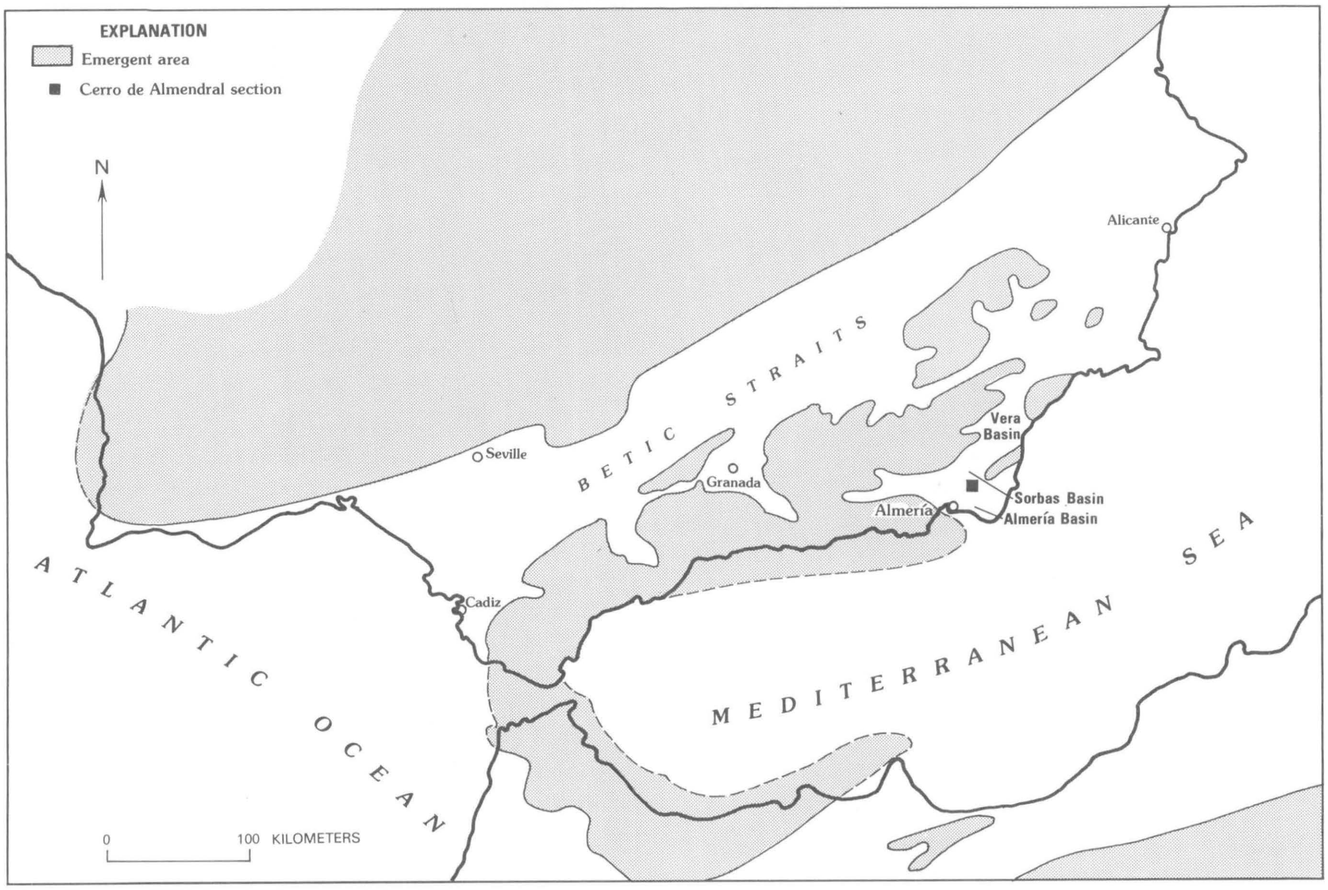

FIGURE 3.—Schematic diagram of southern Spain during the middle Miocene (modified from Fernex and others, 1967).

The Cerro de Almendral section (figs. 2, 3, and 4) consists, in ascending order, of (1) 92 m of tan to light-gray massive foraminiferal siltstone, the base of which is faulted against Triassic dolomite, (2) 22 m of massive-bedded selenite gypsum, and (3) 21 m of tan to brownish-yellow sandy siltstone that is capped by terrace gravel. The gypsum appears conformable with units above and below. This section, excluding the terrace gravel, is referred to the Nijar formation by Addicott and others (1978). The Nijar formation of the Almería Basin is coeval with the Abad member of the Turre Formation (Volk and Rondeel, 1964) of the Vera and Sorbas Basins (Dronkert, 1976), which adjoin the Almería Basin to the north and northeast. Samples from the Cerro de Almendral section examined for this study are those of Addicott and others (1978).

## BIOSTRATIGRAPHY

The stratigraphic distribution of planktic foraminifers in 10 samples examined from the Cerro de Almendral section is shown in table 1. Planktic foraminifers are common to abundant but only moderately well to poorly preserved in samples +0 m through +120 m. In general, the quality of preservation of foraminifers declines upsection. Sample +132 m is almost barren of microfossils.

Common and consistent members of the planktic assemblages throughout the section include *Neogloboquadrina acostaensis* (Blow), *Globigerinoides obliquus* Bolli (s.l.), *Globigerina bulloides* d'Orbigny, and *G. pseudobesa* (Salvatori). *Globorotalia conoidea* Walters, *G. conomiozea* Kennett, and *G. menardii* (Parker, Jones, and Brady) (s.l.) are common in samples below the gypsum bed.

The occurrence of *Globorotalia conomiozea* in samples below the gypsum is significant because the oldest occurrence of this taxon is within upper Zone N17 (Poore and Berggren, 1975; Berggren and Haq, 1976) at a level that coincides with the base of the Messinian Stage as modified by D'Onofrio and others (1975). Following their studies of several sections in

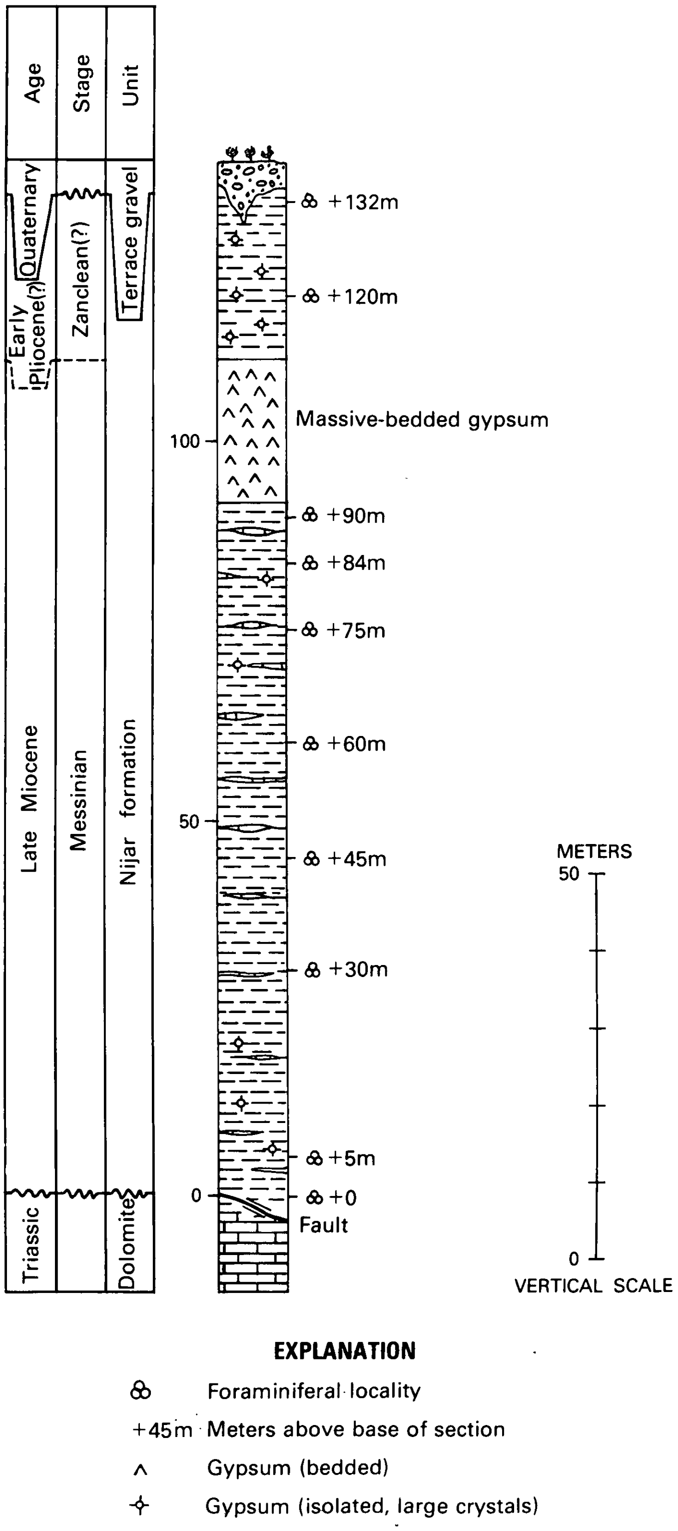

FIGURE 4.—Stratigraphic column of the Nijar formation and location of samples studied at Cerro de Almendral (modified from Addicott and others, 1978).

the Mediterranean area that included the neostratotype of the Messinian Stage and the stratotype of the Tortonian Stage, D'Onofrio and others (1975) used the first occurrence of *Globorotalia conomiozea* and several other related taxa to define the base of a *Globorotalia conomiozea* Zone that is equivalent to the Messinian. Because rich planktic foraminifer assemblages in samples +0 m through +90 m contain *Globorotalia conomiozea* and lack typical Mediterranean Pliocene indicators such as *G. margaritae* Bolli and Bermudez and *G. puncticulata* (Deshayes), the lower 92 m of this section is assigned to the Messinian *Globorotalia conomiozea* Zone of D'Onofrio and others (1975).

The age of the rocks above the gypsum is not certain, but we assign them questionably to the lower Pliocene for the following reasons. In the Vera Basin, which is about 50 km northeast of the Almería Basin, Montenat and others (1976) report that a change from sinistral to dextral coiling preference in *Neogloboquadrina acostaensis*, the last occurrence of *Globorotalia conomiozea*, and the first occurrence of *G. margaritae* mark the Miocene-Pliocene boundary. In the Cerro de Almendral section, a change from sinistral to dextral coiling in *Neogloboquadrina acostaensis* occurs across the interval containing the gypsum (between samples +90 m and +120 m), and *Globortalia conomiozea* is absent in sample +120 m; this evidence suggests a Pliocene assignment for the interval above the gypsum. The occurrence in sample +120 m of *Globigerinoides conglobatus* Brady, a useful indicator for the base of the Pliocene in the South Atlantic (Berggren, 1977), further supports a Pliocene assignment. The lower limit of *Globigerinoides conglobatus*, however, is not well documented in the Mediterranean area, and *Globorotalia margaritae*, an indicator of the Pliocene, does not occur in our samples.

## PALEOBATHYMETRY

Planktic/benthic (P/B) ratios, the quantitative composition of benthic foraminifer faunas at the superfamily level, and the occurrence of selected benthic foraminifer species in five samples were used to infer the bathymetric history of the Cerro de Almendral section. P/B ratios are based on counting splits of approximately 300 foraminifers that were extracted from the ≥149-μm size fraction with a microsplitter. Relative abundances of benthic foraminifer superfamilies are based on counting the first 300 benthic foraminifers found in a strewn slide of the ≥149-μm size fraction. Water depth values used in the following interpretations are modified from values outlined by Berggren and Haq (1976): neritic (0-200 m), upper bathyal (200-600 m), middle bathyal (600-1,000 m), lower bathyal (1,000-2,000 m).

TABLE 1.—*Chart showing stratigraphic distribution of planktic foraminifers in the Cerro de Almendral section*

[aff, affinity]

| | | | Mf3331 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | G-76-2 | | | | | | | |
| Planktic foraminifers | +0 m | +5 m | +30 m | +45 m | +60 m | +75 m | +84 m | +90 m | +120 m | +132 m |
| *Globigerina angustiumbilicata* Bolli | ........ | ........ | ........ | × | ........ | × | ........ | ........ | ........ | ........ |
| *G. apertura* Cushman | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | × | ........ |
| *G. bulloides* d'Orbigny | × | × | × | × | × | × | × | × | × | ........ |
| *G. decoraperta* Takayanagi and Saito | ........ | ........ | ........ | × | ........ | × | ........ | ........ | ........ | ........ |
| *G. falconensis* Blow | × | × | × | × | ........ | ........ | × | × | × | ........ |
| *G. nepenthes* Todd | ........ | ........ | ........ | ........ | ........ | ........ | × | × | ........ | ........ |
| *G. pseudobesa* (Salvatorini) | × | × | × | × | × | × | × | × | × | ........ |
| *G. woodi* Jenkins | × | × | × | × | × | × | × | × | × | ........ |
| *Globigerinita glutinata* (Egger) | × | × | × | × | × | × | × | × | × | ........ |
| *G. uvula* (Ehrenberg) | ........ | × | × | × | × | ........ | × | × | × | ........ |
| *Globigerinoides conglobatus* (Brady) | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | × | ........ |
| *G. extremus* Bolli and Bermudez | × | ........ | × | × | ........ | × | × | × | × | ........ |
| *G. obliquus* Bolli | × | × | ........ | × | × | × | ........ | ........ | × | × |
| *G. sacculifer* (Brady) | ........ | × | × | aff<br>× | × | ........ | ........ | ........ | × | × |
| *G. seigliei* Bermudez and Bolli | ........ | ........ | ........ | ........ | ........ | ........ | ........ | × | ........ | ........ |
| *G. trilobus* (Reuss) s.l | × | × | × | × | × | × | × | × | × | × |
| *Globorotalia cibaoensis* Bermudez | ........ | ........ | ........ | ........ | ........ | ........ | × | ........ | ........ | ........ |
| *G. conoidea* Walters | × | × | × | × | × | × | × | × | ........ | ........ |
| *G. conomiozea* Kennett | × | × | × | × | × | × | × | × | ........ | ........ |
| *G.* aff. *G. lenguaensis* Bolli | × | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| *G. menardii* (Parker, Jones, and Brady) s.l | × | × | × | × | ........ | × | × | × | ........ | ........ |
| *G. nicolae* Catalano and Sprovieri | ........ | × | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| *G.* aff. *G. scitula* (Brady) | × | × | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| *G. subscitula* Conato | × | ........ | ........ | ........ | ........ | ........ | × | ........ | ........ | ........ |
| *Hastigerina siphonifera* (d'Orbigny) | ........ | × | ........ | ........ | ........ | × | × | ........ | ........ | ........ |
| *Neogloboquadrina acostaensis* (Blow) | × | × | × | × | × | × | × | × | × | ........ |
| *N. humerosa* (Takayanagi and Saito) | × | × | ........ | × | ........ | ........ | ........ | × | ........ | ........ |
| *N. pachyderma* (Ehrenberg) s.l | ?<br>× | × | × | × | × | ........ | ........ | ........ | ........ | ........ |
| *Orbulina universa* d'Orbigny | × | × | × | × | × | × | × | × | × | ........ |
| *Turborotalita quinqueloba* Natland | × | × | × | × | × | × | × | × | × | ........ |

Figure 5 shows the P/B ratios, the occurrence of selected benthic foraminifers, and the cumulative percentages of hyaline (perforate) benthic foraminifer superfamilies in the five samples. Porcelaneous and agglutinated species average less than 1 percent of the benthic assemblages and therefore are not plotted.

P/B ratios range from 4/1 to 24/1 but display no particular trend. Following Berggren and Haq (1976) and Berggren and others (1976), these P/B values suggest a lower bathyal water depth of about 1,000 m or greater for all our samples. Analysis of the benthic fauna, however, as discussed below, indicates that water depths were somewhat shallower than this.

Bathymetric data on key living benthic foraminifers used below in making paleobathymetric interpretations are included in the section entitled "Taxonomic notes."

Rocks below the gypsum in the Cerro de Almendral section are interpreted to represent middle bathyal water depths. *Planulina ariminensis* (d'Orbigny) and *Cibicidoides mediocris* (Finlay) are the dominant taxa. *Planulina ariminensis* has an upper depth of about 200 m but is characteristic of upper bathyal to middle bathyal water depths. *Cibicidoides mediocris* is a useful marker for bathyal water depths that increases in frequency with increasing depth. The occurrence of *Gyroidinoides neosoldanii* in percentages greater than 1 percent suggests water depths about 600 m or greater. The occurrence of *Pullenia bulloides* (d'Orbigny) in three samples (+5, +75, and +90 m) with frequencies of 2-3 percent indicates water depths greater than 900 m and suggests that the entire section below the gypsum was deposited in the deeper part (800–1,000 m) of the middle bathyal range. Hispid uvigerinids of the *Uvigerina pygmaea* (d'Orbigny)-*U. hispido-costata* (Cushman and Todd) group occur in all samples below the gypsum. The development of hispid ornamentation is generally considered to indicate bathyal water depths with an upper limit of about 600–1,000 m (for example, Bandy, 1964; Pflum and Frerichs, 1976).

Above the gypsum, benthic foraminifers display a reduction in diversity, as do the planktic foraminifers. *Planulina ariminensis, Cibicidoides mediocris,* and *Gyroidinoides neosoldanii* occur in only small per-

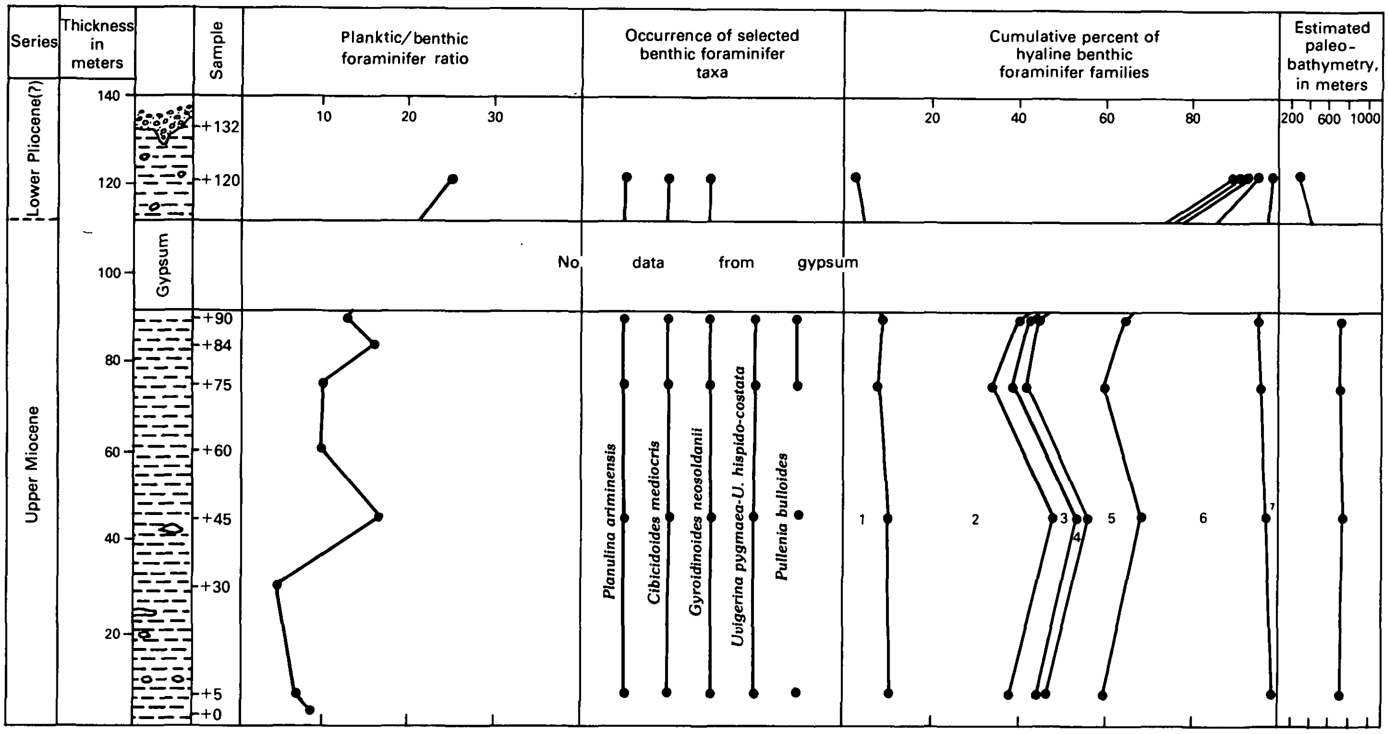

FIGURE 5.—Planktic/benthic foraminifer ratios, occurrence of selected benthic foraminifer taxa, cumulative percent of hyaline benthic foraminifer families, and estimated paleobathymetry of the Cerro de Almendral section. Hyaline benthic foraminifer families include (1) Nodosariacea, (2) Buliminacea, (3) Discorbacea, (4) Rotalinacea, (5) Orbitoidacea, (6) Cassidulinacea, and (7) other.

centages in sample +120 m. Only a general paleobathymetric interpretation of bathyal water depths can be made on the basis of these few occurrences of depth-diagnostic species. Analysis of the benthic foraminifers on the superfamily level, which can serve as a general indication of the paleobathymetry (Sliter, 1977), suggests a depth interpretation of upper bathyal for the rocks above the gypsum. According to Sliter (1977), the Buliminacea dominate the upper bathyal zone and decrease in abundance with increasing water depth. The Cassidulinacea, on the other hand, are less abundant in the upper bathyal zone than at greater depths. These two super-families comprise over 65 percent of the benthic fauna in each sample analyzed in the Cerro de Almendral section (fig. 5). Below the gypsum, the Cassidulinacea are slightly more abundant than the Buliminacea. Above the gypsum, the Buliminacea increase dramatically in relative abundance (from 33 to 88 percent), and the Cassidulinacea show the reverse trend (from 33 to 6 percent). Following Sliter (1977), these trends indicate a change from middle to upper bathyal water depths. Typical shallow-water (neritic) species of Miliolacea, Robertinacea, Lituolacea, and large Nodosariacea (Sliter and Baker, 1972; Sliter, 1976) are rare or absent.

Some downslope transport in the preevaporitic part of the Cerro de Almendral section is suggested by the occurrence of abraded shallow-water benthic foraminifers such as *Elphidium crispum* (Linne), *Elphidium* sp., *Discorbinella bertheloti* (d'Orbigny), and *Florilus boueanum* (d'Orbigny). The very sparse and sporadic occurrences of these taxa, however, indicate that downslope transport was minimal. Above the gypsum (sample +120 m), only a few abraded *Elphidium* sp. were found.

In summary, data from the preevaporite part of the Cerro de Almendral section indicate uniform middle bathyal water depths of 600-1,000 m, probably closer to 1,000 m, whereas limited data from above the gypsum indicate upper bathyal (200-600 m) water depths. Analysis of the foraminiferal faunas below the gypsum provides no evidence for shallowing upsection. We therefore conclude that the gypsum was deposited in a preexisting basin having about 800-1,000 m of relief.

## DISCUSSION

Sedimentary deposits directly referable to the Messinian *Globorotalia conomiozea* Zone are present in a series of basins extending from Alicante south to Almería (Montenat and others, 1976; Bizon and others, 1972; Iaccarino and others, 1975). The similarity of Messinian planktic assemblages from these basins indicates that these basins were interconnected during much of the Messinian, together representing the east end of the Betic Straits. There are, however, differences in the depositional histories of these basins. For example, in the Sorbas Basin, just north of the Almería Basin, cyclic evaporite deposits are 70-100 m thick, and deeper water sedimentary deposits directly underneath these evaporites are upper bathyal (Iaccarino and others, 1975; Dronkert, 1976). In the Vera Basin, 50 km northeast of the Almería Basin, evaporites do not occur in an apparently continuous section across the Miocene-Pliocene boundary. In the Cuevas del Almanzora section of the Vera Basin, laminated sedimentary deposits at the top of the *Globorotalia conomiozea* Zone contain an impoverished benthic fauna but a rich planktic fauna. These laminated sedimentary deposits in this apparently continuous depositional sequence grade upward into bioturbated sedimentary deposits containing a more diverse benthic fauna and planktic foraminifers of the basal Pliocene *Globorotalia margaritae* Zone (Montenat and others, 1976). Water depths are thought to have been upper bathyal throughout this time. The laminated sedimentary deposits represent deposition in a silled basin that became stratified in the latest Miocene because of greatly restricted access to normal marine waters. Restoration of free access to marine waters at or near the beginning of the Pilocene resulted in well-oxygenated bottom waters and consequently a diverse benthic fauna (Montenat and others, 1976).

In summary, the east end of the Betic Straits during the Messinian is best viewed as a series of semi-isolated basins of various depths that became progressively more isolated toward the end of the Messinian.

The amount of evaporites, if any, accumulated in each basin was controlled by the degree and length of time of isolation. Moreover, if the interpretation of the Cuevas de Almanzora section by Montenat and others (1976) is correct, the Betic Straits and thus the Mediterranean Sea were never totally isolated from the Atlantic Ocean during the Miocene.

## TAXONOMIC NOTES

In the following section, comments for selected planktic foraminifers are followed by brief notes concerning benthic foraminifers used for paleobathymetric interpretations.

### PLANKTIC FORAMINIFERS

#### *GLOBIGERINA WOODI* (JENKINS, 1960)

Plate 2, figures 1, 2

*Globigerina woodi* is widely reported from southern Spain. This species ranges through the Miocene and becomes extinct during the early Pliocene. The occurrence of *Globigerina woodi* in sample +120 m sets an upper age limit of early Pliocene for sedimentary deposits above the gypsum in the Cerro de Almendral section. The form illustrated as *Globigerina riveroae* Bolli and Bermudez by Montenat and others (1976, pl. 3) is referable to *G. woodi.*

#### *GLOBOROTALIA CONOMIOZEA* (KENNETT, 1966)

Plate 1, figures 1-3

*Globorotalia conomiozea* is one end member of an important group of late Neogene keeled globorotaliids that evolved from *G. miozea* Finlay. Other members of this plexus include *Globorotalia conoidea* Walters, *G. saphoae* Bizon, *G. mediterranea* Catalano and Sprovieri, and perhaps, *G. saheliana* Catalano and Sprovieri. A recent discussion of the taxonomy of this plexus and the problems of separating end members is given by Berggren (1977). Because much of our material is poorly preserved, we have referred individuals of this group with <5 chambers in the ultimate whorl to *Globorotalia conomiozea* and individuals with ≥5 chambers in the ultimate whorl to *G. conoidea* (see pl. 1).

#### *GLOBOROTALIA MENARDII*
#### (PARKER AND OTHERS, 1865)

Plate 1, figures 7-9

Considerable confusion surrounds the taxonomy of late Miocene "menardii-like" keeled globorotaliids. Because our material is not particularly well preserved, we have employed a broad concept of *Globorotalia menardii* in this study.

#### *NEOGLOBOQUADRINA ACOSTAENSIS*
#### (BLOW, 1959)

Plate 1, figures 10-12

*Neogloboquadrina acostaensis* is one of the more abundant taxa in the Cerro de Almendral section. This taxon shows a change in coiling preference from sinistral to dextral between samples +90 m and +120 m. This coiling change is used to correlate to the Miocene-Pliocene boundary in the Mediterranean area (Zachariasse, 1975; Montenat and others, 1976).

### BENTHIC FORAMINIFERS

#### *PLANULINA ARIMINENSIS* (D'ORBIGNY, 1826)

Plate 2, figures 4-6

*Planulina ariminensis* is characterized by its compressed, essentially flat test, thick curved limbate sutures, and coarse punctae on one side of the test.

This taxon is the second most abundant benthic species in our samples, with frequencies ranging from 1.3 to 12.3 percent. In the neritic to middle bathyal stratotype of the Andalusian Stage on the Southwest coast of southern Spain, *Planulina ariminensis* is the dominant benthic species (Berggren and Haq, 1976), whereas in the nearby lower bathyal El Cuervo section, *P. ariminensis* is replaced by the deeper dwelling *P. wuellerstorfi* (Schwager) (Berggren and others, 1976). Berggren and others (1976) thus suggest that the distribution of these two species provide a means of distinguishing middle to upper bathyal depths from lower bathyal and greater depths.

Parker (1958) found *Planulina ariminensis* at depths between 106 and 1,016 meters in the eastern Mediterranean, and Phleger and Parker (1951) noted *P. ariminensis* from 275 to 2,925 meters in the North Atlantic. Two studies in the Gulf of Mexico (Parker, 1954; Pflum and Frerichs, 1976) show that *Planulina ariminensis* is characteristic of middle and upper bathyal water depths with an upper depth of about 200 m.

### *CIBICIDOIDES MEDIOCRIS* (FINLAY, 1940)

Plate 2, figures 3, 7

*Cibicidoides mediocris* is the most common benthic species in our samples, ranging in abundance from 1 to 18 percent; in four samples the frequency is over 10 percent. This distinctive species is also a dominant component of the El Cuervo section of southwestern Spain (Berggren and others, 1976) and the Andalusian stratotype (Berggren and Haq, 1976).

Cushman (1931) reported the occurrence of this taxon [identified as *Cibicides pseudoungeriana* (Cushman)] in the western Atlantic Ocean at depths between 23 and 2,369 fathoms, but mostly below 500 fathoms. Pflum and Frerichs (1976, figure 14) show the distribution of this taxon [identified as *Cibicides* cf. *C. pseudoungerianus* (Cushman)] as ranging throughout bathyal water depths. Berggren and others (1976) consider *Cibicidoides mediocris* as a useful marker for bathyal depths that increases in frequency with increasing depth.

### *GYROIDINOIDES NEOSOLDANII* (BROTZEN, 1936)

Plate 2, figures 12-14

*Gyroidinoides neosoldanii* is distinguished by its circular outline, medium whorl size with the outer whorl somewhat narrower than the others in larger individuals, closed umbilicus except in larger individuals where the umbilicus is narrow and deep, and channeling of the outer whorl in larger individuals. *Gyroidinoides neosoldanii* is the most common gyroidinid in our samples, ranging in frequency from 0.7 to 4.7 percent.

Parker (1954) recorded *G. neosoldanii* in the northeast Gulf of Mexico with frequencies of 1-5 percent below 585 m and frequencies of less than 1 percent above that depth. Parker (1958) also recorded this species in the eastern Mediterranean (as *Gyroidina* cf. *G. neosoldanii*), where its distribution ranged from 106 to 2,738 m, generally deeper than 200 m and with its highest frequencies deeper than 650 m.

### *UVIGERINA PYGMAEA* (D'ORBIGNY, 1826) *UVIGERINA HISPIDO-COSTATA* (CUSHMAN AND TODD, 1945) GROUP

Plate 2, figures 8-11

This group of uvigerinids reflects a morphologic gradation between forms that are entirely costate (*U. pygmaea*) and forms that are costate but terminally hispid (*U. hispido-costata*). The tests are generally robust and compact, with narrow, prominent costae. Chambers are low and numerous, the later-formed ones being somewhat more inflated. Both *Uvigerina pygmaea* and *U. hispido-costata* occur in the four samples examined for benthic foraminifers below the gypsum, but neither occurs in sample +120 m. This group is also common in the middle bathyal to neritic Andalusian stratotype (Berggren and Haq, 1976) but is absent in the lower bathyal El Cuervo section (Berggren and others, 1976).

Bandy (1956) reported *Uvigerina hispido-costata* from the north-east Gulf of Mexico, where it is diagnostic of water depths of 400-600 m and increases in abundance with increasing depth. The development of hispid ornamentation is generally considered to indicate bathyal depths with an upper depth limit of about 600-1,000 m (Bandy, 1964; Pflum and Frerichs, 1976; Berggren and Haq, 1976).

### *PULLENIA BULLOIDES* (D'ORBIGNY, 1826)

*Pullenia bulloides,* a very distinctive taxon, occurs in three of the five samples studied for benthic foraminifers, with frequencies ranging from 2 to 3 percent.

Parker (1954) reported *Pullenia bulloides* in the northeastern Gulf of Mexico with frequencies of 1 to 2 percent at depths greater than 900 m and frequencies of less than 1 percent at shallower depths. Berggren and others (1976) consider *Pullenia bulloides* to occur in predominantly middle to lower bathyal water depths.

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# INDEX

[Italic numbers indicate major references and descriptions]

# PLATES 1 AND 2

Contact photographs of the plates in this report are available, at cost,
from U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225

# PLATE 1

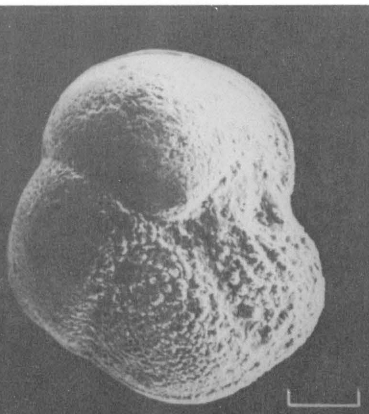
[Planktic foraminifers from the Cerro de Almendral section. All specimens are from sample +30 m. Scale bar = 100 μm for all figures.]

FIGURES 1-3. *Globorotalia conomiozea* Kennet. 1, umbilical view. 2, side view. 3, spiral view of fig. 1.

4-6. *Globorotalia conoidea* Walters. 4, umbilical view. 5, side view. 6, spiral view of fig. 5.

7-9. *Globorotalia menardii* (Parker, Jones, and Brady) (s. 1). 7, umbilical view. 8, side view. 9, spiral view of fig. 7.

10-12. *Neogloboquadrina acostaensis* (Blow). 10, umbilical view. 11, spiral view. 12, umbilical view.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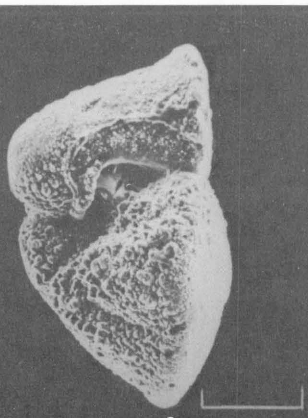
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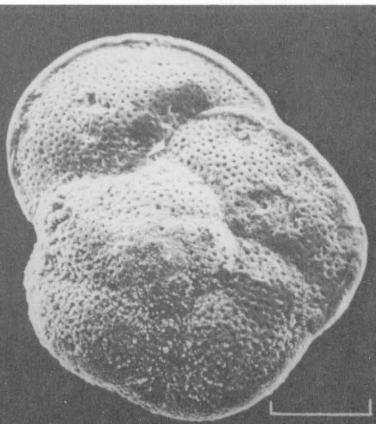
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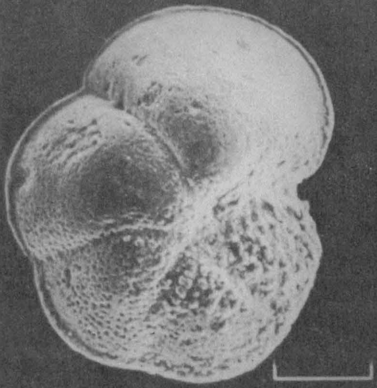
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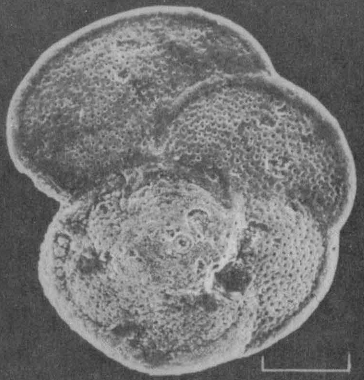
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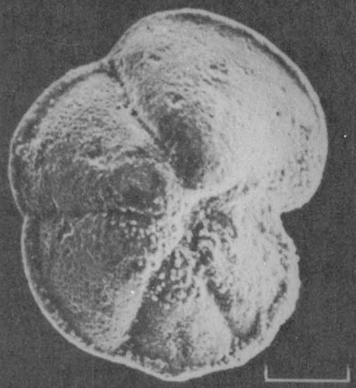
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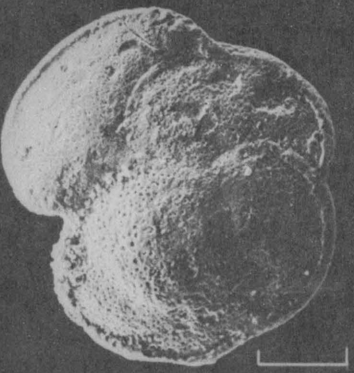
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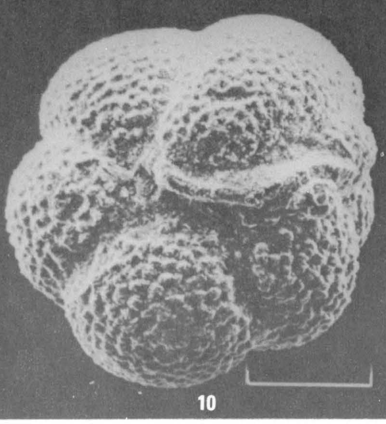
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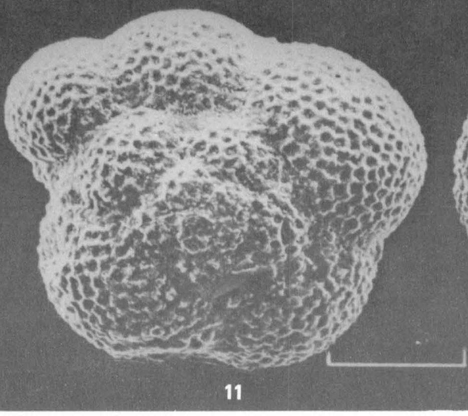
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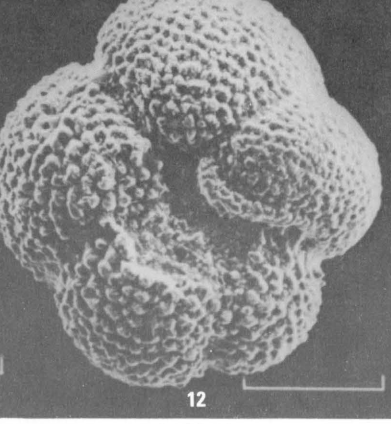
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PLANKTIC FORAMINIFERS FROM THE CERRO DE ALMENDRAL SECTION

# PLATE 2

[Planktic and benthic foraminifers from the Cerro de Almendral section. Figures 1 and 2 are from sample +30 m. All other specimens are from sample +45 m. Scale bar = 100 μm for all.]

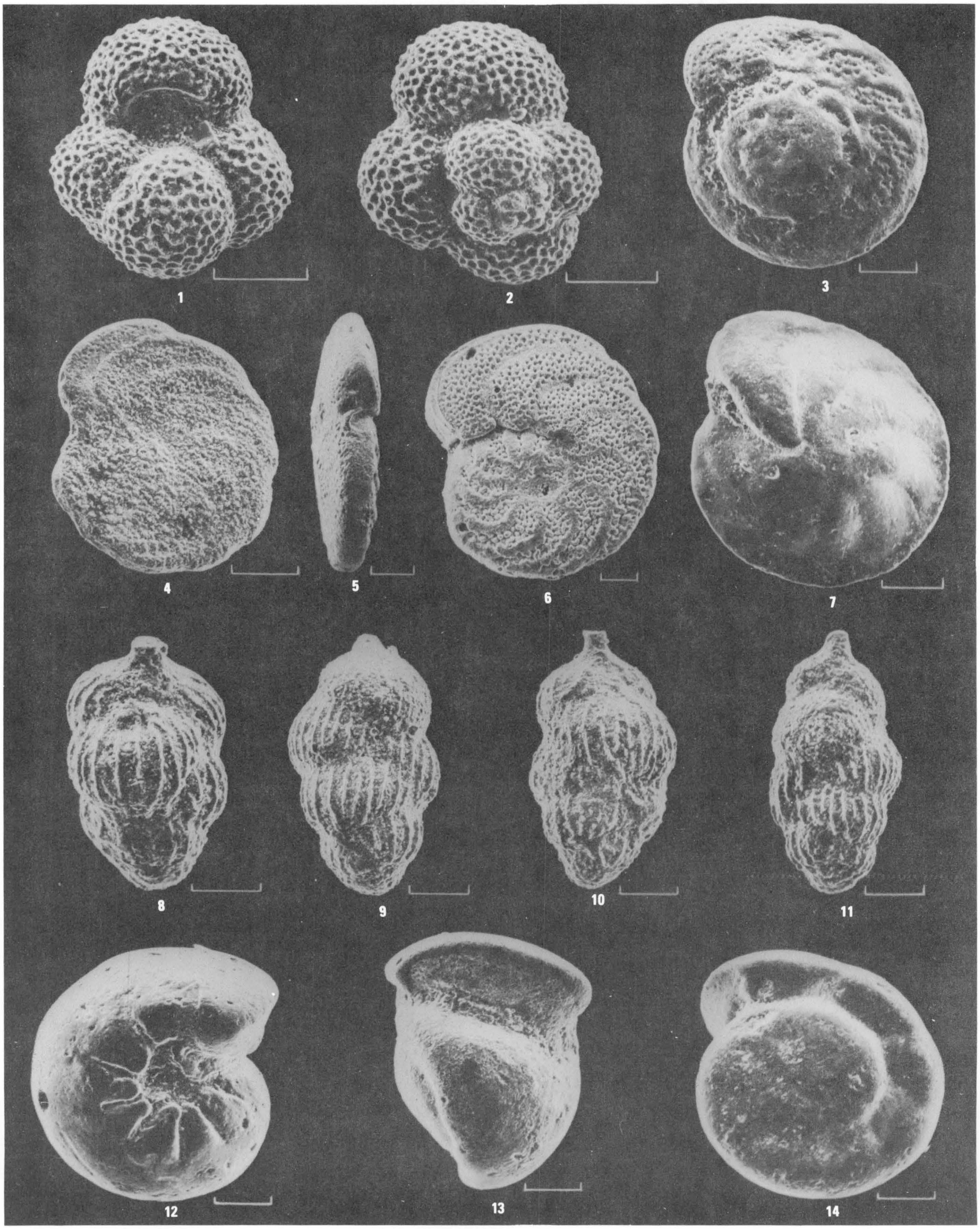
FIGURES 1, 2. *Globigerina woodi* Jenkins. 1, umbilical view. 2, spiral view of fig. 1.

3, 7. *Cibicidoides mediocris* (Finlay). 3, spiral view. 7, umbilical view.

4-6. *Planulina ariminensis* (d'Orbigny). 4, spiral view. 5, side view. 6, umbilical view.

8-11. *Uvigerina pygmaea* (d'Orbigny) *Uvigerina hispido-costata* (Cushman and Todd) group. 8-11, side views. Note variation in ornamentation from all costate to terminally hispid.

12-14. *Gyroidinoides neosoldanii* (Brotzen). 12, umbilical view. 13, side view. 14, spiral view.



*PLANKTIC AND BENTHIC FORAMINIFERS FROM THE CERRO DE ALMENDRAL SECTION*