FORAMINIFERAL BIOSTRATIGRAPHY AND CORRELATIONS IN THE GULF OF ALASKA TERTIARY PROVINCE

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INTRODUCTION

As part of ongoing research by the U.S. Geological Survey on the geology and resource potential of the Gulf of Alaska Tertiary Province, a vast amount of data has been accumulated over the past 25 years on the lithology and paleontology of bedded rocks in the province. This report brings together available information on the occurrence, age, and paleoecological significance of benthonic foraminifers and presents correlations based on these data from 16 measured stratigraphic sections and 12 exploratory wells. Relatively few reports employing modern taxonomic methods developed during the past 40 years have been published on foraminiferal biostratigraphy of the Gulf of Alaska. Reports by Cushman (1941), Cushman and Todd (1947), Tappan (1951), Todd (1953), Loeblich and Tappan (1953), Todd (1957), Rau (1963), Cooper (1964), and Todd and Low (1967) are primarily concerned with taxonony, ecology and paleoecology, or the geologic age of assemblages from isolated outcrops. Almost no data have been published on foraminiferal correlations of measured sections and wells. Thus, the paucity of such information has prompted the synthesis and interpretation of foraminiferal data that provide the framework of correlation presented in this report. Some of the benthonic provincial stages that have been assigned to lower and middle parts of the Tertiary of other west coast areas are recognized for the Gulf of Alaska. Divisions for the upper part of the Tertiary are broad, but specific faunal occurrences are recognized as possible aids to correlations. Regional correlations presented in this report are necessarily broad and may be modified and refined when new data become available from the current round of exploratory drilling for petroleum in the offshore part of the Gulf of Alaska Tertiary Province.

It is anticipated that this report will be of particular interest to readers associated with petroleum exploration. As a convenience to them and because most foraminiferal data from wells, including those of this report, are from cuttings, all faunal lists were prepared by other workers. Most of the material on file in Anchorage, Alaska, at the State Division of Oil and Gas core library. Names used on the checklists for wells represent tentative identifications made without the aid of illustrated publications or type material. Names used on file in Anchorage from wells 2 and 22 were also examined, but additional slides and faunal lists made by other workers were available for more careful study. Only faunal lists prepared by other workers were available for study in Anchorage. Some names have been changed to conform with species concepts used in this report. In the checklists, names are among those preceded by a query, indicating uncertainty of identification. No checklist has been prepared for well 25 because so little data were available. For each measured section (except 28 and 30, for which no foraminiferal data are available) and for all wells not included above, faunal slides were available for detailed study with comparative materials and publications.

ACKNOWLEDGMENTS

The unpublished pioneer studies and interagency reports of a number of micropaleontologists have contributed much to this report. Among these are the late Patsy J. Smith, Helen Tappan Loeblich, and particularly Ruth Todd and Doris Low, who not only made many of the early reports on foraminifers from wells and surface sections but also prepared numerous faunal slides. These slides, together with their reports, have served as the primary base for species identification. Their interpretations on species have been followed largely in our integration of materials from other workers. Most of the material available to the U.S. Geological Survey for this study was from measured stratigraphic sections and cuttings and some cores from wells drilled on Federal lands. In addition, all foraminiferal material from wells on file at the Alaska State Division of Oil and Gas core library in Anchorage was examined for this synthesis. Plafker and Winkler furnished the stratigraphic data and collected many of the samples; the micropaleontology and correlations were done by Rau. Susan J. Hunt provided careful drafting and editing assistance. Constructive technical suggestions were made by W. O. Addicott and P. J. Quintemo.

SUMMARY OF FAUNAL CHARACTERISTICS

BY BIOSTRATIGRAPHIC UNIT

CRETACEOUS ROCKS

Although Cretaceous biostratigraphy in the Gulf of Alaska is beyond the scope of this report, Early Cretaceous faunas are reported here from the lower part of the Yakutat #3 well and Late Cretaceous faunas from both the Yakutat #2 and #3 wells (checklists 23 and 24, sheet 3)
Tertiary assemblages believed to be older than those of the Narizian Stage are recognized in a number of stratigraphic sections of the Kayak Island area and in wells of the Yakutat area. The following forms in these areas are regarded as typically Narizian:

- Anomalina gorsaensisis
- Bulimina schencki
- Cibicides haydoni
- Cibicides mexicanus
- Cassidulina globulifera
- Cibicides hodgei
- Elphidium cf. E. californicum

None of these species is known to range into the Zemorrian Stage; however, all the following four species occur in the subjacent Narizian Stage:

- Cassidulina globulifera
- Elphidium cf. E. californicum
- Uvigerina atwilli
- Uvigerina cacaonaensis

Cold and deep water conditions are suggested by most of the species are dwarfed, perhaps suggesting adverse environmental conditions.

UPPER EOCENE ROCKS, NARIZIAN STAGE

The Narizian Stage is recognized in several stratigraphic sections of the Kayak Island area and in wells of the Yakutat area. The following forms in these areas are regarded as typically Narizian:

- Anomalina gorsaensisis
- Bulimina schencki
- Cibicides haydoni
- Cibicides mexicanus
- Cassidulina globulifera
- Cibicides hodgei
- Elphidium cf. E. californicum

None of these assemblages is the presence of siphogenerinids. Siphogenerina kleinpellii has been recorded most frequently, but S. brenneri and S. transversa also occur in some of the

1Currently some workers are placing essentially all of the Narizian Stage in the middle Eocene (Armentrout, 1981). In order that conformity be maintained with past usage we have chosen to place the stage in the upper Eocene.
samples. Apparently species of *Siphogenerina* have their highest occurrence in this faunal division. In addition, the following species occur with varying frequency and either singularly or collectively are supporting evidence for a Saucian or Reuxian age.

- *Bolivina marginitata* Ratella *becki*
- *Adelaidana* ?*Uvigerina californica*
- *Bulimina inflata* *Uvigerinella obesa*
- *Alliata* *impolita*
- *Dentalina quadrulata* ?*Vulviminella arenacana*
- *Epistominella parva*

Although the following foraminifers are most characteristic of upper Miocene and Pliocene rocks in the Gulf of Alaska, a few also occur in Saucian and Reuxian assemblages:

- *Anomalina globatra* *Nionellina miocenica*
- *Melonis pompilioides* ?*Sphaeroidina variabilis*
- *Melonis saondaneae*
- *Cassidulina crassiformis* *Cibicides elmaensis* var. A, and *Cassidulinoides* sp., although generally more significant in stratigraphically lower assemblages, range upward into the Miocene and occur in some of the Saucian and Reuxian samples.

The preponderance of faunal evidence strongly suggests cold water, bathyal conditions during Saucian and Reuxian time. The occurrence of particularly deep-water foraminifers, such as *Melonis pompilioides* and *Siphogenerina* together with costate *Uvigerina* and buliminids, suggests middle and perhaps even lower bathyal depths. However, a few shallow-water forms such as *Melonis miocenica*, *Rotella becki*, and *Bolivina marginata* suggest shallow (middle to inner shelf) depths. Other shallow-water forms such as *Nonionella miocenica*, *Rotalia becki*, and *Elphidium clavatum* and *E. bartletti*, and the presence of *Elphidium frigidum* and *Buccella frigida* show sinistral coiling in samples from the upper part of the undifferentiated Miocene and Pliocene. However, dextral coiling dominates in the Middleton Island section.

In the six stratigraphic sections in which *Elphidium nitida* occurs, and the one section in which *Elphidium frigidum* occurs, both species are either restricted to or at least noticeably more common in the Pliocene than in the Pleistocene strata as subdivided in this report. Some species of *Globigerina pachyderma* show sinistral coiling in samples from the upper part of the undifferentiated Miocene and Pliocene. However, dextral coiling dominates in the Middleton Island section.

Fossils from the Pliocene, or lower part of the undifferentiated Pliocene and Pleistocene, display a greater abundance of *Epistominella pacifica*, *Glandulina laevigata*, *Pulmonia solsburyi*, and *Uvigerina yabei* than do faunas from the upper part of the undifferentiated sequence. These, and other forms, suggest slightly deeper water conditions for the lower part than for the upper part of the Pliocene and Pleistocene sequence. In contrast, the dominance of *Elphidids*, especially *Elphidium clavatum* and *E. bartletti*, and the presence of several species of *Cassidulina*, suggest shallow (middle to inner shelf) and cool water conditions, particularly in the Pleistocene or upper part of the undifferentiated Pliocene and Pleistocene sequence.

**FAUNAL CHARACTERISTICS OF STRATIGRAPHIC SECTIONS AND WELLS**

Stratigraphic sections and wells in the Gulf of Alaska Territory Province have been assigned a number from 1 to 30, and are located on the accompanying index maps. On the charts, measured sections are depicted with standard lithologic symbols and descriptions, and wells are depicted with electric logs (spontaneous potential curves on the left, resistivity on the right). The same numbers are used in the following discussions of individual sections and wells and to identify faunal checklists. There is no foraminiferal information for two sections—(28) Topsy Creek and (30) Icy Point.

(1) MIDDLETON ISLAND SECTION

Foraminifers from 16 samples collected throughout the Middleton Island stratigraphic section show no major differences in faunal composition. Furthermore, no specific taxon appears useful for correlation. However, as pointed out by Ruth Todd (written commun., 1971), a change in fossil preservation occurs near the base of the section between samples 7573 and 7574. Specimens from the upper part of the section are usually well preserved and relatively undeformed, whereas in the lower part of the section they are discolored (generally an amber color), sometimes deformed, and display fewer morphologic details. The foraminiferal data indicate that the Middleton Island section is Pliocene and Pleistocene in
galvinensis, Globocassidulina globosa, and Uulgerina cf. C. cocoaensis, occur together with a greater number of Zemorforaminifers above this depth are known to occur in the upper part of this sequence.

Several assemblages from the lower part of the section lack distinctive Saucesian character and are generally more typical of the Oligocene Zemorrian Stage. The presence of Rotalia crassaformis, Anomalina costata, and Cyclolites spatulata collectively are supporting criteria for a Saucesian age. However, faunas of the lower and middle Miocene part of the Middleton Island section typify the Upper Eocene, Nartilian Stage. The occurrence of several deep-water taxa in the middle part of the section lack distinctive Saucesian character and are generally more typical of the Oligocene Zemorrian Stage. The upper Eocene Refugian Stage is well represented in the lower part of the section. Among key species occurring together in a number of assemblages from this part of the section are Uvigerina atwilli, Cibicides elmosensis, Plectofrondicularia packardi packardi, Uvigerina cf. U. gallowayi, Gyroidina condoni, and Valuulineria tumejensis.

Paleoecologic evidence from all assemblages of this section indicates deep and cold water. Significant environmental indicators are costate buliminids and uvigerinids, Plectofrondicularia packardi packardi, Melolobites pomplioides, Valuulineria tumejensis, and several species of Gyroidina and Globocassidulina.

The uppermost assemblage from the Kayak Island west section is clearly referable to the lower and middle Miocene Saucesian Stage; because diagnostic species are absent, these assemblages could be referred alternatively to the Zemorrian Stage. The lower part of the Kayak Island north section is referred to the upper Eocene Refugian Stage. Although a number of the species present are known to occur in both the Refugian and Zemorrian Stages in the conterminous United States, the sporadic occurrence throughout the section of Refugian species such as Uvigerina cocoaensis, Sigmodomorpha pseudoschencki, and Plectofrondicularia packardi packardi favors a Refugian age.
Because deep, cold-water species occur in all assemblages, the entire section was most likely deposited under bathyal conditions. Siphogenerina and hiplid and costate uvigerinids in the upper part of the section and such taxa as Plectofrondicularia packardi packardi, Melonis pomphiloides, several species of Gyroidina, and costate uvigerinids in the lower part all substantiate bathyal conditions.

(8) KAYAK ISLAND EAST SECTION AND (9) CREEK "E" AND REEF SECTION

Two assemblages from widely spaced localities of the Kayak Island east section and several from the upper part of the Creek "E" and Reef section all firmly suggest a Saucesian age. The mutual occurrence of Siphogenerina kleinpellii and Uvigerina obesa impollita in many of these assemblages supports this conclusion. One assemblage from the Creek "E" and Reef section is unquestionably referred to the Zemorrian Stage, mainly on the basis of the presence of Anomalina californiensis and Cibicides cf. C. elmoensis var. A; diagnostic Saucesian and Refugian forms are missing. The Refugian Stage is well represented by a number of assemblages containing such significant species as Cibicides hodgei, Bulimina schencki, Bulimina sculpitilis lactintata, Plectofrondicularia packardi packardi, Uvigerina atwilli, and Uvigerina cocoensia. The base of the section is referred to the upper Eocene Narizian Stage largely on the basis of the occurrence of Cibicides natandi in one assemblage.

Bathyal depths are indicated clearly by the foraminifers occurring throughout most of both sections. Upper bathyal depths may have existed during most of the Saucesian deposition as suggested by the mutual occurrence of Siphogenerina kleinpellii, Uvigerina obesa impollita, and Bulimina marginata adelaidana. Middle or upper bathyal depths most likely existed during Zemorrian and Refugian deposition as suggested by the combined occurrences of deep water and intermediate depth foraminifers such as costate uvigerinids and bulliminds. Plectofrondicularia packardi packardi, Bulimina schencki, and Globocassidulina. Shallower conditions, possibly sublittoral (nearl), may have existed during Narizian time because no demonstrably deep-water species occur in the Narizian assemblages. Furthermore, several taxa, particularly Cibicides natandi and quinqueloculinds, are present that probably lived in shallow water.

(10) SUCKLING HILLS SECTION

None of the eleven assemblages from localities in this section is diagnostic of a precise age. However, the combination of Pliocene and Pleistocene species such as Elphidium clavatum, Globigerina pachyderma, Buccella frigida, and Cassidulina californica together with species known from the lower and middle Miocene sequence such as Nonionella miocenica, Uvigerina peregrina, Sphaeroidina sp., and Cibicides cf. C. pseudoungerianus evoitus suggests an intermediate stratigraphic position that is referred to as undifferentiated upper Miocene and Pliocene.

In assemblages from the upper part of the section, cool to cold water shelf conditions are indicated by the occurrence of Elphidium clavatum, a dominance of sinistrally coiled Globigerina pachyderma, and by the presence of several species of Cassidulina. Costate uvigerinids and Epistomiminella pacifica in the lower part of the section indicate deeper water conditions, perhaps upper bathyal depths.

(11) KULHTETH MOUNTAIN SECTION

Much of the upper part of this section is broadly referred to the undifferentiated Pliocene and Pleistocene, on the basis of eight assemblages from widely spaced localities. Further refinement does not appear warranted on the basis of the available materials. About 1,500 feet of the lower part of the section is referred to the undifferentiated upper Miocene and Pliocene. Both Anomalina cf. A. glabrata and Melonis saandamae occur here, and, although their presence does not necessarily connote a precise age, they are not known to occur above our locally designated undifferentiated upper Miocene and Pliocene. These forms together with a number of species common to the Pliocene and Pleistocene sequence apparently indicate an age no older than late Miocene.

Cold water shelf conditions are suggested by most of these assemblages. Elphidium clavatum, Elphidium cf. E. bartlettii, Cassidulina tortuosa, Epistomiminella pacifica, and several arenaceous species collectively indicate cold water sublittoral conditions. Slightly deeper upper slope depths may have existed during the deposition of the lower part of the section, as indicated by the presence of Uvigerina cf. U. juncea and Melonis saandamae.

(12) DUERTOTH RIVER "1" WELL

No faunal data were available to a depth of 1,400 feet. From 1,400 to 2,700 feet very sparse data indicate an age possibly no younger than the Zemorrian Stage. Stratigraphically lower assemblages to a total depth of 10,360 feet suggest a Refugian age. Species present that are particularly indicative of the Refugian are Cibicides hodgei, Bulimina sculpitilis, Uvigerina cocoensia, Uvigerina atwilli, Valoullneria willapaensis, Sigmomorphina schencki, and Bulimina schencki.

Water depths during Refugian deposition were most likely in the upper bathyal range. This range is evidenced by the collective presence of bathyal foraminifers such as large costate uvigerinids and bulliminds, robust species of Eponides, and possibly Valoullneria willapaensis in combination with a few shallower or intermediate depth foraminifers such as large quinqueloculinds, and species of Elphidium and Pseudoglandulina. These Intermediate depth foraminifers may also indicate relatively warm water for such depths.

(13) YAKATAGA REEF SECTION

Faunas from nine localities throughout much of the Yakataga Reef section can be divided generally into two age groups. Those faunas from the upper five and possibly six localities contain a number of species that locally typify the undifferentiated upper Miocene and Pliocene sequence. Elphidium clavatum, Cibicides cf. C. mckannai, Anomalina cf. A. glabrata, Virgulinata sp., and Cassidulina cf. E. islandica in aggregate occur only in those assemblages that we have assigned to the undifferentiated upper Miocene and Pliocene, although some species are known to occur higher and others lower in local sections.

Faunas from the lower three localities of the section are referred to the Oligocene Zemorrian Stage although they are not easily differentiated from faunas of the lower and middle Miocene Saucesian Stage. The presence of Melonis pomphiloides, Gyroidina solidani, Sphaeroidina varitabilla, Cibicides cf. C. pseudoungerianus evoitus, and Bulimina inflata alligata, which are not commonly known above the Saucesian Stage locally, distinguish this part of the section from the undifferentiated upper Miocene and Pliocene. Furthermore, the presence of Sigmomorphina pseudoschencki, a species that has not been recorded above the Zemorrian Stage, suggests that this lower part of the Yakataga Reef section may be Zemorrian.
Assemblages from the upper part of the section suggest cool to cold water temperatures at sublittoral depths. Shallower depths probably existed during the deposition of the uppermost part of the section as indicated by the greatest abundance of *Elphidium clavatum* as well as *quinqueloculinids*. Greater water depths are indicated by the assemblages of the lower part of the section where foraminifers appear that characterize bathyal depths— *Melonis pompilioides*, *Gyroidina soldanii*, *Sphaeroidina varitabula*, and *Bulimina inflata alligata*. The combined foraminiferal fauna of this lower part of the section indicates that deposition took place in cold water at depths no shallower than upper bathyal.

(14) WHITE RIVER #2 WELL

Faunas from approximately the upper 500 feet of the well are not particularly diagnostic of age, but several species, *Melonis* cf. *M. saandanae*, *Anomalina* cf. *A. glabrata*, and possibly *Cassidulina* cf. *C. islandica* occur consistently in those parts of other sections and wells that are broadly referred to the undifferentiated upper Miocene and Pliocene. The first two of these species have not been recorded above this interval, and therefore the containing beds are not likely to be younger than our undifferentiated upper Miocene and Pliocene interval. Almost no data are available for the interval from 500 feet to a depth of about 1,200 feet where Saucsonian siphogerinitids first appear. Saucsonian foraminifers continue to appear to depths of at least 3,000 feet, but a few Zemorrian foraminifers also appear. Because assemblages are from well cuttings, the top of the Zemorrian Stage could be in the interval 1,200-3,000 feet even though it is shown questionably below this interval on the chart. No appreciable data were available from a depth of approximately 3,000 feet to the total depth of 6,982 feet.

Foraminifers from the upper 500 feet of this well indicate temperate to cool water shelf conditions. Species of *Quinqueloculina*, *Florilus*, and *Elphidium*, together with several species of *cassidulinids*, are among those forms supporting this conclusion. In contrast, foraminifers from the lower part of this well indicate bathyal conditions—particularly by species of *Siphogerinita* associated with costate buliminids, uvigerinids, and species of *Epistominella*.

(15) WHITE RIVER #2 WELL

The sparse fauna from the upper 1,200 feet of this well broadly suggests a correlation with our undifferentiated Pliocene and Pleistocene interval. *Elphidium clavatum* and *Elphididiella oregonensis* are among species that characterize the foraminiferal fauna of this interval. No data are available from 1,200 feet to 1,600 feet. Although none of the assemblages from approximately 1,600 feet to 3,600 feet is particularly diagnostic of age, the occurrence of several species, particularly *Melonis* cf. *M. saandanae* and *Anomalina* cf. *A. glabrata* in the lower part, suggests assignment to the undifferentiated upper Miocene and Pliocene. The lower to middle Miocene Saucsonian Stage is marked by the highest occurrence in this well at approximately 3,600 feet of *Siphogerinita kleinpellii*, *Bulimina inflata alligata*, *Bulimina marginata adelaidana*, and several other Saucsonian species. Although the top of the Zemorrian Stage is not precisely defined by available data, the stage is generally suggested in assemblages from the interval between approximately 4,100 feet and 5,000 feet. *Kerriella* sp., *Cassidulina crassipunctata*, and *Florilus* cf. *F. incusum* are among characteristic Zemorrian foraminifers occurring in this interval. The top of the Refugian Stage is suggested by the highest occurrences of *Epontides mexicanus* and *Cibicides elmaenas* at about 5,200 feet. The possible occurrence of *Valulinerfa tumeyensis* at 5,500 feet to 5,600 feet further substantiates a Refugian age. The available data below a depth of about 6,000 feet are insignificant and probably largely represent cavings from higher in the wall.

Relatively cool to cold water conditions at sublittoral depths most likely persisted during the deposition of the Pliocene and Pleistocene, as evidenced by such species as *Elphidium clavatum* and *Elphidium bartletti* together with *Elphididiella oregonensis* and other cold or shallow water species. Deeper water conditions at possibly outer shelf to upper bathyal depths probably existed, at least at times, during upper Miocene and Pliocene deposition. *Melonis pompilioides* and several species of costate uvigerinids are among foraminifers suggesting greater water depths. Bathyal depths also are suggested by the Saucsonian and Zemorrian assemblages of this well. Diagnostic deep-water taxa are siphogerinitids, *Sphaeroidina* sp., *Bulimina marginata adelaidana*, and *Gyroidina soldanii*.

(16) SULLIVAN #1 WELL

Pliocene and Pleistocene species such as *Elphidium clavatum*, *Cassidulina californica*, and *quinqueloculina akertiana* occur in approximately the upper 300 feet of this well. *Uvigerinella obesa impolita* and *Nonionella miiocenica* occur between approximately 300 and 400 feet and suggest a Saucsonian age. Typical Zemorrian assemblages first appear at about 400 feet and continue to occur to at least a depth of 3,700 feet. Among characteristic Zemorrian species are *Buccella mansfeldi* *oregonensis*, *Sigmomorpha pseudosanchenki*, *Florilus incusum*, *Cibicides elmaenas*, and *Gaudynina alazanensis*. The top of the Refugian Stage is indicated at about 3,800 feet by the highest occurrence of both *Valulinerfa villapaenans* and *Melonta halkyardi*. Additional species that characterize the Refugian Stage continue to make appearances nearly to the bottom of this well at 10,113 feet. Among these species are *Elphidium* cf. *E. californicum*, *Sigmomorpha* cf. *S. schencki*, *Uvigerina cocoensis*, *Cassidulina galimusensis*, and *Cibicides hodgeti*.

Pliocene and Pleistocene assemblages generally suggest shelf depths and possibly cool to cold water. Deeper, colder-water environments, possibly in the middle to upper bathyal range, are suggested by both Zemorrian and Refugian assemblages. *Gyroidina soldanii*, *Gaudynina alazanensis*, *Uvigerina cocoensis*, and *Cassidulina crassipunctata* are among those species thought to favor substantial depths. *Elphidium* cf. *E. minutum* in a few Zemorrian assemblages and *Elphidium* cf. *E. californicum* in some Refugian assemblages may indicate short periods of slightly shallower conditions.

(17) SULLIVAN #2 WELL

Assemblages from the upper 300 feet of this well are tentatively referred to our undifferentiated upper Miocene and Pliocene sequence largely because *Anomalina* cf. *A. glabrata*, a species recorded lower but rarely higher than this interval, occurs here with higher ranging forms such as *Elphidium clavatum*, *Florilus labradoricus*, *Elphidium bartletti*, and *Bucella frigida*. A distinct faunal break occurs at a depth of about 300 feet where, for the most part, Zemorrian species first occur. All or part of the interval between 300 and 400 feet may be Saucsonian in age on the basis of the questionable identification of *Siphogerinita* cf. *S. transversa*. Other assemblages from this interval are better referred to the Zemorrian Stage, and therefore this small interval is tentatively regarded as part of the Zemorrian Stage. Occurring between about 300 and 1,300 feet are species typically associated with the Zemorrian Stage. Among these are *Gyroidina soldanii*, *Pseudoglan-
Faulding is indicated by anomalous faunal sequences in several intervals in this well. The occurrence of Cassidulina galvaniensis and questionable occurrence of Vaginulinopsis saundersi in an interval between 1,300 and 1,500 feet suggests a Refugian age. However, beginning at about 1,500 feet and continuing to possibly 2,000 feet additional Zemorran species occur; thus a block of Refugian (at 1,300-1,500 feet) may be faulted into an otherwise continuous sequence of Zemorran strata. Refugian species once again appear at about 2,100 feet and continue to dominate the assemblages to a depth of some 8,000 feet. Elphidium californicum, Vagulineria willaepensis, Uvigerina cocoaeans, Cibicides hodgsei, and Sigmomorphina cf. S. schencki are among the diagnostic species appearing in this interval.

Although the evidence is not conclusive, Zemorran beds may again be present between approximately 8,800 and 9,600 feet. No additional Zemorran species appear here, but several that occurred higher in the well reappear. These occurrences, of course, could also be the result of contamination from higher in the well.

A distinct faunal break occurs at 9,900 feet where younger beds are indicated by the presence of Saucian species such as Siphogenerina cf. S. transversa and Uvigerinella obesa impolita. These and (or) other characteristic Saucian species continue to the bottom at 12,054 feet.

The upper Miocene and Pliocene faunas suggest a cold water, outer shelf environment. Substantiating evidence is the combination of several species of cold water Elphidium, Buccella frigida, and Cassidulina islandica together with deeper water foraminifers such as Epistominella pacifica. Saucian assemblages distinctly indicate bathyal conditions, as substantiated by the presence of Siphogenerina and Bollina marginata adieldana together with costate buliminids and uvigerinids. Both Zemorran and Refugian assemblages also suggest bathyal depths, however, the presence of species of both Elphidium and Quinqueloculina in each assemblage together with typical bathyal foraminifers such as Gyroidina soldanii, Melonis pampillioades, and Uvigerina cocoaeans, indicates that depths were probably no greater than upper bathyal.

(18) RIOU BAY #1 WELL

Approximately 500 assemblages from small intervals throughout this well were examined in detail. A summary of the faunal distribution is presented in the checklist. Data from small intervals were combined into larger depth intervals where no significant faunal change was observed.

The upper part of this well to a depth of approximately 6,400 feet is referred to the Pleistocene; strata in the lower part of the well between approximately 8,400 and 14,107 feet, the total depth of the well, are questionably referred to the Pliocene. The age boundary occurs somewhere within about 2,000 feet of section where faunal data is insufficient to distinguish between Pliocene and Pleistocene. Among the differences in the faunas of these subdivisions is the dominance of dextrally coiled Globigerina pachyderma in the lower part, suggesting warm conditions. Furthermore, fossils from the lower part of the well are less well preserved than those from the upper part. In addition, Uvigerina cf. U. yabei is restricted to the lower part of this well. This species, although not restricted to the Pliocene, is more common in the lower part of the Pliocene and Pleistocene sequence of the Gulf of Alaska. Furthermore, Elphidiella nitida and Elphidium frigidum, which are confined to the upper part of the well, characterize the Pleistocene part of the local sequence. Other faunal occurrences that may be useful for local correlation are the highest occurrence of both Cassidulina californica and Elphidium oregonensis at approximately 1,500 feet. Perhaps a more practical reference horizon is the highest common occurrence of Elphidium oregonensis at approximately 2,860 feet. The lower occurrence of Elphidiella nitida at about 6,500 feet may also be useful for local correlation. This horizon corresponds closely to a change in fossil preservation. Most of these marker horizons have been noted in some of the other sections and wells of the Malaspina and Yakutat Districts, and they generally occupy the same relative positions in the sequence (see correlation charts).

The abundance and diversity of elphidiids throughout this thick sequence of Pliocene and Pleistocene rocks indicate that sublittoral water depths prevailed during deposition. The greatest depths are suggested in the lower (Pliocene?) part of the section where, in addition to shallow-water forms, Uvigerina cf. U. yabei and Epistominella pacifica occur consistently. Collectively, these species indicate that water depths were perhaps outer sublittoral (outer shelf).

Water temperatures were most likely relatively cool or cold during the deposition of at least the upper (Pleistocene) part of this section because, for the most part, the elphidiids such as Elphidium clavatum and Elphidium groenlandica together with Buccella frigida and other cold-water foraminifers appear consistently through this part of this section. Some of these taxa are not present, at least not consistently, in the lower (Pliocene?) part of the well but others, such as Elphidium clavatum, continue to be common consistently. Dextrally coiled Globigerina pachyderma supports evidence for relatively warm water conditions. In view of somewhat conflicting evidence for water temperature in the lower part of this well, it would seem that surface temperatures, as represented by the planktonic foraminifers, may have been relatively warm but, because of the greater depths of deposition, bottom temperatures were relatively cool to cold.

(19) CHAIX HILLS SECTION

Two assemblages, one from near the top of the section and one from the base, are referred to the undifferentiated Pliocene and Pleistocene on the basis of the common occurrence in the lower assemblage of both Elphidium clavatum and Pseudonion auricula together with a few Buccella frigida, Cassidulina islandica, and Elphidium oregonensis. Elphidium clavatum, present in both assemblages, suggests cold, shallow water conditions of deposition. This species in the basal assemblage, together with Buccella frigida, Cassidulina islandica, Elphidium oregonensis, and Quinqueloculina okinari, collectively support cool to cold water conditions at sublittoral (shelf) depths.

(20) SAMOVAR HILLS SECTION

Three sparse assemblages from widely spaced intervals of the upper half of this measured section are broadly referred to the undifferentiated Pliocene and Pleistocene sequence. Elphidium clavatum and E. bartletti together with Florilus labradoricus and Uvigerina yabei locally characterize beds of the undifferentiated Pliocene and Pleistocene sequence.

Cool water and sublittoral depths are suggested by Elphidium clavatum and E. bartletti together with Buccella frigida. Uvigerina yabei in the lowest assemblage is suggestive of the greater water depth.

(21) MALASPINA #1A WELL

Studies of this well are based largely on assemblages from about 150 intervals between depths of 120 and 8,000 feet.
A summary of the faunal content of this part of the well is presented in the checklist. Data from small intervals were combined into larger intervals where no significant change in the fauna was observed. The entire sequence is broadly referred to the Pliocene and Pleistocene undifferentiated.

Sinistral coiling of Globigerina pachyderma dominates in the upper part of this well, suggesting cold water conditions, as would be expected in a Pleistocene sequence. A change in fossil preservation was noted at approximately 5,600 feet, similar to that observed in the Riou Bay well at about 6,400 feet, a position corresponding generally to the base of the Pleistocene as interpreted in that well. In addition, the highest occurrence of Cassidulina californica at 2,100 feet, Elphidium oregonensis at 4,100 feet, and the common occurrence of this species near 5,600 feet, may represent significant horizons for at least local correlations. It is noteworthy that these events occur in the same sequence in the Riou Bay well. Furthermore, for the most part they continue to occur in the same sequence in wells of the Yakutat area to the southeast. No significant faunal data were available from this well below 8,000 feet.

The foraminifers from the undifferentiated Pliocene and Pleistocene sequence suggest cool to cold water at sublittoral depths, possibly no greater than a depth of 60 meters. This interpretation is based on the consistent and relatively common occurrence of Elphidium clavatum, the scattered occurrence of Elphidium bartlettii, and the consistent occurrence of Cassidulina islandica, and Elphidium groenlandica throughout this interval. In addition, the sinistral coiling of Globigerina pachyderma further supports cold water conditions in the upper half of this sequence, while the presence of Elphidium oregonensis in only the lower part of the sequence may indicate slightly warmer water.

(22) YAKUTAT #1 WELL

Faunas from the interval between 600 and 4,900 feet are broadly referred to the undifferentiated Pliocene and Pleistocene. Within this interval the highest occurrence of Elphidium oregonensis at a depth of about 1,200 feet and its common occurrence between depths of 3,300 feet and 3,500 feet are elements potentially useful for at least local correlations. Inoceramus prisms are reported as high as 4,900 feet and occur sporadically in the records to nearly the total depth of 9,314 feet. These are believed to be reworked into younger rocks at least throughout much of this interval because Eocene foraminifers appear at a depth of about 5,400 feet and continue to appear nearly to the total depth. Late Eocene foraminifers referable to the Narizian Stage appear between depths of 3,200 feet and 6,800 feet. Between 6,800 feet and the total depth (9,314 feet) only scattered occurrences of a few Eocene species are reported, and many intervals are barren of faunal data. This large interval, therefore, is tentatively regarded as undifferentiated Ulatisian and Narizian in age.

Shallow, depths and cool to cold water conditions throughout deposition of the Pliocene and Pleistocene sequence are evidenced by the consistent and frequently common occurrence of Elphidium clavatum and Elphidium nitido, together with scattered occurrences of Buccella frigida. Cassidulina islandica and Elphidium bartlettii also indicate cold water conditions largely in the upper part of this sequence whereas the scattered and sometimes common occurrence of Elphidium oregonensis and the sparse occurrence of Bultimella elegansissima in the lower part provide supporting evidence for slightly warmer conditions.

The Eocene foraminifers as a whole suggest fairly deep water conditions. Smooth buliminids, several species of Eponides and Cibicides, together with many of the remaining foraminifers, most likely would have thrived in an outer shelf or upper bathyal environment.

(23) YAKUTAT #2 WELL

The upper 2,600 feet of this well is referred to the undifferentiated Pliocene and Pleistocene. Although the available data are somewhat generalized throughout parts of this interval, several possible horizons of correlation are suggested. The highest occurrence of Cassidulina californica at a depth of about 450 feet corresponds to the highest occurrence of this taxon in the upper part of several other wells to the north. Elphidium nitido occurs commonly between depths of about 900 feet and 1,400 feet. This species occurs in the nearby Yakutat #2 well at a similar relative position. Elphidium oregonensis is common in the interval between depths of 2,340 feet and 2,430 feet. This relative position also corresponds to the common occurrence of this species in several wells to the north. Between depths of about 2,600 feet and 3,250 feet almost no foraminiferal data have been recorded. However, the first and common occurrence of glauconite at a depth of about 2,950 feet corresponds to a similar stratigraphic occurrence in the nearby Yakutat #1 well. The occurrence of Bulimina cf. B. schencki at about 3,250 feet marks the highest occurrence of Eocene foraminifers in this well. The relative position of this occurrence corresponds to that in the nearby Yakutat #1 well. Eocene foraminifers referable to the Narizian Stage continue to occur sporadically to a depth of some 7,300 feet. Inoceramus prisms together with characteristic Cretaceous foraminifers make their highest occurrence at a depth of about 7,600 feet. Late Cretaceous species are recorded to a depth of 9,400 feet and Early Cretaceous species are recorded from a core taken between depths of 10,446 feet and 10,456 feet (W. V. Sliter, written commun., 1977).

Pliocene and Pleistocene faunas of this well indicate much the same paleoecologic conditions of cool to cold water at shelf depths as are indicated locally in other Pliocene and Pleistocene sequences. Eocene assemblages suggest outer shelf to upper bathyal conditions. Smooth buliminids, Gyroidina orbiculatis planata, Plectofrondiculata, and several species of Anomalina are among those foraminifers indicative of such conditions. Shelf conditions are indicated by most of the Cretaceous elements particularly such taxa as Choffatella and Orbitolina, together with fragments of bryozaons, echinoids, and Baculites (W. V. Sliter, written commun., 1977).

(24) YAKUTAT #2 (A-1) WELL

Foraminifers reported from approximately the upper 2,500 feet of this well are representative of the local undifferentiated Pliocene and Pleistocene sequence. The highest occurrence of Cassidulina californica at a depth of approximately 950 feet and the common occurrence of Elphidium nitido between depths of approximately 1,000 feet and 1,200 feet are noted as possible points of local correlation. These species are present at similar relative stratigraphic positions in the nearby Yakutat #3 well, and Cassidulina californica makes its highest occurrence in the upper part of a number of other wells to the northwest. No data are available for the depth interval from approximately 2,500 to 3,200 feet. Inoceramus prisms are reported to first occur at about 3,200 feet and continue throughout most of the lower part of the well. Other Cretaceous taxa, all regarded as Late Cretaceous (W. V. Sliter, written commun., 1977), are not reported above 10,000 feet. Evidence for a Cretaceous age for the depth interval from 3,200 and 10,000 feet is the appearance of Inoceramus prisms and a major lithologic change at about 3,200 feet.
Typical cool to cold water shelf conditions are suggested by the faunas of the undifferentiated Pliocene and Pleistocene sequence. Elphidium clavatum occurs less frequently and in fewer numbers in this well than it does in wells and sections to the north and west. Perhaps this is evidence for slightly warmer water conditions, particularly when considered with the occurrence of Bulimina elegantissima and Cibicides mckanii. The first occurrence of Epistominella pacifica in the lower 1,200 feet or so of the undifferentiated Pliocene and Pleistocene interval suggests that water depths were probably greater during the deposition of the lower part of the sequence (possibly middle shelf). The dominance of a variety of arenaceous foraminifers in Cretaceous assemblages is evidence for cold water, outer shelf to upper slope conditions.

(25) DANGEROUS RIVER #1 WELL

Foraminiferal data on this well are from a report prepared by Ruth Todd (written commun., 1962) on 33 slides that were made from cuttings taken between depths of 3,660 feet and 8,634 feet. Because these specimens are so poorly preserved and are largely nondiagnostic arenaceous foraminifers, they provide limited biostratigraphic information. No checklist has been prepared. Inoceramus prisms were reported in the lower part of the sequence below a depth of 5,670 feet, and Globotruncanina sp. was identified from the Interval between depths of 7,650 and 7,680 feet. On the basis of these data, the rocks penetrated in the lower part of the well are Cretaceous in age. The top of the Cretaceous is not apparent from these data but is placed at about 1,700 feet on the basis of the well cuttings and electric logs.

(26) FABWEATHER GLACIER SECTION

Available foraminiferal assemblages are confined to the upper one-half or about 700 feet of this section. As a group, these faunas best compare with those of Pliocene and Pleistocene strata of the Gulf of Alaska Tertiary Province. The common and only occurrence of Epistominella oregonensis at approximately 700 feet below the top of this section seems to be significant to local biostratigraphic correlations because this species occurs in large numbers in a similar stratigraphic position in the La Perouse Glacier section to the south and in several other sections and wells to the northwest.

Shallow cool to cold water conditions are suggested by the persistent occurrence of Elphidium clavatum, together with scattered Elphidium bartlettii, Buccella frigida, Nonionella miocenica, and Floriis labradoricus. In contrast, slightly greater depths and are suggested by the persistent occurrence of Epistominella cf. E. pacifica and Ulvalinera cf. U. abei and by one occurrence of Pullenia salisburiyi. Considering both depth indications, optimum conditions for such foraminifers most likely would have been middle shelf at depths something less than outer shelf.

(27) CENOTAPH ISLAND SECTION

The material available for study consisted of a few meager foraminiferal assemblages from the upper 700 feet of this section. The presence of Anomalina cf. A. globrata together with Nonionella miocenica, Buccella frigida, and Pseudonannina auriculata in the lower part of this interval suggests that this part of the section, at least, is best referred to the undifferentiated upper Miocene and Pliocene sequence.

Shallow, cold water conditions are suggested by the combined foraminiferal fauna.

(29) LA PEROUSE GLACIER SECTION

The entire section is referred to the Pliocene and Pleistocene. The lower part is specifically referred to the Pliocene and the upper part to the Pleistocene. However, the Pliocene-Pleistocene transition is represented by over 2,500 feet of section designated as undifferentiated Pliocene and Pleistocene. No data are available for a large part of this interval.

In the Pleistocene part of the section Globigerina pachyderma commonly displays striatal coiling. Furthermore, Elphidium nitida is confined to this part of the section, an occurrence that conforms to its high stratigraphic occurrence in nearly all other undifferentiated Pliocene and Pleistocene sections studied.

In the Pliocene part of the section Epistominella pacifica and Glandulina laevisata occur consistently throughout, and Pullenia salisburiyi and Virgulina nodosa have a limited occurrence. Although all of these species may be more indicative of a difference in depositional environment than age, they nevertheless are characteristic elements of a lower (Pliocene) part of the local Pliocene and Pleistocene sequence.

Several additional faunal elements are noted as possibly significant for local correlations because they occur consistently in other Pliocene and Pleistocene sections described in this report. Both Elphidia oregonensis and Cassidulina californica make their highest occurrence in the upper part of the section. The common occurrence of Elphidia oregonensis slightly below its highest occurrence in this section also corresponds to a similar occurrence in other local sections. Furthermore, a distinct change in the quality of fossil preservation is noted about 5,000 feet below the top of the section; all assemblages below are referred to the Pliocene. This relative position generally corresponds to similar changes in preservation noted in several other sections.

Cool to cold water conditions at sublittoral depths are indicated by the common occurrence of Elphidium clavatum throughout this Pliocene and Pleistocene section. Buccella frigida, Cassidulina teretis, and Cassidulina islandica particularly are indicative of cold water. Slightly greater depths are suggested in the Pliocene part of the section by the consistent occurrence of Epistominella pacifica and Glandulina laevisata together with the sporadic occurrence of Pullenia salisburiyi. At times water temperature may have been slightly warmer than during the Pleistocene deposition even though water depths may have been greater, because several species of milolids appear in this part of the section together with a few dextrally coiled Globigerina pachyderma.

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