# Age and Correlation of California Paleogene Benthic Foraminiferal Stages

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# ILLUSTRATIONS

# AGE AND CORRELATION OF CALIFORNIA PALEOGENE BENTHIC FORAMINIFERAL STAGES

By Richard Z. Poore

ABSTRACT

Comparisons of age determinations and correlations derived from calcareous plankton with those derived from benthic foraminifers in a number of sections in California show significant overlap in time of the Ynezian through the Ulatisian Stages. Thus interbasin time correlations deduced from these stage assignments must be treated with caution.

Calcareous plankton occasionally associated with benthic foraminifers diagnostic of the Narizian through the Zemorrian Stages indicate that the Narizian-Refugian boundary is within the upper Eocene of international usage and that the Refugian is entirely upper Eocene. Overlap of the Narizian and the Refugian appears to be minimal. The Zemorrian correlates, mostly, with the Oligocene, although the upper limit of the Zemorrian might be in the lower Miocene.

## INTRODUCTION

Age assignments and correlation of Paleogene marine strata of California are usually accomplished through the use of the benthic foraminiferal stages of Schenck and Kleinpell (1936), Kleinpell (1938), and Mallory (1959) (fig. 1). Although type sections or areas are designated for these stages, they are recognized and defined, in large part, by associations of benthic foraminifers (Oppel-zones). Thus, outside of the type section or area, assignment of strata to a stage and the resultant age assignment and correlation to other strata are derived from benthic foraminiferal assemblages. An increasing body of data on calcareous plankton (planktic foraminifers and calcareous nannofossils) found associated with benthic foraminifers shows that the traditional age assignments of these benthic foraminiferal stages need revision and, more important, that correlations made by equating stage assignments in different sections may be significantly time-transgressive.

This paper documents in terms of calcareous plankton the range in age of benthic foraminiferal assemblages characteristic of the benthic stages and thereby determines the reliability of these benthic foraminiferal assemblages for interbasin time-stratigraphic correlations. This report represents an initial part of an ongoing project aimed at developing an interrelated set of biostratigraphic zonations based on various microfossil groups suitable for use in the Pacific Coast Province.

## ACKNOWLEDGMENTS

I thank David Bukry, Kristin McDougall, and W. V. Sliter for discussions and suggestions concerning this manuscript. A. D. Warren kindly provided access to data in press on calcareous nannofossils in the Arroyo el Bulito and San Lorenzo River sections.

## PLANKTIC ZONATIONS AND AGE ASSIGNMENTS

Hardenbol and Berggren (1978) have formulated a Paleogene time scale that correlates the planktic foraminiferal zonation of Blow (1969) and Berggren (1969, 1972) with the calcareous nannofossil zonation of Martini (1971) and further relates these zonations to standard ages guided by nannofossil data derived from European stage type sections. For the purposes of this paper the time scale of Hardenbol and Berggren (1978) is accepted as the standard (fig. 2). Because I prefer the nannofossil zonation of Bukry (1975) to that of Martini (1971), Bukry's zonation is also plotted on figure 2, and nannofossil assemblages discussed below are reported in terms of Bukry's zonations. Subzones of Bukry (1975), however, are not used as these subzones are often difficult to resolve in California sections, and the finer resolution gained by their use is not critical to this study.

Note that possible sources of error in the time scale of Hardenbol and Berggren (1978) include correlation of the nannofossil and foraminiferal zonations to one another and correlation of the combined zonations to standard ages. Nonetheless, the scheme of Hardenbol and Berggren represents the best biostratigraphic standard available to evaluate the time-stratigraphic significance of the benthic foraminiferal assemblages used to recognize the California stages.

| Epoch | | Benthic foraminiferal stage |
|---|---|---|
| Miocene | Early | Saucesian |
| Oligocene | | Zemorrian |
| | | Refugian |
| Eocene | Late | Narizian |
| | Middle | Ulatisian |
| | Early | Penutian |
| Paleocene | Late | Bulitian |
| | Early | Ynezian |

FIGURE 1.—California Paleogene benthic foraminiferal stages and their generally accepted age assignments. Both mollusks and benthic foraminifers were originally used to characterize the Refugian Stage.

### YNEZIAN TO NARIZIAN STAGES

I have reinterpreted and synthesized data for benthic foraminifers, planktic foraminifers, and calcareous nannofossils for several lower Tertiary sections (fig. 3, 1–12) covering a wide geographic area of California (Poore, 1976). Results of that study indicated that the ages of benthic foraminiferal stages as recognized in these sections could vary significantly. For example, benthic foraminifers indicative of the Bulitian Stage are associated, depending upon the section examined, with nannofossils of the upper Paleocene *Discoaster multiradiatus* Zone through the upper lower Eocene *Discoaster lodoensis* Zone, whereas benthic foraminifers indicative of the Penutian Stage are associated with nannofossils of the lower Eocene *Tribrachiatus orthostylus* Zone through the middle Eocene *Discoaster sublodoensis* Zone. Both Bulitian and Penutian benthic foraminiferal assemblages are associated with nannofossils of the *Tribrachiatus orthostylus* Zone and the *Discoaster lodoensis* Zone. The correlations of benthic foraminiferal stage assignments and calcareous nannofossil zones from the sections covered by Poore (1976) are shown on figure 4. Planktic foraminiferal assemblages in two of these sections contained diagnostic taxa that allowed reliable zone assignments. These planktic foraminifer zone assignments are compatible with age assignments and correlations between sections indicated by calcareous nannofossils (fig. 5).

Additional information concerning correlation of early Paleogene benthic foraminiferal assemblages that are diagnostic of California benthic foraminiferal stages to planktic zonations comes from the lower part of the Arroyo el Bulito section in the Santa Ynez Mountains (Gibson, 1976). My present interpretation (fig. 6) of the foraminiferal data, however, differs slightly from that given by Gibson (1976, tables 2 and 3). Briefly, changes in interpretation of planktic foraminifer data include: (1) removal of Zone P 1–P 3 assignment for samples 67–81b because the assemblages reported are too sparse to allow confident zone assignments, (2) placing the top of Zone P 4 between samples 34 and 34a because the last occurrence of *Planorotalites pseudomenardii* (Bolli) is in sample 34a, (3) correlating samples 11 through 20 with Zone P 8 because of the lowest occurence of *"Subbotina" senni* (Beckmann) in sample 20 followed by the highest occurence of *Morozovella formosa formosa* (Bolli) in sample 11, and (4) correlating sample 1 with Zone P 11 because the assemblage from this sample contains *Globigerinatheka index rubriformis* (Subbotina).

The only change to Gibson's benthic foraminiferal stage assigments is in placing the Penutian-Ulatisian boundary between samples 24 and 25 because a distinct faunal change which includes the lowest occurrence of *Anomalina midwayensis* (Plummer) and *Dentalina delicatula* Cushman in sample 24 (Kristin McDougall, oral commun., 1978) occurs between these samples.

Correlation of California stage assignments and planktic zones for the lower part of the Arroyo el Bulito section shown on figure 6 are plotted on figures 4 and 5. Also shown on figure 4 are the association of calcareous nannofossil zones and the benthic foraminiferal stage assignments in the Devils Den aqueduct section (Warren, 1980) and those reported for several localities in the Coast Ranges of California by Bukry, Brabb, and Vedder (1977). Note that the results from the Arroyo el Bulito section suggest older ages for the Penutian and Ulatisian Stages than the other studies.

Even if one considers data from the Arroyo el Bulito section an anomaly and removes them from figures 4 and 5, there is still significant overlap of many of the benthic foraminiferal stages. On the other hand, the Ulatisian-Narizian boundary closely coincides with the *Discoaster sublodoensis* Zone-*Nannotetrina quadrata* Zone boundary in all sections. Thus correlations made by equating the Ulatisian-Narizian transition in different sections are probably reliable and according to the time scale of Hardenbol and Berggren (1978; see fig. 2), the Ulatisian-Narizian boundary approximates,

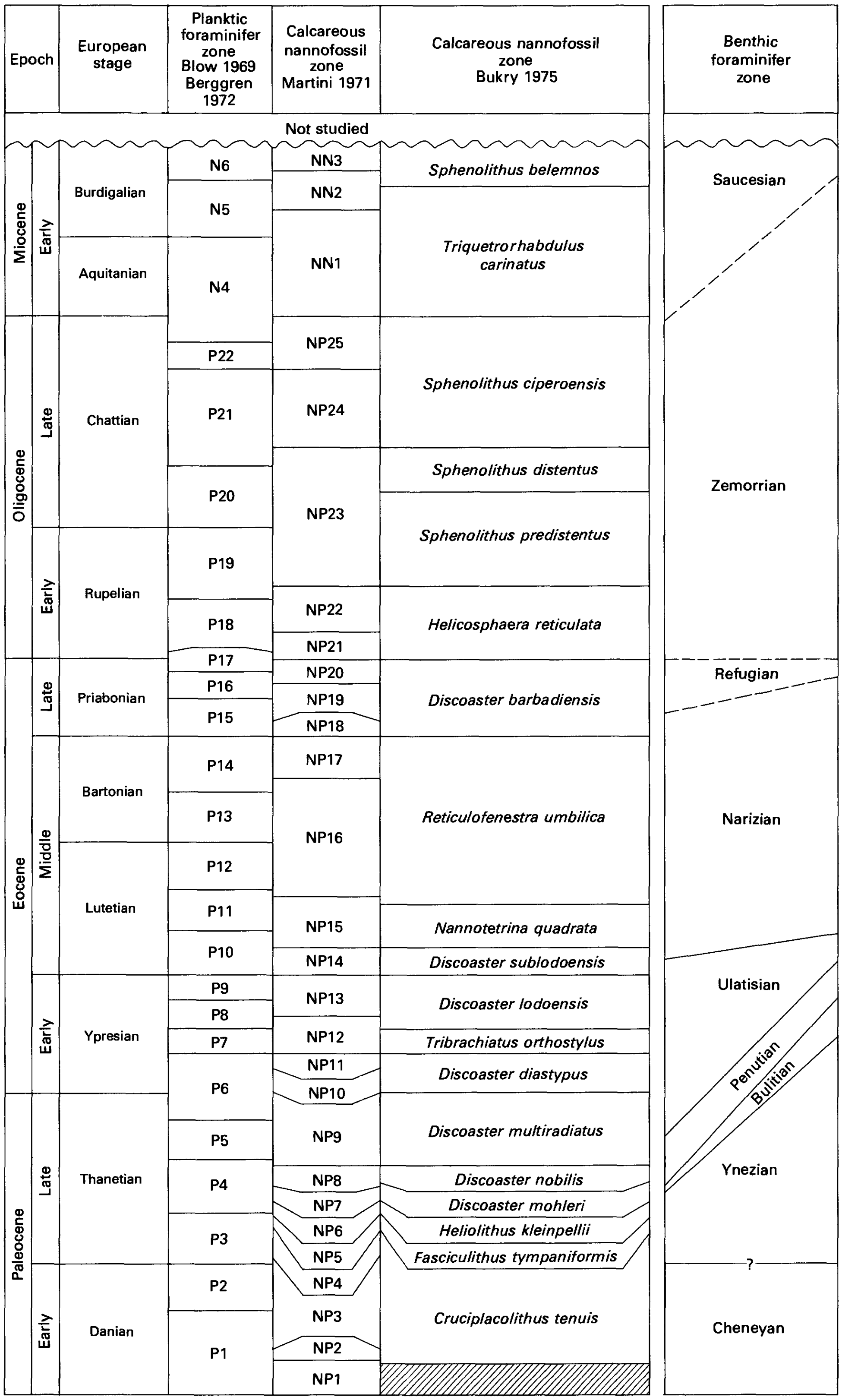
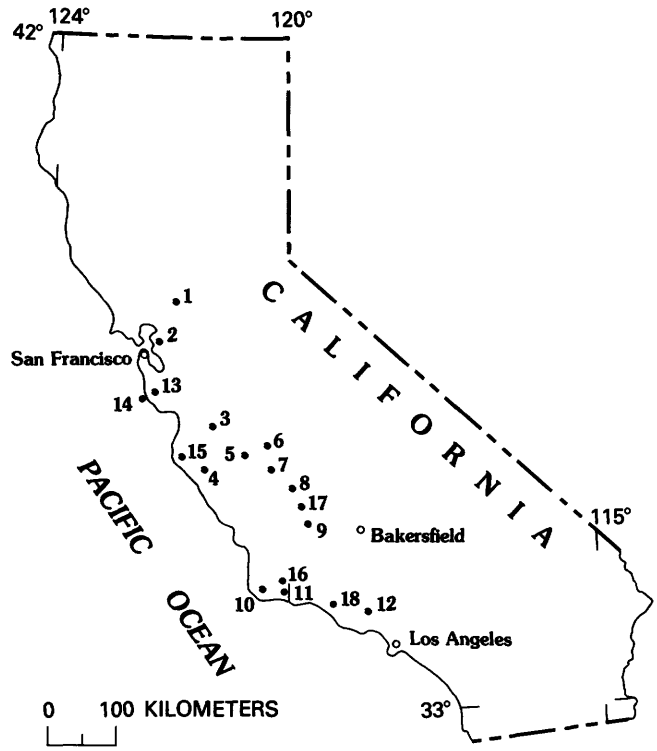



FIGURE 2.—Correlation of planktic foraminiferal zonation and calcareous nannofossil zonations with California Paleogene benthic foraminiferal stages. Columns 1 through 4 from Hardenbol and Berggren (1978) for the Paleogene, and Ryan and others (1975) for the Miocene. Correlation of Bukry's zonation to Martini's zonation follows Bukry (1978). Correlation of benthic foraminiferal stages to calcareous plankton zonations is discussed in text. Dashed lines denote areas where data points are limited.




EXPLANATION

1. Vaca Valley
2. Pacheco syncline
3. Tres Pinos
4. Upper Reliz Creek (Reliz Canyon)
5. New Idria
6. Lodo Gulch
7. Oil City
8. Garza Creek
9. Media Aqua Creek
10. Upper Cañada de Santa Anita
11. Las Cruces
12. Simi Valley
13. San Lorenzo River, Zayante Creek, and Kings Creek sections, Santa Cruz Mountains
14. Año Nuevo section
15. Northern Santa Lucia Range
16. Arroyo el Bulito section, Santa Ynez Mountains
17. Devils Den aqueduct section
18. Los Sauces Creek

FIGURE 3.—General location of sections and areas discussed in text. Modified from Poore, 1976.

but is slightly younger than, the lower Eocene-middle Eocene boundary of international usage.

## NARIZIAN STAGE

In the previous section it was shown that the lower limit of the Narizian Stage approximates the lower Eocene-middle Eocene boundary. Data allowing estimation of the upper limit of the Narizian Stage are available from the Santa Ynez Mountains and the Santa Cruz Mountains.

Warren and Newell (1980) studied calcareous nannofossils from the upper part of the Arroyo el Bulito section in the Santa Ynez Mountains. Here they found the *Reticulofenestra umbilica* Zone-*Discoaster barbadiensis* Zone boundary within the upper Narizian stage.

Similar results were obtained from sections in the Santa Cruz Mountains. Studies of calcareous plankton from the San Lorenzo River section (Poore and Brabb, 1977; Poore and Bukry, 1980) show that the planktic foraminifer Zone P 14–Zone P 15 boundary and the calcareous nannofossil *Reticulofenestra umbilica* Zone-*Discoaster barbadiensis* Zone boundary occur at about the same stratigraphic level within rocks assigned to the Narizian Stage. The observations made at the San Lorenzo River section are corroborated in the nearby Kings Creek section where nannofossils from a sample containing lower Narizian benthic foraminifers are assigned to the middle Eocene *Reticulofenestra umbilica* Zone (Bukry and others, 1977) whereas planktic foraminifers from a sample higher up in the section containing upper Narizian benthic foraminifers are referable to upper Eocene Zone P 15 or Zone P 16 (Poore and Bukry, 1980).

Following the correlation of Hardenbol and Berggren (1978), these data from the Santa Ynez Mountains and the Santa Cruz Mountains (figs. 7 and 8) indicate that the upper limit of benthic foraminiferal assemblages characteristic of the Narizian Stage is in the upper Eocene of international usage (fig. 2).

## REFUGIAN STAGE

In the Arroyo el Bulito section in the Santa Ynez Mountains, nannofossils of the *Discoaster barbadiensis* Zone are associated the Refugian benthic foraminifers (Warren and Newell, 1980; Lipps and Kalisky, 1972).

The Church Creek Formation in the northern Santa Lucia Range yields benthic foraminifers characteristic of the Refugian Stage and nannofossils of the *Discoaster barbadiensis* Zone (Brabb and others, 1971). In addition, planktic foraminifers from several localities in the Church Creek Formation are correlative with Zones P 16 or P 17 (Poore and Bukry, 1980).

A final correlation point for the Refugian Stage is derived from the San Lorenzo River section of the Santa Cruz Mountains. Here Warren and Newell (1980) recorded a sparse nannofossil assemblage referable to the *Discoaster barbadiensis* Zone associated with Refugian benthic foraminifers.

These data (figs. 7 and 8), albeit limited, indicate that the Refugian Stage is upper Eocene.

## ZEMORRIAN STAGE

Most of the data bearing on correlation of the Zemorrian Stage to planktic chronologies are found in the Santa Cruz Mountains.

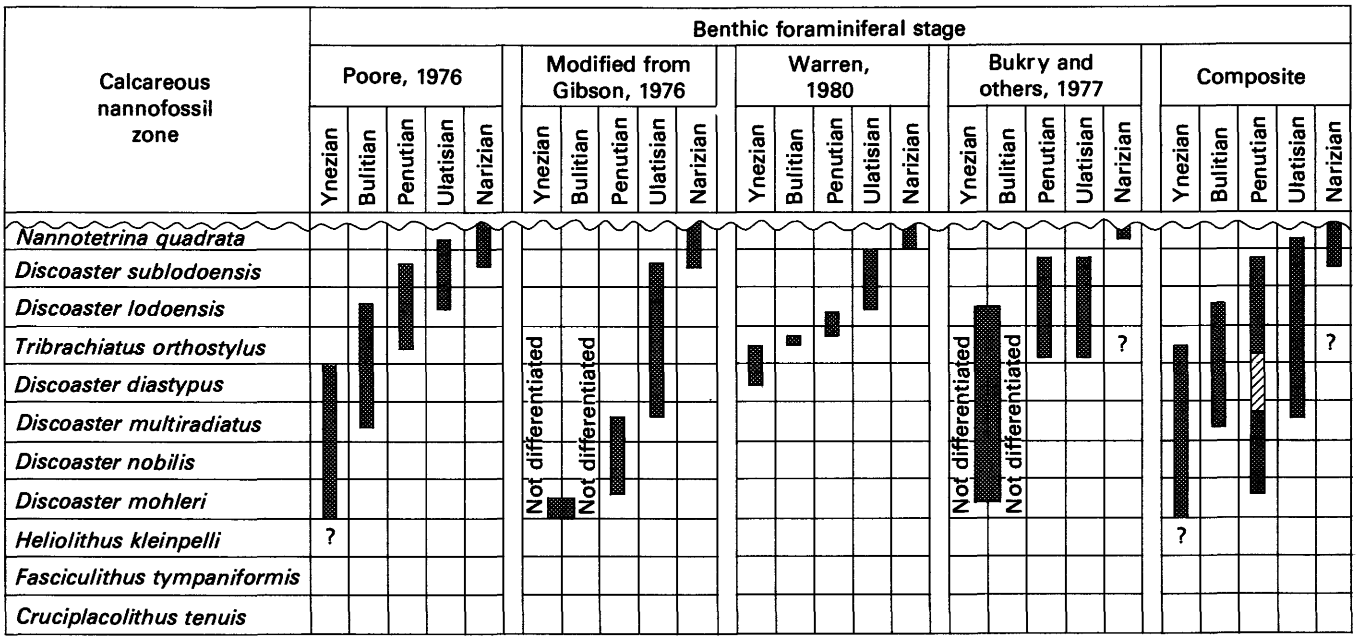



FIGURE 4.—Correlation of calcareous nannofossil zones with the benthic foraminiferal Ynezian to Narizian Stages. Heavy vertical bars delineate range of nannofossil zones associated with each stage. Diagonal lines delineate inferred association.

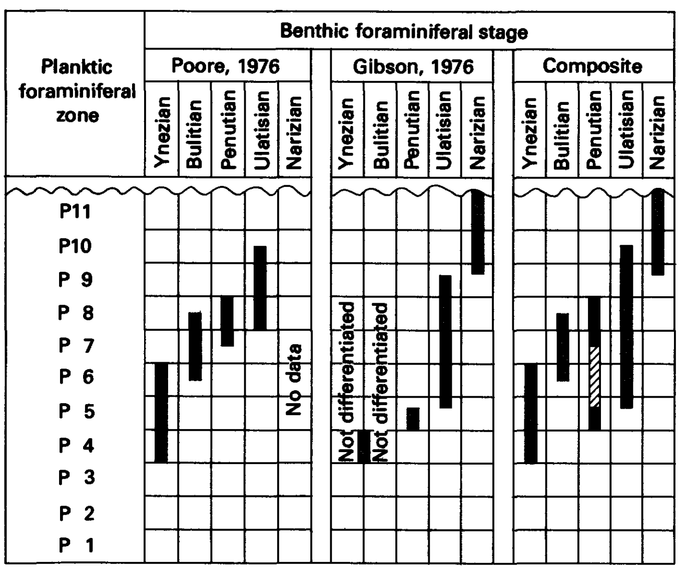



FIGURE 5.—Correlation of planktic foraminifer zones with the benthic foraminiferal Ynezian to Narizian Stages. Heavy vertical bars delineate range of foraminifer zones associated with each stage. Diagonal lines delineate inferred association.

In the San Lorenzo River section, Poore and Brabb (1977) record planktic foraminifers assigned to zonal interval P 19–P 20 associated with benthic foraminifers diagnostic of the Zemorrian Stage. Nannofossils from a sample in this same interval of the San Lorenzo River section were tentatively assigned to the *Sphenolithus distentus* Zone by Bukry, Brabb, and Vedder (1977). These authors reported nannofossils suggesting a generalized upper Oligocene (*Sphenolithus predistentus* Zone to *Sphenolithus ciperoensis* Zone) position from two samples yielding Zemorrian benthic foraminifers at nearby Mountain Charlie Gulch. Similarly, Poore and Bukry (1980) recorded upper Oligocene (*Sphenolithus predistentus* Zone to *Sphenolithus ciperoensis* Zone) nannofossils from samples assigned to the Zemorrian Stage at the Zayante Creek section and nannofossils of the *Sphenolithus ciperoensis* Zone from Zemorrian rocks at the nearby coastal Año Nuevo section.

Outside of the Santa Cruz Mountains, published data on the occurrence of calcareous plankton in rocks assigned to the Zemorrian Stage are sparse. Lipps and Kalisky (1972) recorded *Dictyococcites bisectus* (Hay, Mohler, and Wade) (listed as *Reticulofenestra scissura* Hay, Mohler, and Wade) from upper Zemorrian rocks at Los Sauces Creek. The occurrence of *Dictyococcites bisectus* indicates that the Zemorrian here is no younger than Oligocene, but the calcareous nannofossil assemblage Lipps and Kalisky (1972, fig. 6) recorded cannot be assigned to a specific zone or zonal interval on their own. Although planktic foraminifers from the Zemorrian rocks at Los Sauces Creek recorded by Lipps (1964, 1966, 1967a, 1967b) are not especially diagnostic, Lamb and Hickernell (1972) recorded sparse specimens of *Globigerinoides primordius* Blow and Banner from this locality. The association of *Dictyococcites bisectus* and *Globigerinoides primordius* indicates an upper Oligocene Zone P 23 to N 4 and

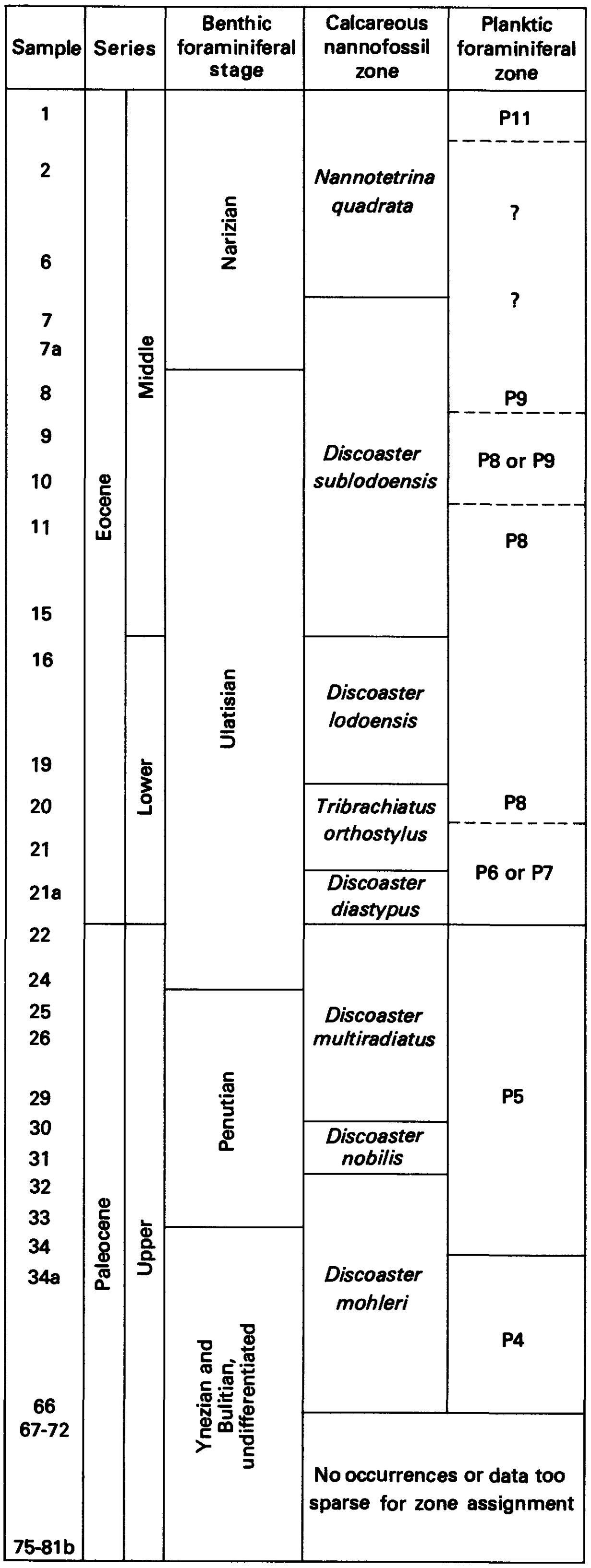



FIGURE 6.—Benthic foraminiferal stages, and planktic foraminifer and calcareous nannofossil zone assignments for lower part of Arroyo el Bulito section. See Gibson (1976, fig. 3) for stratigraphic column and sample locations.

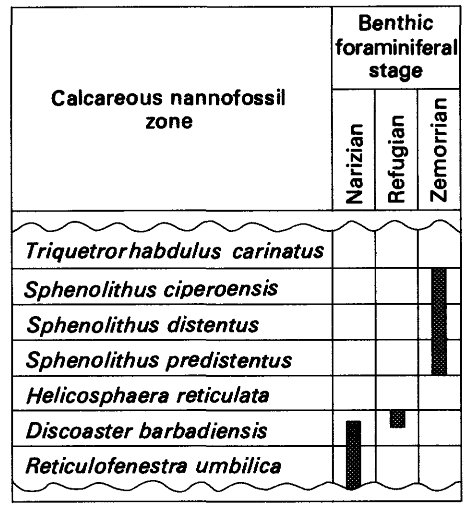



FIGURE 7.—Correlation of calcareous nannofossil zones with the Narizian through Zemorrian Stages. Heavy vertical bars delineate range of nannofossil zones associated with each benthic foraminiferal stage.

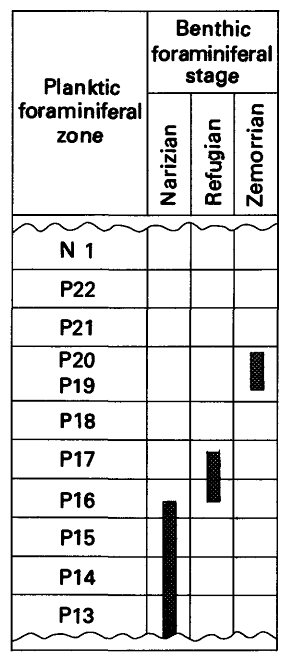



FIGURE 8.—Correlation of planktic foraminifer zones with the Narizian through Zemorrian Stages. Heavy vertical bars delineate range of planktic foraminifer zones associated with each benthic foraminiferal stage.

*Sphenolithus ciperoensis* Zone assignment for these Zemorrian rocks.

Aside from the data from Los Sauces Creek and the Santa Cruz Mountains, there is no documentation of direct association of stratigraphically diagnostic calcareous plankton with benthic foraminifers diagnostic of the Zemorrian Stage in California onshore sections.

Thus, the available data (figs. 7 and 8) indicate correlation of the Zemorrian Stage at least in part with the Oligocene.

The upper limit of the Zemorrian Stage can be estimated from the occurrence of calcareous plankton in rocks assigned to the Saucesian Stage. Calcareous nannofossils listed by Lipps and Kalisky (1972) from the lower (but not basal) type section of the Saucesian Stage at Los Sauces Creek are indicative of the lower Miocene *Sphenolithus belemnos* Zone. Bukry, Brabb, and Vedder (1977) also report nannofossils referable to the *Sphenolithus belemnos* Zone from samples assigned to the lower Saucesian in the San Rafael Mountains. Bandy, Morin, and Wright (1969) recorded planktic foraminifers from the "upper part of the lower Saucesian" in Reliz Canyon that could be correlated with Zone N 5, which is in agreement with the stratigraphic assignment suggested by the nannofossils.

In the Año Nuevo section (fig. 3), a sample (Mf 4664) considered by McDougall (1980) to be very near the Zemorrian-Saucesian boundary, but still judged to represent the Zemorrian, yields nannofossils of the *Sphenolithus ciperoensis* Zone (Poore and Bukry, 1980). In a study of dart core samples from the California Continental Borderland, Crouch and Bukry (1979) report the association of Zemorrian benthic foraminifers (2 samples) and Saucesian benthic foraminiers (1 sample) with nannofossils of the *Sphenolithus belemnos* Zone. Therefore, the upper limit of Zemorrian Stage benthic foraminifers and the Zemorrian-Saucesian boundary appears to be within the interval from the *Sphenolithus ciperoensis* Zone through the *Sphenolithus belemnos* Zone (fig. 2).

## DISCUSSION

The associations of calcareous plankton with benthic foraminifers characteristic of the California benthic foraminiferal stages shown in figures 4, 5, 7, and 8 were used to correlate these stages with the Hardenbol and Berggren time scale in figure 2.

In discussing the age assignment of his stages, Mallory (1959, p. 74) noted that his early Paleocene Ynezian Stage was younger than the European Danian Stage. The results of this study confirm his correlations. The only Danian (that is lower Paleocene of Hardenbol and Berggren) documented in California is from the type section of the Cheneyan Stage (of Goudkoff, 1945) in the Jergins Oil Company Cheney Ranch Well No. 1 (Loeblich, 1958). Planktic foraminifers reported from this well by Loeblich are referable to Zone P 1. The oldest determination for the Ynezian in this study was a questionable assignment to the *Heliolithus kleinpellii* Zone (fig. 4). Data are insufficient to estimate the upper limit of the Cheneyan Stage, and the Cheneyan Stage and the Ynezian Stage are separated by question marks on figure 2.

The correlations shown on figure 2 indicate that the Ynezian through Ulatisian Stages as currently recognized on the basis of benthic foraminifers are in large part coeval. Nannofossil data from this interval are substantial. Diagnostic planktic foraminifers in this interval, though more limited, corroborate the pattern and degree of time-overlap suggested for the benthic stages by calcareous nannofossils. Aside from minor discrepancies, the observed correspondence of planktic foraminifer and calcareous nannofossil zones closely matches the correlation proposed by Hardenbol and Berggren (1978) except for the *Discoaster sublodoensis* Zone. According to the model shown on figure 2, one would expect to find planktic foraminifers referable to Zone P 10 associated with nannofossils of the *Discoaster sublodoensis* Zone. In the Arroyo el Bulito section planktic foraminifers associated with the *Discoaster sublodoensis* Zone are assigned to Zones P 8 and P 9 (see fig. 6), and the same association occurs in the Media Agua Creek section (Poore, 1976). These discrepancies could be due to incorrect zone assignments for the planktic foraminifers, as in both sections the zone assignments are based on secondary rather than primary markers. Alternatively, these discrepancies may reflect miscorrelation of nannofossil and planktic foraminiferal zones by Hardenbol and Berggren (1978).

Fewer data are available for correlation of the Narizian, Refugian, and Zemorrian Stages, but where they occur together, age assignments indicated by planktic foraminifers and calcareous nannofossils are compatible. The Narizian Stage correlates with most of the middle Eocene and the lower part of the upper Eocene, and the Refugian Stage with the remainder of the upper Eocene. Ovelap of the Narizian Stage with the Refugian Stage appears to be minimal.

The Zemorrian Stage correlates with the Oligocene, though the upper limit of Zemorrian benthic foraminifers could be in the lower Miocene (probably no higher than the *Sphenolithus belemnos* Zone).

At the present time correlation points for determining the relation of the Refugian-Zemorrian boundary and the Zemorrian-Saucesian boundary to planktic microfossil zonations are sparse, and future work on these boundaries is necessary to establish more confident age relations.

In conclusion, it is clear that many if not all of the California Paleogene benthic foraminiferal stages as presently defined and recognized are in need of revision. Benthic foraminifers, however, cannot be abandoned as a correlation tool as they occur throughout most of the California marine section in abundance, whereas the occurrence of other microfossil groups is sporadic. Some of the type sections or areas of the benthic foraminiferal stages contain diagnostic calcareous plankton that could be used to fix these stages to an international standard such as the one proposed by Hardenbol and Berggren (1978). Such action, however, does little to solve the problem of interbasin correlations based on benthic foraminifers.

A more appropriate research strategy is to identify and study Pacific coast sections that contain planktic microfossils (calcareous or siliceous or both) and benthic foraminifers. By using planktic microfossils for time control, it should be possible to recognize benthic foraminiferal events suitable for defining a zonation (or zonations) that can be used for reliable time-stratigraphic correlation over a wide geographic area and in a variety of environments.

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