# 1. INTRODUCTION

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## GENERAL PURPOSE

Leg 19 was conceived and planned to collect geologic data that would provide a basis for outlining the Cenozoic and Late Mesozoic histories of sedimentation and biostratigraphic evolution in the North Pacific and deep-water regions of the Bering Sea. From the outset, it seemed highly probable that the results of these studies would also enable us to formulate general and perhaps even restrictive statements about the structural and tectonic development of this vast region—a region that geomorphically includes a normal oceanic basin, a bordering trench and volcanic arc (Aleutian), and an inner or marginal oceanic basin (Bering Sea) (Figure 1).

### Sedimentology

The answers to a number of important sedimentological questions were to be sought on Leg 19. For example, in the northeastern Pacific region, we hoped to determine the age and source terrane of the buried turbidite deposits of the Aleutian Abyssal Plain (Figure 1) as well as the beginning of and reason for pelagic sedimentation above the plain. Results obtained by drilling here (Site 183) were to be contrasted to those derived at a second North Pacific site (192), this one at the summit of Meiji Guyot, the northernmost seamount of the Emperor chain. Here a thick blanket of pelagic deposits rather than terrigenous turbidites had accumulated in the Early Tertiary and perhaps the Late Mesozoic. Questions to be probed here included:

1) Why are pelagic deposits so thick (1000-2000 m) in the northwest corner of the Pacific and are hemipelagic deposits significant contributors to this section?

2) Does a change in style of sedimentation occur that is time-equivalent to the cessation of turbidite deposition over the abyssal plain, far northcentral Pacific? At what time (times) does volcanic ash, presumably derived from nearby Kamchatka, appear abundantly in the pelagic section?

The Aleutian Ridge (Figure 1) has been volcanically active and subaerially exposed since the middle Eocene (Scholl et al., 1970). Several of the sites to be occupied were selected to determine the history of the ridge as both a source of terrigenous detritus as well as primary volcanic (pyroclastic) debris. Of special interest is the record of volcanic ash in deposits of Plio-Pleistocene age, because the lofty and magnificent stratocones that crest the ridge presumably began to form at this time. But what about volcanism prior to this time, especially in the late Miocene which is represented by a meager rock record on the Aleutian Islands? Also, insular mapping has shown that the ridge was a source of terrigenous detritus during most of the Cenozoic (Scholl et al., 1970; in press). Did some of this debris accumulate at the base of the ridge to form a thick rise sequence and could such a sequence in part or wholly form the "acoustic basement" beneath the generally undeformed beds of the Aleutian Terrace, or is this basement in part or wholly pelagic and trench deposits scraped off a descending oceanic plate? Answers to these questions, as well as a documentation of the age and lithology of deposits flanking the ridge and overlying the Aleutian Terrace, were to be sought at Sites 184, 186, 187 and 189.

In the Bering Sea (Figure 1) the thickness of the sedimentary section is typically greater than 3 km; in some areas it is as thick as 10 km. In view of this, sites in the Bering Sea were selected only where sedimentological problems could be investigated within a subbottom drilling limit of 1000 to 1500 meters. These included investigations of (1) the origin of the prominent, bottom-simulating reflector (BSR) in the Umnak Plateau area (Sites 184, 185) and its possible relation to the formation of gas hydrates (Stoll, et. al., 1971), (2) the geologic significance of the "P" reflector (Ewing et al., 1965; Ludwig et al., 1971a) (Site 188) within the deposits draping the inner flank of the curved Bowers Ridge; (3) the age and lithology of the insular rise prism (Site 189) flanking the Aleutian Ridge to the north; (4) the textural and sedimentary structures of the thick turbidite sequence underlying the abyssal floors of the Aleutian (Site 190) and Kamchatka basins (Site 191); (5) the age of the base of the sequence in relationship to the onset of Late Cenozoic continental glaciation; and (6) the style of pre-Pliocene sedimentation in both basins.

### Biostratigraphy and Paleoclimatology

The North Pacific and Bering Sea region is presently the "home" of diatoms. Thus it is of considerable importance to trace the evolutionary history of this siliceous microorganism as far back as possible, comparing the results with onshore sections of Japan, Sakhalin, and Western North America. Biozonation of other siliceous microfossils, e.g., silocoflagellates and radiolarians, is of equal interest, especially so because little information is presently available from the Bering Sea and the far north Pacific. Drilling sites, especially 183, 184, 190, 192, and 193, were selected in part to accommodate these purposes.

The carbonate compensation depth has likely changed with time in the North Pacific-Bering Sea region. Hence, besides intrinsically important biozonation studies of the calcareous microflora and fauna, foraminiferal and nannofossil investigations were needed to attempt to piece together a record of compensation-depth migration. To this end, drilling sites were selected that would represent a wide range of water depths (1800 to 4800 m). For North Pacific

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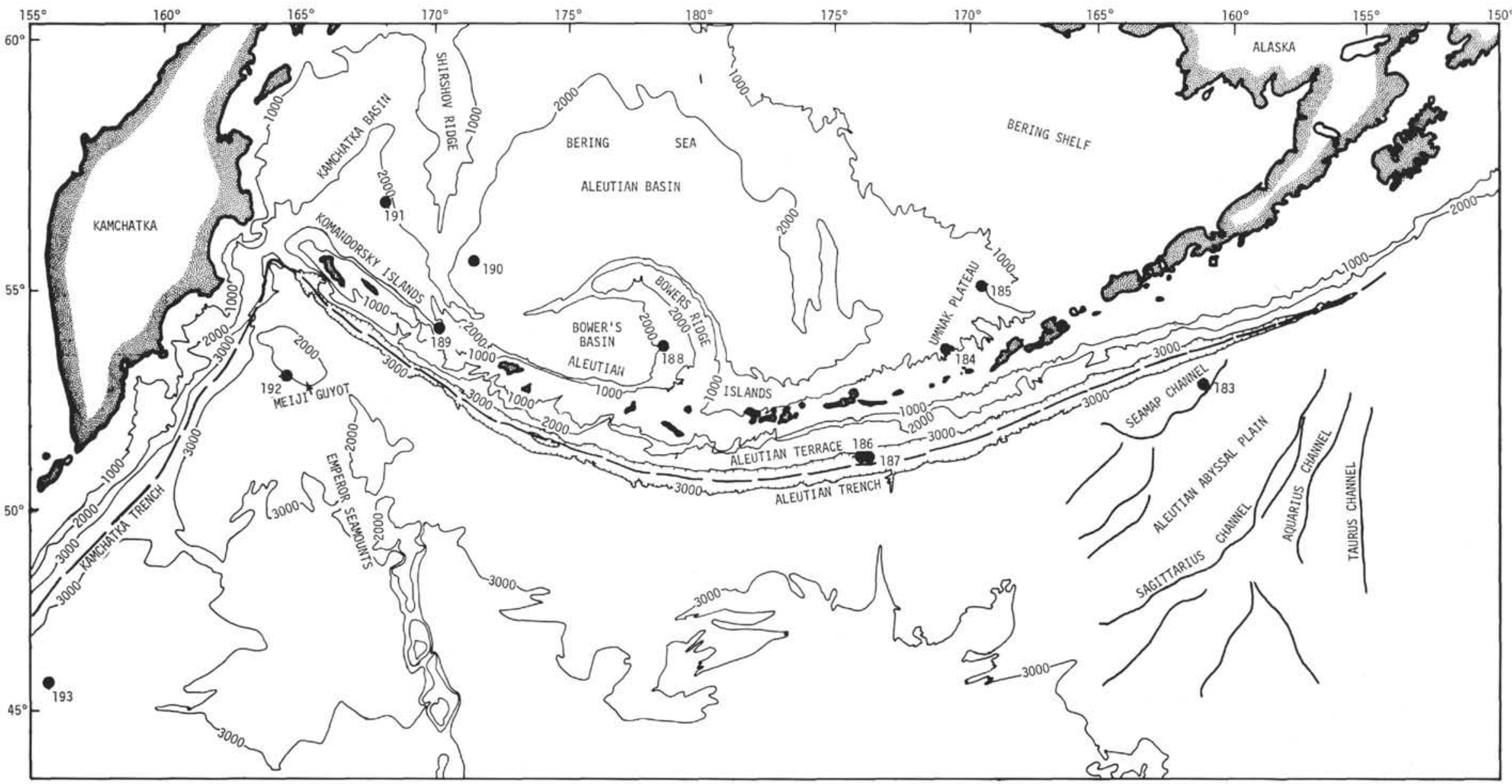



Figure 1. *Base map, Leg 19, showing drill sites in the northern Pacific Ocean and Bering Sea.*

sites clues implying changes in climate or latitude with time were also needed from the paleontologic data. It is known from onshore studies that northwestern North America was climatically warmer and even tropical in Paleogene time (Wolfe et al., 1966, Wolfe and Hopkins, 1967; Wolfe, 1971). A similar record will presumably turn up in offshore sections. However, there is good reason to believe that the North Pacific crust has migrated several thousand kilometers northwestward since the beginning of Cenozoic time (Atwater, 1970). This could be substantiated if a northward-displaced climatic zonation is found in the North Pacific. Hopefully, aspects of the faunal and floral assemblages will enable recognition of paleolatitudes. To no small degree, the rationale for selecting Sites 183, 192, and 193 was based on the interest in paleolatitude control.

### Tectonics

Several of the Leg 19 sites (specifically 183, 186, 192, and 193) were drilled in an attempt to derive critical information about the tectonic and structural development of the North Pacific-Bering Sea region. For example, drilling beneath the Aleutian Abyssal Plain (Site 183) was carried out in order to determine the age and possibly the drainage terrane of the buried turbidite sequence thought to exist there. The age alone, early or late tertiary, would tend to support different tectonic models regarding the amount of relative motion that has occurred between the Pacific and American plates during the Cenozoic (Pitman and Hayes, 1968; Atwater, 1970; Hayes and Pitman, 1970; Mammerickx, 1970; Jones et al., 1971). If paleolatitude control could be provided by the floral and faunal assemblages found in the turbidites, then the amount of northward motion of the Pacific plate could be fixed. If the source terrane of the turbidites could be located, then the relative motion of the two plates could be fixed. Similarly, at Site 192, located on the summit of the northwestern seamount (Meiji Guyot) of the Emperor Seamount chain, biological and sedimentological evidence was to be sought regarding its latitude stability during the Cenozoic. This same question, i.e., the relative amount of Cenozoic Pacific plate motion, could be investigated further at Sites 186 and 187, outer Aleutian Terrace, where a "bedrock" high occurs that may be underlain by deformed and uplifted trench deposits.

Within the Bering Sea, served problems having tectonic significance were also to be studied. For example, at Sites 184 and 185, Umnak Plateau, evidence for subsidence or uplift was to be sought that might lead to an understanding of its formation. A similar question concerning the importance of vertical tectonics was to be investigated at Site 188, Bowers Ridge, and Site 189, north flank of the Aleutian Ridge. An understanding of the tectonic implications of the relatively shallow subbottom depth to the "basement rock" of Kamchatka Basin was perhaps the cardinal reason for drilling at Site 191. Marginal basins such as Kamchatka are thought by many to form through arc migration (e.g., Aleutian Ridge) and the upwelling of basaltic magma behind them (Karig, 1970, 1971; Matsuda and Uyeda, 1971; Packham and Falvey, 1971). Thus it was of considerable importance to sample the "acoustic basement" of Kamchatka Basin.

## GENERAL RESULTS

Detailed information about the geologic findings at each of the eleven sites (183-193) occupied by the *Glomar Challenger* during Leg 19 are found in Part II of this volume. However, included below are brief summaries describing the general results and early conclusions suggested by them for each site. These summaries are assembled in numerical order, which is the order of drilling; this grouping thereby provides a cursory glance at an east to west geologic transect across the far north Pacific and the Bering Sea (Figure 2). The location of each site is listed on Table 1 and shown on a general bathymetric base on Figure 1. Sediment penetration and recovery data are also listed in Table 1. The stratigraphic column for the first ten sites is included on Figure 2 along with tentative correlations.

### Site 183

Site 183 is located near the northern edge of the Aleutian Abyssal Plain, western Gulf of Alaska. The 505-meter-thick sedimentary sequence drilled and cored here is comprised of Holocene through middle Miocene pelagic deposits (0-210 m) of diatom-rich silty clay and diatom ooze, with intercalated ash layers above 185 meters and ice-rafted (?) pebbles above 127 meters; barren lower Miocene and upper Oligocene pelagic (?) clay (210-239 m); middle to lower Oligocene nannofossil chalk (239-248 m); lower Oligocene to upper lower Eocene turbidite beds (248-501 m) consisting of clay with size graded silt and silty sand layers increasing in abundance downward; and upper lower Eocene (?) (501-505 m) nannofossil limestone, calcareous ferruginous clay, and pyritic, aragonitic limestone. Alkali olivine basalt underlies the sediment sequence (see Stewart et al., this volume, Part III).

The Holocene-Miocene siliceous fossil assemblage resembles that of California and Japan. A dinoflagellate flora, chiefly one species, was recovered from the Eocene turbidite beds. The dominant species is geographically wide ranging and also occurs in beds of late Eocene age on nearby Adak Island in the Aleutians (see Evitt, this volume, Part III). From its low diversity, the Oligocene-Eocene nannoflora appears to be a high-latitude assemblage ($50^{\circ}$ or higher; see Worsley, this volume, Part III). Even the two carbonate beds have remarkably low species diversity and only three discoaster species were found throughout the entire Lower Tertiary section. In agreement, the conifer-dominated pollen assemblage in lower Oligocene and Eocene beds implies an Alaskan source area and a paleolatitude equivalent to that of the Cook Inlet area in early Tertiary time (see Wolfe, this volume, Part III).

Both the Oligocene and lower Eocene carbonate beds are bounded by pelagic clays, not turbidites, and may be considered autochthonous, indicating two downward incursions of carbonate compensation depth during this interval. The upper chalk, apparently somewhat older than the one encountered in Hole 178 of Leg 18, was probably deposited at approximately 5 km below sea level.

The oldest dateable sediment above the alkali olivine basalt (upper lower Eocene) is approximately 12 m.y.

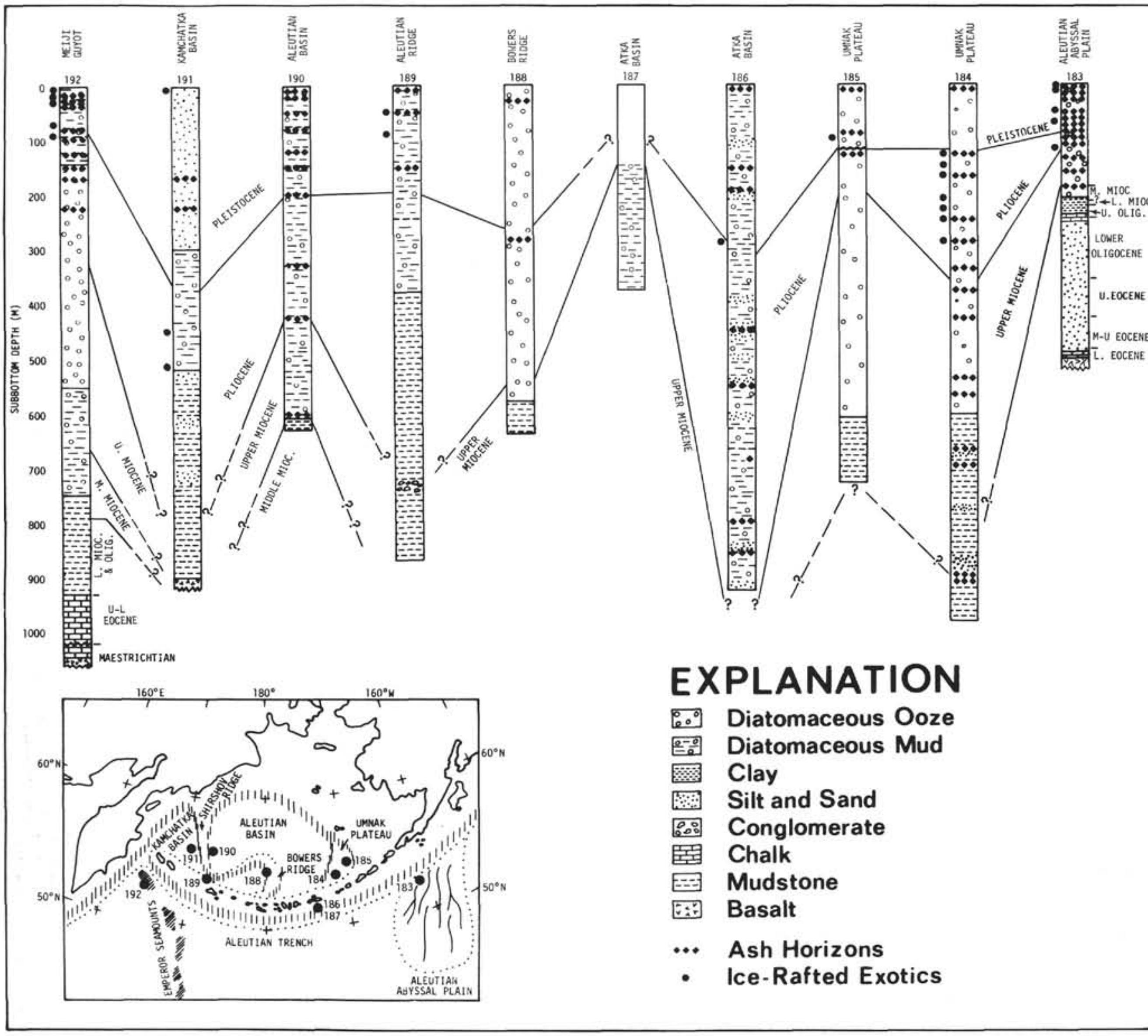



Figure 2. *Stratigraphic summaries of Leg 19 drill sites.*

younger than the probable age of the basalt as indicated by the associated magnetic anomaly (24). Although uncertainties remain, the occurrence of goethite-bearing calcareous ironstones and pyrite-bearing unfossiliferous aragonitic limestone, factors implicating precipitation in hot brines rather than hydrothermal alteration of pelagic deposits, suggests that the age disparity is not due to intrusion of basalt into Eocene deposits (see Natland, this volume, Part III). If this is true, then perhaps the 12 m.y. hiatus can be related to the nondeposition of Paleocene deposits, a circumstance commonly observed in the Pacific and also found at Site 192, Meiji Guyot, or to the nonrecovery of Paleocene beds in the final core (39) containing sediment, which recovered only 30 percent of the section penetrated. It is interesting to speculate that the alkali basalt may be related to the formation of nearby Derickson or Sirius seamounts in early Tertiary time.

The mineralogy of the buried early Tertiary turbidite sequence of sand and silt underlying the Aleutian Abyssal Plain suggests derivation from a plutonic or metamorphic provenance supplying, in order of abundance, quartz, plagioclase, and K-feldspar to the light mineral suite, and hornblende, epidote, and garnet to the heavy mineral assemblage. The species-limited but population-rich nannoflora and the Pinaceae-dominated pollen assemblage from these beds imply deposition in high northern latitudes and an Alaskan source terrane. These findings are perhaps most easily harmonized with the post-Mesozoic history of the Gulf of Alaska worked out by Hamilton (1967; in press) and Pitman and Hayes (1968). Plate solutions requiring more than about 1000 km of northwestward displacement of the Pacific plate relative to North America are not easily reconciled with the implied high latitude of deposition (see Scholl and Creager, this volume).

TABLE 1
Coring Summary

| Hole | Dates (1971) | Latitude | Longitude | Water Depth (m) | Penetration (m) | No. of Cores | Meters Cored | Meters Recovered | Percent Recovery |
|---|---|---|---|---|---|---|---|---|---|
| 183 | 25-28 July | 52°34.30'N | 161°12.33'W | 4708 | 516 | 40 | 361 | 149.8 | 41.0 |
| 184 | 30 July-1 Aug. | 53°42.64'N | 170°55.39'W | 1910 | 603 | 23 | 186 | 123.2 | 66.2 |
| 184A | 1-2 August | 53°42.64'N | 170°55.39'W | 1910 | 669 | 0 | 0 | 0.0 | 0.0 |
| 184B | 2-4 August | 53°42.64'N | 170°55.39'W | 1910 | 973 | 14 | 121 | 50.2 | 41.5 |
| 185 | 5-7 August | 54°25.73'N | 169°14.59'W | 2110 | 728 | 27 | 216 | 98.0 | 45.4 |
| 186 | 9-12 August | 51°07.81'N | 174°00.34'W | 4522 | 926 | 28 | 245 | 142.7 | 58.0 |
| 187 | 12-13 August | 51°06.6'N | 173°57.2'W | 4567 | 370 | 4 | 36 | 6.8 | 18.9 |
| 188 | 15-16 August | 53°45.21'N | 178°39.56'E | 2649 | 638 | 18 | 146 | 57.4 | 39.3 |
| 189 | 18-22 August | 54°02.14'N | 170°13.38'E | 3437 | 871 | 20 | 174 | 74.2 | 42.6 |
| 190 | 22-24 August | 55°33.55'N | 171°38.42'E | 3875 | 627 | 16 | 142 | 85.0 | 59.9 |
| 191 | 25-28 August | 56°56.70'N | 168°10.72'E | 3854 | 919 | 16 | 130 | 44.2 | 34.0 |
| 191A | 28 August | 56°56.70'N | 168°10.72'E | 3860 | 50 | 4 | 36 | 21.5 | 59.7 |
| 191B | 28 August | 56°56.70'N | 168°10.72'E | 3860 | 9 | 1 | 9 | 8.5 | 94.4 |
| 192 | 30 Aug.-2 Sept. | 53°00.57'N | 164°42.81'E | 3014 | 942 | 35 | 308 | 152.4 | 49.5 |
| 192A | 2-4 September | 53°00.57'N | 164°42.81'E | 3014 | 1057 | 6 | 47 | 38.2 | 81.3 |
| 193 | 6-7 September | 45°48.20'N | 155°52.27'E | 4811 | 71 | 4 | 29 | 12.3 | 42.4 |
| | | | | | Totals | 256 | 2186 | 1064.4 | 48.7 |

## Site 184

Site 184 is located at the southwestern corner of Umnak Plateau, southeastern Bering Sea, in water 1910 meters deep.

The 973-meter-thick sediment and sedimentary rock sequence drilled and cored is comprised of two basic lithologic units designated A and B. Unit A consists of Pleistocene to Upper Miocene clay-rich diatom ooze (0-603 m) with a variable admixture of sand and silt layers, volcanic ash beds, pumice pebbles, and a microflora typical of a neritic environment in the Pliocene section. Unit B (603-973 m) is a sparsely fossiliferous clayey siltstone (or mudstone) with sporadic occurrences of foraminifera and typically non-age diagnostic coccoliths and diatoms. Thin beds of calcite- and silica-cemented (?) size-graded, volcanic sandstone and siltstone and lithified glass ash are present (see Fullam et al., this volume, Part IV).

The occurrence of neritic diatoms in beds of Pliocene age is of considerable interest because it implies cycles of uplift and subsidence of Umnak Plateau. However, deep-water foraminifera and the absence of lithofacies typical of a shelf environment indicate that the neritic flora is allochthonous and presumably derived from the summit platform of the nearby Aleutian Ridge, possibly during episodes of glacially lowered sea level or tectonic elevation of the ridge. The finding of *Melonis pompilioides* in diatomaceous beds of Late Miocene age, and again in slightly older beds within the underlying mudstone sequence, suggests the Umnak Plateau has remained at or below its present summit depth (near 2000 m) during the last 8 to 10 m.y.

The perplexing bottom-simulating reflection horizon (BSR), one that mimics changes in bathymetry and crosses bedding plain reflections at low to moderate angles, was found to correspond closely to the top of the lower siltstone or mudstone unit. No gas, possibly indicative of the base of a clathrated section (Stoll et al., 1971), was detected in the vicinity of the BSR. The apparent implication is that the BSR was formed by the shingle-like burial of the lower mudstone unit by the upper one. Geometrically this is difficult to accept because the upper sequence is principally a pelagic unit of diatomaceous debris, which should depositionally conform to preexisting topography rather than be at angles to it. There is little age control in the lower mudstone unit, but calcareous foraminifera recovered 145 meters below the BSR are no older than late Miocene and thereby suggest that the BSR does not coincide with a major time hiatus. The BSR may represent an acoustically traceable diagnetic boundary (see Scholl and Creager, this volume).

## Site 185

Site 185 is located on the southern flank of the broad spur separating Bristol and Bering canyons, southeastern Bering Sea, in water 2110 meters deep.

The drilled and cored sedimentary sequence consists of 728 meters of Holocene, Pliocene, and upper Miocene hemipelagic clay-rich diatom ooze and diatomaceous silty clay or clayey silt. Thin, terrigenous sand and silt beds, a few ash layers, and some limestone beds also occur. A gradual decrease in diatom content and enrichment in clay takes place between 600 and 728 meters.

The terrigenous fraction is most likely derived from a terrane underlain by volcanic rocks or rocks rich in volcanic debris. The upper portion of the section (above 250 m at Core 10) contains discrete beds of pyroclastic and volcanoclastic debris composed of glass- and feldspar-rich sand and sandy silt, thin ash layers, scattered erratics, and pumice fragments. Additionally, above 250 meters, the section locally contains up to 10 percent glass as a constituent of the terrigenous fraction. Unlike Site 184, only a few neritic diatoms occur here and these are scattered throughout the sediment sequence.

Because the sediments at this site are characterized by gradual lithologic and age changes with superimposed minor fluctuations in the relative amounts of terrigenous and pelagic components, the section was not subdivided into units. However, from 0 to 587 meters (through Core 17), the sediments are similar to Unit A defined at Site 184. The sediments of the lower portion of the hole from 644 to 728 meters are either Site 184 Unit B equivalents (in which case they are less indurated, less extensively burrowed, and contain more diatom remains) or are a thicker equivalent of a thin transition zone separating Units A and B at Site 184.

At Site 185 the bottom-simulating reflector (BSR) occurs at 670 meters and is apparently coincident (unlike Site 184) with a 10- to 15-meter-thick section of gaseous (virtually all methane) sediment and a lithologic transition from terrigenous-rich diatomaceous deposits to a virtually unfossiliferous siltstone sequence.

The lithologic transition found near the BSR may represent an upward migrating zone of diagenesis involving the alteration of former detritus-rich diatomaceous beds to siltstone or claystone units that bear only vestiges of their original siliceous microflora. The lithologic transition may in part account for some of the reflected energy encountered at the bottom-simulating horizon and may be locally associated with gas accumulations (see Scholl and Creager, and Fullam et al., this volume).

### Site 186

Site 186 is located near the outer or southern edge of Atka Basin, Aleutian Terrace, in water 4522 meters deep. The sediment sequence penetrated is 926 meters thick and consists predominantly of diatomaceous silty clay ranging in age from upper Pleistocene through lower Pliocene.

A section (at 622 m) less than 60 meters thick of middle Miocene diatomaceous silty clay is enclosed within a larger section of lower Pliocene silty clay. The microfossils, which include calcareous forms, suggest that the middle Miocene unit is an allochthonous block. Reworked middle Miocene forms also occur in the associated Pliocene beds.

Volcanic ash is interbedded throughout the section and ash beds are particularly common above 20 meters. A middle Pleistocene pumice-bearing ash layer 4.5 meters thick occurs at 165 meters Beds of sand and silt up to 4.5 meters thick are commonly intercalated with the diatomaceous silty clay. Benthic foraminifera in the thick sandy layer of Cores 10 to 11 (middle to lower Pleistocene) are apparently displaced from shallower depths, implying that the sands are turbidites. Thin layers of calcite-cemented siltstones and diatomaceous calcitic silt are present in the middle Pliocene between 386 and 509 meters.

The lens-shaped mass of generally undeformed sedimentary deposits underlying Atka Basin, Aleutian Terrace, is approximately 2000 meters thick and consists chiefly of diatomaceous clay younger than late Miocene. Siliceous microorganisms constitute about 35 percent of these Neogene beds. The bulk, about one-half, of the accumulated debris was contributed by the nearby Aleutian Ridge as either hemipelagic silt- and clay-size particles (40%) or sandy turbidite layers (10%) bearing shallow-water foraminifera. Vitric volcanic debris, although rather abundant in the Pleistocene section, is a minor constituent (5%) throughout most of the drilled section.

Atka Basin is guarded by an outer ridge that is underlain by an acoustically unresolvable structure. The deepest prominent acoustic reflector (about 815 m) at Site 186 was not identified stratigraphically but occurs within the lower Pliocene. Drilling at Sites 186 and 187 established that this ridge is in part constructed of uplifted and deformed Pliocene and upper Miocene basin deposits.

### Site 187

The sediment sequence at Site 187, located 2.3 miles southeast of Site 186, consists of diatomaceous silty clay that is older but otherwise virtually identical to that recovered at Site 186. The only four cores attempted to a total depth of 370 meters contained sediment of Pleistocene, lower Pliocene, and upper Miocene age. Limestone fragments (one of which contains fecal pellets), silty mud, and an ice-rafted (?) rounded graywacke pebble were recovered from the core catcher of Core 1 at 164 meters. The two limestone fragments contain a lower Pleistocene flora and probably caved from higher in the hole, as the associated silt is of lower Pliocene age. Upper Miocene disturbed (probably by coring operations) and indurated silty clay (claystone) with associated diatomaceous sediment was recovered between 175 and 370 meters.

Site 187 is located above the "acoustic basement" underlying the outer ridge of Atka Basin, Aleutian Terrace. This ridge is also the summit of the steeply sloping inner wall of the Aleutian Trench. Drilling at this site shows that at least part of the acoustic basement is deformed sedimentary rock as old as late Miocene. These deposits presumably accumulated in the Atka Basin. At nearby Site 186, beneath this basin, stratigraphically equivalent beds lie deeper than 926 meters. Thus, since the late Miocene (5 m.y.), the structural displacement of late Miocene beds between Sites 186 and 187 has been at least 750 meters. The source area for the allochthonous block of middle Miocene silty clay cored at Site 186 in beds of lower Pliocene age is presumably the ridge drilled at Site 187 (see Grow, this volume).

### Site 188

Site 188 is located at the outer edge of the mid-slope terrace on the western flank of Bowers Ridge, Bering Sea, in water 2649 meters deep. The 638-meter-thick sedimentary sequence drilled and cored consists basically of a Pleistocene to upper upper Miocene (0-580 m) unconsolidated and semiconsolidated interbedded diatom ooze, silt-rich diatom ooze, and diatomaceous silt, overlying mudstone (580-638 m) lacking diagnostic fossils. The upper diatomaceous unit is similar to Unit A at Sites 184 and 185, and the lower to the mudstone sequence, Unit B, at Site 184.

Variations in the relative abundance of diatoms and inorganic silt plus thin layers of volcanic ash, black sand and silt, and limestone occur throughout the upper 580 meters. Neritic diatom species typical of the Pliocene section at Site 184, Umnak Plateau, are common at 330 meters and are present throughout the Plio-Pleistocene section. Foraminiferal assemblages are typical of present water depths.

Except for a few thin sand layers, no evidence of turbidite deposition was encountered at Site 188, hence it seems unlikely that any part of the Neogene section was deposited beneath the abyssal floor of the adjacent Bowers Basin. Thus, the drilled section at Site 188 appears to be an in situ pelagic and terrigenous blanket depositionally draped over a deeper basement underlying the inner flank of Bowers Ridge (Ludwig et al., 1971a).

The prominent reflection horizon, "P", noted by Ewing et al. (1965) and Ludwig et al. (1971a; 1971b) in this area is caused by the major lithologic transition at a subbottom depth of 580 meters. This transition, from terrigenous-rich diatom ooze to terrigenous mudstone of late Miocene age takes place over a vertical thickness less than about 15 meters. A similar lithologic break was found at Site 184 and 185, also in deposits of late Miocene age. The BSR beneath Umnak Plateau and the "P" horizon of Bowers Ridge are thus equivalent to the top of a lithified terrigenous sequence. However, the subbottom depth to this lithified section is not everywhere a measure to a stratigraphic level; the BSR is time transgressive and its position and geometry are partly related to diagenetic alteration of terrigenous-rich diatomaceous deposits of early late to late late Miocene age (see Scholl and Creager, this volume, also Fullam et al).

## Site 189

Site 189 is located on a deeply submerged ridge (3400 m) at the base of the north flank of the Aleutian Ridge, Bering Sea.

The 871-meter-thick sediment and sedimentary rock sequence drilled and cored consists of a Pleistocene to Pliocene (0-260 m) diatomaceous silty clay to clay-rich diatom ooze; an upper Pliocene (260-370 m) diatom-, carbonate-, and pyrite-bearing silty clay; and an upper Pliocene to upper Miocene, and possibly older (370-871 m), mudstone sequence that includes sedimentary breccia.

Diatoms show a regular and gradual increase from ~5% at the top to ~40 to 50% at a depth of 260 meters (upper Pliocene). Discrete beds of ash and sand, pumice pebbles, and erratic sedimentary rock pebbles occur in the Pleistocene section. Part of the Pliocene section (260-360 m) is a transitional facies of silty clay with 5 to 10% diatoms showing solution effects and pyritization.

The mudstone (370-871 m) is mottled and burrowed with beds dipping up to 30 degrees below 640 meters and showing tension cracks normal to the bedding.

The prominent acoustic basement beneath Site 189 (0.87 sec total reflection time) was determined to be associated with a deformed 20- to 40-meter-thick sequence (at 730 meters) of size-graded sedimentary breccia and calcite-cemented sandstone of probable late Miocene age. Claystone with inclined bedding also occurs for about 100 meters above the breccia. This discovery implies that a thick apron or insular rise unit flanking the base of the Aleutian Ridge was arched after or during late Miocene time to form the Site 189 ridge. Since this time, the ridge has received a thick covering of terrigenous-rich hemipelagic deposits. Uplift of the ridge, beginning shortly after the turbidite layers of sandstone and breccia were deposited, appears to coincide with a late Miocene orogenic episode that affected the length of the Aleutian Ridge.

The terrigenous nature of the sedimentary section drilled at Site 189 in part attests to the importance of the adjacent Aleutian Ridge as a source of detrital debris. However, terrigenous debris from Kamchatka and eastern Siberia can also reach this area via a Pacific route (Lisitsyn, 1969; see Scholl and Creager, this volume, Part IV, and Fullam et al., Part IV). At other Bering Sea sites (e.g., 184, 185, and 188), the late Miocene and younger deposits are dominated by diatomaceous debris. In contrast, except for a short upper Pliocene-lower Pleistocene section, diatoms at Site 189 are only an important secondary constituent. In comparison to other sites, the lower diatom content of Site 189 deposits may also reflect oceanographic conditions less favorable to planktonic productivity. Also noted at Site 189 was the uphole appearance of calcareous foraminifera and nannoplankton near the Plio-Pleistocene boundary, a phenomenon found at all other Bering Sea sites that implies a major downward shift in the carbonate compensation depth in the early Pleistocene.

## Site 190

Site 190 is located in the southwestern Aleutian Basin just east of the southern terminus of the main or northern part of Shirshov Ridge, Bering Sea. The 627-meter-thick sediment and sedimentary rock sequence drilled and cored consists of a Holocene through upper Miocene (0-615 m) silty clay with variable amounts of diatoms, and diatom ooze with variable amounts of silt and clay overlying an upper to middle (?) Miocene (615-? m) section of mudstone, limestone, and clay. Discrete layers of vitric volcanic ash and thin layers of volcanically derived (?) silt occur throughout the upper Miocene and younger section (0-615 m).

Although Site 190 is located over part of the abyssal floor of the Aleutian Basin, which previous geologic studies and seismic reflection profiles (Ludwig et al., 1971a, 1971b) imply is underlain by a thick (as much as 1000 m) sequence of turbidite beds of Late Cenozoic age, the bulk of the cored deposits are not visibly size-graded sand or silt but rather silty or clayey diatomaceous layers. However, grain size analyses show that many of these layers are, in fact, graded units (see Fullam et al., this volume). It can be conjectured that the leveling of the abyssal plain in the vicinity of Site 190 resulted from the deposition of only distal turbidites in conjunction with a continual rain of siliceous microorganisms. However, the fact that the site is located over a slight structural dome, across which the acoustically definable turbidite sequence thins, may have in part contributed to the general paucity of coarser graded sand and silt layers.

Within the acoustically measured turbidite section (250 m), only the upper 175 meters contain coarse size-graded beds. Presumably, this section, which corresponds to the entire Pleistocene, signifies glaciation and glacially lowered sea levels. However, displaced fresh-water and littoral diatoms occur to a depth of 200 meters in upper Pliocene diatomaceous and silty beds, and, acoustically, the turbidite-bearing sequence extends at least 50 meters deeper (see Scholl and Creager, this volume, Part IV). The silty diatom ooze and diatom silty clay below 375 meters is worm burrowed and semi-indurated and largely of late late Miocene age. Except for the occurrence of size-graded terrigenous turbidites, the entire diatomaceous section (0-615 m) is similar in age and lithology to Unit A recognized at other Bering Sea sites (except 188). The upper or middle (?) Miocene claystone and limestone recovered below this depth are temporally and lithologically equivalent to Unit B encountered at other sites.

**Site 191**

Site 191 is located at a water depth near 3800 meters on the east-central side of the Kamchatka Basin. A 900-meter sediment and sedimentary rock sequence consists of 520 meters of upper Pleistocene to upper Pliocene diatomaceous silty clay, diatom ooze, silty sand, and sandy silt; and 380 meters of underlying Pliocene to upper Miocene (?) indurated silty clay and diatomaceous silty clay containing beds of indurated lithic wacke. These overlie a tholeiitic or low-K (0.24% $K_2O$) basalt, cored for 19 meters (1.4 m recovered), containing textural variation that suggests it is a submarine flow (see Stewart et al., this volume, Part III). The upper 520 meters has recognizable variations in the abundance of sand, degree of induration, and occurrence of limestone beds. Volcanic ash is present in the upper 240 meters (middle and upper Pleistocene). Reworked extinct Miocene species of diatoms are found to a depth of 520 meters throughout the Pleistocene section and into upper Pliocene beds as well. Shallow-water foraminiferal assemblages are typically associated with the sand layers.

The upper 300 meters of sandy and silty deposits cored in Kamchatka Basin are rather "classically" a turbidite sequence. Size-graded layers are present as are reworked fossils and displaced fresh-water and shallow-water species. Below 300 meters, visually graded units were not found, but silty clay containing displaced fresh- and shallow-water diatoms occurs to 520 meters, close to the base of the turbidite sequence indicated on seismic reflection records. The coarser upper 300 meters includes all but the lower part of the lower Pleistocene, whereas the finer grained distal turbidites between 300 and 520 meters include beds of late Pliocene age. Nearly identical relationships were found at Site 190 in the adjacent Aleutian Basin (see Scholl and Creager, this volume).

In Kamchatka Basin, the turbidites are much coarser grained and far less diatomaceous than those in the adjoining but much larger Aleutian Basin. Similarly, in Kamchatka Basin, Pliocene and late Miocene (?) mudstone beds containing lithic wackes underlie the turbidite sequence, whereas in the Aleutian Basin the sequence is underlain by silty biogenic pelagic deposits. The coarser and far more terrigenous nature of the Neogene deposits of Kamchatka Basin reflect its small size and nearness to high-gradient drainages.

The geologic implication of the basalt beneath late Miocene deposits in Kamchatka Basin is difficult to assess. Because seismic records (Ludwig et al., 1971a) reveal that the mafic layer is regional in extent, has a gentle but undulating relief, and appears to be buried depositionally. However, during its emplacement, probably in middle Oligocene time, it may have engulfed older Tertiary deposits filling the basin (see Scholl and Creager, and Stewart et al., this volume).

**Site 192**

Site 192, at a water depth of 3000 meters, is located atop Meiji Guyot at the northwest end of the Emperor Seamounts. The sediment and sedimentary rock sequence (0-1044 m) consists of Holocene through Pliocene (0-320 m) diatomaceous silty clay and diatom ooze with abundant volcanic ash beds and ice-rafted (?) erratics through the first 110 meters; upper Miocene (320-550 m) diatom-rich clay; lower upper Miocene through upper middle Miocene (350-705 m) diatom-rich clay; lower middle Miocene through Oligocene (705-940? m) claystone with minor calcareous layers; and upper Eocene to Cretaceous (lower Maestrichtian) (940?-1044 m) chalk and calcareous claystone and minor size-graded sand and silt beds between 950 and 1000 meters. An unconformity separates upper lower Eocene and Cretaceous (middle Maestrichtian) beds. At 1044 meters the sedimentary sequence apparently depositionally overlies a complex of alkali basalt and trachybasalt flows (see Stewart and Natland, and Natland, this volume).

It is notable that abundant ice-rafted (?) debris and volcanic ash occur down to middle Pliocene deposits, although a few ash layers occur in lower Pliocene beds. Presumably this means that formation of glaciers in Kamchatka and a Late Cenozoic episode of intense volcanism in the Kamchatka-Kuril region began about 3 m.y. ago.

The richly diatomaceous beds, 550 meters thick, overlying the seamount attest to high fertility of the overlying surface waters back to early late Miocene time (8-10 m.y.). Prior to this, and through the Oligocene, the seamount was buried beneath a nearly equally thick pile of pelagic clay, 60 percent of which is now a worm-burrowed and mottled claystone. These fine-grained deposits are about 400 meters thick and, between lower Miocene time and early late Miocene (16-8 m.y.), about 250 meters accumulated at a rate of near 30 m/m.y., which, when roughly corrected for compaction (see Lee, this volume) converts to at least 50 m/m.y. This is an exceptionally high rate for pelagic deposits generally and for the northwestern Pacific specifically, where Pleistocene rates as high as 22 m/m.y. have been measured (Opdyke and Foster, 1970). Lower Miocene and Oligocene rates are more typical oceanic values, about 7 m/m.y. (uncorrected), and are similar to those (5-6 m/m.y.) for upper and middle Eocene claystone and chalk and middle and lower Maestrichtian chalk (3-4 m/m.y.) overlying the basaltic core of Meiji Guyot. Eocene turbidites and several species of nannoflora typically preserved only in shallow-water deposits suggest that parts of Meiji Guyot was at or above sea level during this time.

Microfauna and flora suggest that the sediment-water interface has remained near the carbonate compensation depth throughout deposition of the entire sediment section cored at this site. Subarctic flora and fauna are present in the sedimentary section back through the Oligocene, implying that the north-to-south current presently passing over this site has been in this location since that time. The Eocene assemblage suggests a warmer climate; however, because the Eocene was a globally warm period, conclusions about the paleolatitude of Meiji Guyot in the Eocene cannot be made.

The thick, lower Miocene to lower upper Miocene (16-8 m.y.) pelagic clay requires that Meiji Guyot was near a sediment source at this time and undoubtedly somewhat earlier because rapid claystone deposition began at an unknown time in the Oligocene or early Miocene. The only possible source areas are Kamchatka to the west and the Aleutian Ridge to the north, which were both tectonically and volcanically active in the Mid-Tertiary. Inasmuch as Kamchatka, with its much larger drainage area and known thick Neogene deposits blanketing its eastern margin immediately west of Meiji Guyot, is the more obvious choice, it seems unlikely that the relative motion between the Pacific plate and Kamchatka has exceeded about 500 km during the last 16 to 20 m.y. (see Scholl and Creager, this volume).

### Site 193

Site 193 is located just west of the Hokkaido Rise at a water depth of 4811 meters. The sediment sequence penetrated consists of 71 meters of upper to lower Pleistocene ash-bearing diatomaceous silty clay to clayey diatom ooze. Ice-rafted (?) erratics of sedimentary rock, dark vitric ashes, and clay balls are present throughout the section.

## EXPLANATORY NOTES

### Organization of This Volume

Part I of this volume consists of an introductory section giving the reasons drilling in the northern Pacific and the Bering Sea was carried out, plus a scientific summary of major findings at each site. An integrated synopsis appears later in the volume.

Part II consists of the site reports, basically a detailed reporting of the geological data obtained at each site. For this volume the philosophy has been that the site report is intended to provide basic information for intelligent sample selection by the outside investigator. Text has been kept brief, with the major emphasis on presentation of geological information on the core summary forms. Particularly, the biostratigraphic sections of the site reports have been kept very brief; the specialist interested in details of occurrence and paleoecological interpretations is referred to the chapters on individual fossil groups. The section on lithostratigraphy has been kept almost entirely descriptive. The site reports are outlined as follows:

Site Data
Summary
Background and Objectives
Operations
Lithostratigraphy
Physical Properties
Paleontology
Correlation of Profiles and Stratigraphy
References

The chapters of Part III consist of reports done ashore subsequent to the cruise, both by shipboard scientists and by others not directly associated with the cruise. The guiding philosophy here was that a study should be undertaken for inclusion in this Initial Report only if that study was expected to produce data and results which would be useful to the Co-Chief Scientists for their overall geological synthesis of Leg 19. This is in line with the policies of the Deep Sea Drilling Project, which endeavors to ensure that detailed scientific investigations for the greater part be left to the geological community at large, to be performed on DSDP samples requested through the approved manner, using the Initial Reports as a guide.

A synthesis of the lithostratigraphy of the north Pacific and Bering Sea and a synthesis of the overall geological findings of Leg 19 appear in Part IV. A biostratigraphic comparison and synthesis was deemed inappropriate, since the calcareous nannoplankton and foraminifera were not well represented in these high-latitude cores.

### Responsibility of Authorship

Site reports are co-authored by the entire scientific party. In general, the summaries and the background and objectives were written by D. Scholl; the operations by J. Creager; physical properties by Homa J. Lee; the lithostratigraphy by R. Boyce, T. Fullam, R. Stewart, and P. Supko; and the biostratigraphy by R. Echols (foraminifera), I. Koizumi (diatoms), J. Ling (radiolaria and silicoflagellates), and T. Worsley (calcareous nannoplankton). The section of correlation of profiles and stratigraphy was written by J. Grow.

T. Fullam redrafted the core summary forms ashore and compiled the site summaries at 250 meters per page scale.

### Geophysical Data

The *Glomar Challenger* underway geophysical data were collected using a Varian proton-precession magnetometer, a 12 kHz (30° half-angle) transducer transceiver system recorder on Gifft GDR-IC-19 recorders for precision depth determination, and a seismic reflection profiler system consisting of a Bolt PAR 600A air gun, a 20 phone EVP-23 element towed array, a Bolt PA-7 band pass filter and Edo Western Model PRB 333 recorders. The normal frequency recording band was 30 to 150 Hz.

All navigation was accomplished with the aid of the Navy satellite navigation system and precision fixes obtained about every 2 hours using an ITT model satellite receiver-computer system.

The data obtained on passage between sites are not presented here. These data are available from DSDP and may be obtained by addressing inquiries to the Chief Scientific Editor. Seismic reflection profiles obtained by the *Glomar Challenger* in the vicinity of the drilled sites (approach and departure tracks) are included in the site reports.

Seismic profiles used in site selection were those variously collected by E. L. Hamilton, E. C. Buffington, and D. W. Scholl. Extensive pre-site surveys were conducted by G. G. Shor on the Scripps ANTIPODE expedition. Data for those site surveys in the vicinity of sites actually drilled are presented here (Fornari et al., this volume).

### Numbering and Depth Convention

A site number refers to a single hole or group of holes drilled in essentially the same position using the same acoustic beacon. The first hole at a site is given the number of the site. Second holes drilled by withdrawing from the first hole and redrilling were labeled "A" holes (e.g., Hole 192A).

A core is taken by dropping a core barrel down the drill string and coring for 9 meters as measured by lowering of the drill string. The sediment is retained in a plastic liner 9.28 meters long inside the core barrel and in a 0.20 meter long core catcher assembly below the liner. The liner is not normally full.

On recovery the liner is cut into sections of 1.5 meters measured from the lowest point of sediment within the liner. In general the top of the core does not coincide with the top of a section. The sections are labeled from 1 for the top (incomplete) section to a figure as high as 6 for the bottom (complete) section, depending on the total length of core recovered.

By convention, when partial recovery results, the recovered sediment is assumed to represent the top of the cored sequence. The core catcher represents sediment immediately below the lowest section.

An example of accepted convention for a sample number is "19-183-3-1 (10-20 cm)." The sample represents the interval between 10 and 20 centimeters in Section 1 of Core 3, Site 183, Leg 19.

### Handling of Cores

After a core section had been cut, sealed, and labeled, it was brought into the core laboratory for processing. The routine procedure listed below was usually followed:

1) Weighing of the core section for mean bulk density measurement.

2) GRAPE analysis for bulk density and porosity

3) Gamma-ray counting for radioactivity

4) Sonic velocity determination, using a Hamilton Frame.

After the physical measurements were made, the core liner was cut. The core could then be split into halves by a cheese cutter, if the sediment was a soft ooze. At times, when compacted or partially lithified sediments were included, the core had to be split by a machine band saw or diamond wheel.

One of the split halves was designated a working half. Samples, including those for grain size, X-ray mineralogy, interstitial water chemistry, and total carbonate content were taken, labeled, and sealed. Larger samples were taken from suitable cores for organic geochemical analysis.

The working half was then sent to the paleontology laboratory. There, samples for shipboard and shore-based studies of nannoplankton, foraminifera, radiolarians, diatoms, and silicoflagellates were taken.

The other half of a split section was designated an archive half. The cut surface was smoothed with a spatula to bring out more clearly the sedimentary features. The color, texture, structure, and composition of the various lithologic units within a section were described on standard visual core description sheets (one per section) and any unusual features noted. A smear slide was made, usually at 75 cm if the core was uniform. Otherwise, two or more smear slides were made, each for a sediment of distinct lithology. The smear slides were examined microscopically. The archive half of the core section was then photographed. Both halves were sent to cold storage on board after they had been processed.

Material obtained from core catchers and not used up in the initial examination was retained in freezer boxes for subsequent work. Sometimes significant pebbles from the core were extracted and stored separately in labeled containers. On other occasions, the liners contained only sediment-laden water. This was usually collected in a bucket and allowed to settle, the residue being stored in freezer boxes.

At several sites hard cores were obtained either of basement or indurated sediment. Each separate core fragment was numbered and labeled consecutively from the top downwards, and its orientation indicated by an upward pointing arrow. Where possible the fragments were arranged in their original relative orientation and were then sliced longitudinally for examination and separation into working and archive halves.

All samples are now deposited in cold storage at the DSDP West Coast Repository at Scripps Institution and are available to investigators.

### Sediment Classification

Prior to Leg 18, no sediment classification then in existence had proven sufficiently compatible with the need of shipboard scientists, with rare exceptions. The result was that each shipboard scientific party outlined its own sediment classification system, rendering comparison between cruises difficult. Recognizing the great benefit possible by such comparison of sediment types in various oceanic regions, particularly in light of DSDP's intention of entering all geological data into a computer-based data storage and retrieval system, it was decided to undertake the construction of a standard classification system suitable for description of the major oceanic sediment types and acceptable to shipboard scientists.

A basic sediment classification was devised by O. E. Weser of DSDP and was first used at sea on Leg 18. Over the ensuing 18 months (to the time of this writing), the system has been reviewed and changed in-house several times, based upon experience gained during utilization at sea.

The complete DSDP sediment classification system will be published in later volumes of the Initial Report series. The following is that portion of the Weser sediment classification pertinent to Leg 19 sediments.

## CLASSIFICATION AND NOMENCLATURE RULES

I. Rules for class limits and sequential listing of constituents in a sediment name

A. Major constituents

1. Sediment assumes name of those constituents present in major amounts (major defined as >25%). See example in rule IA3.
2. Where more than one major constituent is present, the one in greatest abundance is listed farthest to the right. In order of decreasing abundance, the remaining major constituents are listed progressively farther to the left.
3. Class limits when two or more major constituents are present in a sediment are based on 25% intervals, thusly: 0-25, 25-50, 50-75, 75-100.

Example illustrating rules IA and IB and the resulting sediment names:

| % Clay | % Nannos | | |
|---|---|---|---|
| 0-25 | 75-100 | = | Nanno ooze |
| 25-50 | 50-75 | = | Clayey nanno ooze |
| 50-75 | 25-50 | = | Nanno clay |
| 75-100 | 0-25 | = | Clay |

B. Minor constituents

1. At the discretion of the geologist, constituents present in amounts of 10-25% may be prefixed to the sediment name by the term **rich.**

   Example: 50% nannofossils, 30% radiolarians, 20% zeolites would be called a **zeolite-rich rad nanno ooze.**
2. At the discretion of the geologist, constituents present in amounts of 2-10% may be prefixed to the sediment name by the term **bearing.**

   Example: 50% nannofossils, 40% radiolarians, 10% zeolites would be called a **zeolite-bearing rad nanno ooze.**

C. Trace constituents. Constituents present in amounts of <2% may follow the sediment name with addition of the word **trace.** This again is at the discretion of the geologist.

II. Specific rules for calcareous and siliceous tests

A. Nannofossil is applied only to the calcareous tests of coccolithophorids, discoasters, etc.

B. The term **calcareous** or **siliceous**, depending on skeletal composition is applied where no attempt is made to distinguish fossils as to major subgroup. Thus, if no percent estimate is made, a mixture of radiolarians, diatoms, and silicoflagellates would be called **siliceous ooze.** Where this distinction is made, the appropriate fossil name is used.

C. Fossil tests are not qualified by a textural term unless very obviously redeposited.

D. Abbreviations, as nanno for nannofossil, rad for radiolarian, etc., may be used in the sediment name.

E. The term **ooze** follows a microfossil taxonomic group whenever it is the dominant sediment constituent.

F. Usage of the terms **marl** and **chalk** to designate amounts of microfossils, 30-60% and >60% respectively, as used by Olausson (1960) and others, is dropped. The term **chalk** is retained to designate a compacted calcareous ooze.

III. Clastic sediments

A. Clastic constituents, whether detrital, volcanic, biogenous or authigenic, are given a textural designation. When **detrital**[2] grains are the sole clastic constituents of a sediment, a simple textural term suffices for its name. The appropriate term is derived from Shepard's triangle diagram (see Figure 3). The textural term can be preceded by a mineralogical term when this seems warranted. Such mineralogical terms are applied as per rules IA and B.

[2]Detrital = all clastic grains derived from the erosion of preexisting rocks except for those of biogenous, authigenic, or volcanic origin.

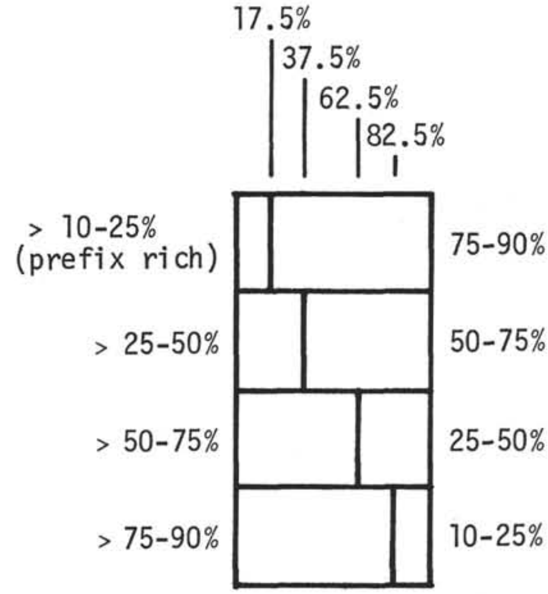



Figure 3. *Textural classification of clastic sediments, after Shepard (1954).*

B. When the tests of a fossil biocoenosis or authigenic and detrital grains occur together, the fossil or authigenic material is not given a textural designation (as per rule IIC). However, the detrital material is classified texturally by recalculating its size components to 100%. With the presence of other constituents in the sediment, the detrital fraction now requires a compositional term.

C. Clastic volcanics

Redeposited pyroclastics also become a clastic component. They are again recognized by the term **volcanic** and receive a textural term such as **gravel, sand, silt**, etc. It is particularly difficult at times to differentiate between **volcanic sand** (i.e., transported by tractive mechanisms) and **crystal ash** (i.e., direct outfall resulting from explosion of a volcano).

D. Clastic authigenic constituents

Where authigenic minerals are recognized as being a redeposited constituent, they are given a textural designation in addition to their mineral names.

IV. Volcanic and authigenic constituents

A. Volcanic constituents

Pyroclastics are given textural designations already established in the literature. Thus, **volcanic breccia** = >32 mm, **volcanic lapilli** = <32 mm to >4 mm, and **volcanic ash** = <4 mm. It is at times useful to further refine the textural designations by using such modifiers as **coarse** or **fine**. An ash wholly, or almost wholly, of glass shards is termed **vitric ash.**

B. Authigenic constituents

1. Authigenic minerals enter the sediment name in a fashion similar to that outlined under rules IA and B. Normally, as with a fossil biocoenosis, the authigenic minerals are not given a textural designation and texture.
2. The terms **ooze** and **chalk** are applied to carbonate minerals of all types using the same rules that apply to biogenous constituents.

V. Color

A. Color is not formally part of the sediment name. However, its employment for sediment description is important particularly as it provides one of the criteria used to distinguish **pelagic** and **terrigenous** sediments.

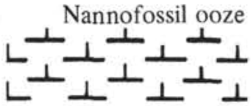
B. Common usage dictates that it is no longer expedient to employ the term **red** for sediments (*usually* pelagic) which are various shades of red, yellow, and brown. The proper color designation should be used.

VI. General comments
   A. Sediments are not formally divided into the two groups, pelagic and terrigenous, by the sediment classification. This distinction is left to be made on an informal basis.
   B. The distinction between clastic and nonclastic fossil material is often not clear in the deeper pelagic realm. Therefore, fossil material receives a textural designation if, and only if, there is evidence of obvious and significant current transport. Similar consideration applies to volcanic material.

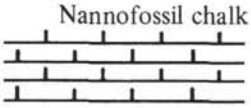
### Lithologic Symbols

Accompanying the introduction of the sediment classification to the DSDP volumes is the employment of a new set of lithologic symbols. These symbols and their method of employment has continued, with only minor modification, through all volumes subsequent to Volume 18. The basic sediment symbols pertinent to Leg 19 are as follows:

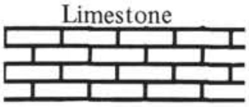
B1 Nannofossil ooze



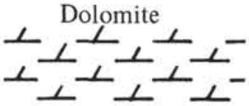
B4 Nannofossil chalk



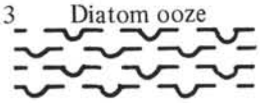
B8 Limestone



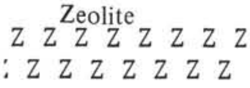
B9 Dolomite



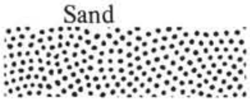
B13 Diatom ooze



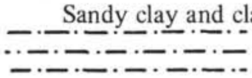
A1 Zeolite



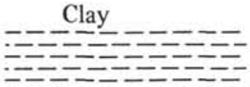
T1 Sand



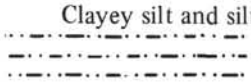
T2 Sandy clay and clayey sand



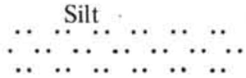
T3 Clay



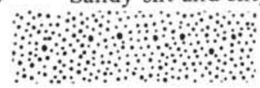
T4 Clayey silt and silty clay



T5 Silt

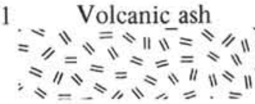


T6 Sandy silt and silty sand

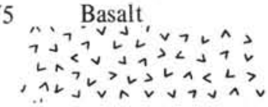


T8 Conglomerate

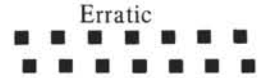
V1 Volcanic ash



V5 Basalt



Erratic



These symbols have been used on all core and site summary forms. Where complex lithologies occur, each major constituent is represented by a vertical bar. The width of each bar corresponds to the percentage value of the constituent it represents in the manner shown on Figure 4. It will be noted that the class limits of the vertical bars corresponds to those of the sediment classification. With this system of graphical representation, the **rich** portion of the major constituents and the minor constituents may be shown.

In some cases it is not possible to show all major and **rich** constituents graphically; here the geologist must make a value judgment, showing those components most geologically significant.

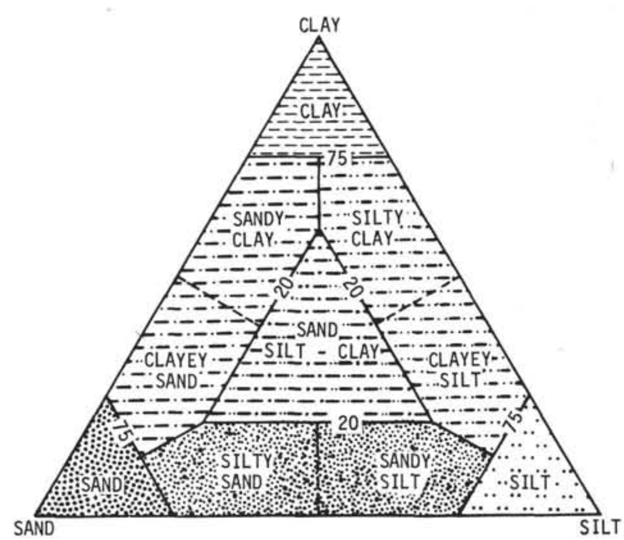



Figure 4. *Vertical bar width representations of class limits.*

### Smear Slides

Smear slides were the basic means of mineral identification on shipboard. The shipboard party tried to be as specific as possible with regard to mineral identifications. It was thought that it is better to err than to hesitate to guess and thus have the potential sample requestor never realize that material of interest to him might be present.

Smear slide estimates of mineral abundances were based on area of the smear slide covered by each component. Specific mineral identification and quantification was attempted for sands, but for silts and clays, only the textural categories were really quantified. Past experience has shown that accuracy may approach a percent or so for very distinctive minor constituents but that, for major constituents, accuracy of ±10 to 20% is considered very good. Of more importance to the geologist than absolute accuracy are relative changes in component abundances.

### Core Forms

The basic lithologic data are contained on core summary forms at the end of each site report. These are opposed by black and white photographs of the cores. As far as possible the data are presented in the following order:

Sediment name
Color name and Munsell or GSA number
Composition
Structure
X-ray or grain size data

Many cores contain minor important lithologies as well as a basic lithology. The description of the basic lithology is so indicated in most cases. Descriptive information for minor lithologies is placed at the appropriate core depth wherever possible. X-ray data are those generated by the DSDP X-ray mineralogy laboratory on samples collected on shipboard. Grain size results are from the DSDP sedimentology laboratory at Scripps unless otherwise noted.

Paleontologic zonal boundaries are preceded by a letter designating fossil group, i.e., N – calcareous nannofossil, D – diatom, R – radiolaria, S – silicoflagellate, F – foraminifera. Fossil characteristics are preceded by these same letters with the F for foraminifera being preceded by a P (planktonic) or B (benthonic). The fossil characteristics described are abundance and preservation. Letter codes are: Abundance – F, flood; A, abundant; C, common; R, rare; and Preservation – G, good; M, moderate; and P, poor.

Four degrees of drilling deformation were recognized as follows:

slightly deformed

moderately deformed

highly deformed

watery

Slightly deformed cores exhibit a slight bending of bedding contacts; extreme ending defines moderate deformation. In highly deformed cores, injected bedding planes may approach the vertical. In extreme cases, bedding may be completely disrupted to produce a "drilling breccia." Watery intervals generally have lost any bedding characteristics originally available. Where intervals of alternating hard and soft layers are encountered, the corer will normally recover pieces of undeformed harder material separated by injected softer material, producing what is here termed "biscuit and paste" deformation.

## ACKNOWLEDGMENTS

Reference geophysical data, particularly continuous seismic reflection profiles, were made available to DSDP and to the authors by E. L. Hamilton and E. C. Buffington of the U. S. Navy Undersea Center, San Diego; by D. W. Scholl of the U. S. Geological Survey; by William Ludwig of Lamont-Doherty Geological Observatory; and by G. Shor of Scripps Institution of Oceanography.

The Analytical Laboratories of the USGS kindly provided whole rock chemical analyses of the basement rocks from Sites 183, 191, and 192. Strontium isotope studies of these same rocks were carried out by C. E. Hedge and Z. E. Peterman of the USGS, Denver.

G. Bryan and R. Stoll, aboard D/V *Glomar Challenger* on the first portion of Leg 19 to study clathrate phenomena, provided stimulating discussion of geological problems.

The authors wish to thank Capt. Joseph E. Clarke and Drilling Superintendent T. Rayborn and their crews; Cruise Operations Manager E. Maxwell of Sun Oil Company; and the very competent staff of marine technicians under the direction of M. Lehmann, DSDP Laboratory Officer.

## REFERENCES

Atwater, T., 1970. Implications of plate tectonics for the Cenozoic tectonic evolution of western North America. Bull. Geol. Soc. Am. **81**, 3513.

Ewing, M., Ludwig, W. J. and Ewing, J., 1965. Oceanic structural history of the Bering Sea. J. Geophys. Res. **70**, 4593.

Hamilton, E. L., 1967. Marine geology of abyssal plains in the Gulf of Alaska. J. Geophys. Res. **72**, 4189.

————, in press. Marine geology of the Aleutian Abyssal plain. Marine Geology.

Hayes, D. E. and Pitman, W. C., III, 1970. Magnetic lineations in the North Pacific. *In* Geological Investigations of the North Pacific. J. D., Hays, (Ed.). Geol. Soc. Am. Mem. 126. 291.

Jones, E. J. W., Ewing, J. and Truchan, M., 1971. Aleutian plain sediments and lithospheric plate motion. J. Geophys. Res. **76**, 8121.

Karig, D. E., 1970. Ridge and basins of the Tonga-Kermadec island arc system. J. Geophys. Res. **75**, 239.

————, 1971. Origin and development of marginal basins in the western Pacific. J. Geophys. Res. **76**, 2542.

Lisitzin, A. P., 1969. Recent sedimentation in the Bering Sea. Israel Program for Scientific Translations. 614 p.

Ludwig, W. J., Houtz, R. E. and Ewing, M., 1971a, Sediment distribution in the Bering Sea; Bowers Ridge, Shirshov Ridge and enclosed basins. J. Geophys. Res. **76**, 6367.

Ludwig, W. J., Murauchi, S., Den, N., Ewing, M., Hotta, H., Houtz, R. E., Yoshi, T., Asanuma, T., Hagiwara, K., Sato, T. and Ando, S., 1971b. Structure of Bowers Ridge, Bering Sea. J. Geophys. Res. **76**, 6350.

Mammerickx, J., 1970. Morphology of the Aleutian abyssal plain. Bull. Geol. Soc. Am. **81**, 3457.

Matsuda, T. and Uyeda, S., 1971. On the Pacific-type orogeny and its model-extension of the paired belt concept and possible origin of marginal seas. Tectonophysics. **11**, 5.

Olausson, E., 1960. Description of sediment cores from the central and western Pacific with the adjacent Indonesian region. Rept. Swedish Deep-Sea Exped. Sediment Cores from the West Pacific. **7** (8), 163.

Opdyke, N. D. and Foster, J. H., 1970. Paleomagnetism of cores from the North Pacific. *In* Geological Investigations of the North Pacific. J. D. Hays (Ed.). Geol. Soc. Am., Memoir 126. 83.

Packham, G. H. and Falvey, D. A., 1971. An hypothesis for the formation of marginal seas in the western Pacific. Tectonophysics. **11**, 79.

Pitman, W. C., III and Hayes, D. E., 1968. Sea-floor spreading in the Gulf of Alaska. J. Geophys. Res. **73**, 6571.

Scholl, D. W., Greene, H. G. and Marlow, M. S., 1970. Eocene age of Adak "Paleozoic(?)" rocks, Aleutian Islands, Alaska. Bull. Geol. Soc. Am. **81**, 3582.

Scholl, D. W., Buffington, E. C., and Marlow, M. S., in press. Plate tectonics and the structural evolution of the Aleutian-Bering Sea region; solutions and complications. *In* Geology of the Bering Sea and Adjacent Regions. R. B. Forbes (Ed.). Geol. Soc. Am. Spec. Paper.

Shepard, F. P., 1954. Nomenclature based on sand-silt-clay ratios. J. Sediment. Petrol. **24**, 151.

Stoll, R. D., Ewing, J. and Bryan, G. M., 1971. Anomalous wave velocity in sediments containing gas hydrates. J. Geophys. Res. **76**, 2090.

Wolfe, J. A., 1971. Tertiary climatic fluctuations and methods of analysis of Tertiary floras. Paleogeography, Paleoclimatology, Paleoecology. **9**, 27.

Wolfe, J. A. and Hopkins, D. M., 1967. Climatic changes recorded by Tertiary land floras in northwestern North America. *In* Tertiary Correlations and Climatic Changes in the Pacific. K. Hatai (Ed.). 11th Pacific Sci. Congr. Japan Univ., Tokyo. 67.

Wolfe, J. A., Hopkins, D. M. and Leopold, E. B., 1966. Tertiary stratigraphy and paleobotany of the Cook Inlet Region, Alaska. U. S. Geol. Survey Prof. Paper 398-A. 29 p.