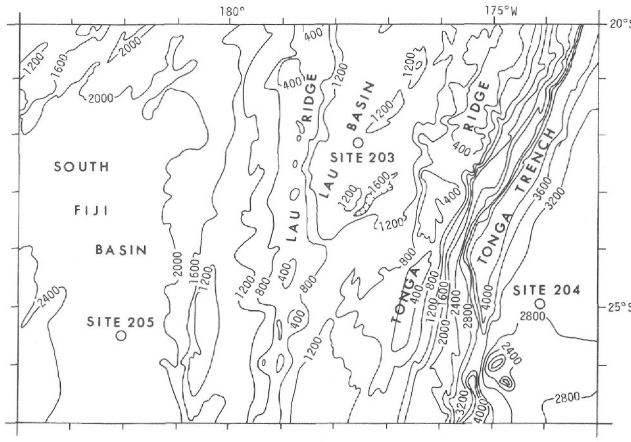
3. SITE 203

The Shipboard Scientific Party[1]

Location: Lau Basin
Position: 22°09.22′S, 177°32.77′W
Water Depth: 2720 meters (corrected)
Total Penetration: 409 meters



Contour interval 400 fathoms. (After Mammerickx, Chase, Smith, and Taylor, 1971. Bathymetry of the South Pacific, Charts 11 and 12: Scripps Institution of Oceanography, California.)

Summary: Intermittently cored, the sediment is primarily a calcareous fossil ooze with high concentration of ash and volcanic sands. The oldest dated sediment is early Pliocene, but extrapolation based on estimated accumulation ratio indicates approximate late Miocene age for acoustic basement.

BACKGROUND AND OBJECTIVES

General

The Lau Basin forms the interarc basin between the Tonga and Lau ridges and has morphologic continuity southward with the Havre Trough and the Taupo volcanic zone of New Zealand. Earlier work by Karig (1970) summarized its general characteristics and suggested that there was no observable systematic variation in depth or structural style across the basin. The area is one of ridge-trough topography with axial trends generally northeast-southwest. The acoustically opaque basement is similarly lineated and has been interpreted as tilted fault blocks. Sediment cover over most of the central portion of the basin is very thin and patchy. It generally thickens near the margins of the basin and consists primarily of calcareous pelagic sediments and volcanic detritus.

Site 203 was tentatively located on the basis of seismic profile records from *Argo, Conrad, Eltanin, Horizon*, and *Kana Keoki.* It was proposed with the objectives of determining the age and composition of the interarc basin sediments and dating the basement. As such, it is one of a series of sites to be drilled on Leg 21 in several of the marginal basins in this region of the southwest Pacific.

Review by the JOIDES Panel on Pollution Prevention and Safety indicated that the proposed site and drilling program were acceptable with intermittent coring, moderate drilling precautions, and standard abandonment procedures.

Site Survey

Site 203 was the only one on Leg 21 for which a detailed site survey was not available prior to departure from Fiji. Although R/V *Kana Keoki* had carried out a brief survey in the northern part of the area, the actual site selected for drilling was in the southern portion of the Lau Basin. Here, available bathymetry indicated a narrower, smoother, and more clearly defined interarc basin than the site which had been suggested originally. Because of the lack of specific survey data, the site approach was designed to provide necessary site information prior to dropping the beacon.

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OPERATIONS

Site Approach

Six hours on the site approach were devoted to defining local characteristics and making a final selection of a drilling site. A preliminary box pattern (Figure 1) showed the area to be quite rough, with several small sedimentary basins of apparently limited longitudinal extent (e.g., Figure 2). Just east of the area of the box survey, a somewhat larger basin was found, and the site was occupied there after an initial pass to determine the east-west limits of the basin. Although the length of this basin was not determined, it is presumed to follow the general north-northeast trend of the Lau Basin. Sediment thickness in the center of the pond reaches a maximum of 1.5 sec two-way travel time, and the width of 6 nautical miles makes this basin larger than others encountered within the Lau Basin. Prominent seismic reflecting horizons occur at 0.2 and 0.4 sec subbottom across the width of the basin. The approach profile crossing the basin shows no clear evidence of slumping or mass movement of sediments from either the Lau or Tonga Ridges, suggesting generally pelagic and eolian sedimentation. Reflective horizons in the upper three quarters of the section are roughly horizontal, while a few of the deepest reflectors follow the basement slope suggesting deformation during the early history of the basin.

In order to obtain a representative section and basement age with minimal drilling, the site was occupied at the eastern margin of the basin where sediment thickness was 0.55 sec.

Sonobuoys

Two successive sonobuoys malfunctioned during attempts to record a vertical reference profile. Because of the need to conserve equipment for measurements at later sites, no further trials were made and no vertical profile was obtained at Site 203.

Drilling Program

The drilling program was planned to sample the principal units indicated by the seismic reflection profile and to get cores at and in the basement.

Cores 1 and 2 sampled the uppermost 15 meters of the section. The drill was then washed down to 108 meters, and Core 3 was obtained as a sample of the unit above the 0.2-sec reflector. Core 4 was taken in the vicinity of the 0.2-sec reflector and Core 5 in the vicinity of the 0.4-sec reflector.

Although drilling and coring had been routine, after Core 5 was recovered and drilling operations were resumed, the pipe was found to be jammed in the hole. Neither rotation nor pumping could be accomplished, and several hours were expended working the assembly loose.

In view of the constraint of having only two bottom hole assemblies aboard, it was decided to abandon the site short of the objective of reaching basement. Upon recovery of the gear, it was concluded that loose sand which had been drilled somewhere in the interval following Core 4 had caved and frozen the pipe. During the working of the assembly, while trying to free it, several meters of the sand had been collected in the core barrel. These have been retained as a sample, but are not considered to be a core.

Table 1 is a summary of the coring at Site 203.

LITHOLOGY

General

Five cores were taken at Site 203 before the drill string became stuck and drilling operations were abandoned. The principal lithologies are calcareous biogenic ooze and volcanic ash. Data are insufficient for subdividing the sequence into lithologic units. Consequently, the following discussion is on a core-by-core basis. Grain size and organic carbon determinations and descriptions of each of the cores are given in Appendixes A, B, and F, respectively.

Core 1 (0 to 6 meters) in the soft surface sediment is mainly brown nanno ooze of Recent to late Pleistocene age. The core is slightly to highly disturbed, with an increase in glass content downwards. Two layers in the core are rich enough in ash to be called volcanic ash.

Core 2 (6 to 15 meters) which is extremely disturbed and is composed of post-mid or late Pleistocene nannofossil ooze with 5% to 10% volcanic glass. Most of the glass is silt sized, colorless, and contains spherical to rod-like vesicles. In a specimen from Sample 203-2-1, 99 cm, this glass has a refractive index of 1.506 to 1.510, suggesting a silica content of about 68% according to the refractive index–silica content curve of George (1924). A smaller percentage of green glass is also present in the sample. This has a refractive index of 1.580 to 1.596, indicating a composition of 48% to 50% silica using the same method. The other volcanic products are plagioclase and clinopyroxene. The feldspar refractive index measured range from 1.570 to 1.582, suggesting a calcic bytownite if only a single composition is present. No quartz was detected in the sample by X-ray diffractometry.

The brown color of the samples is attributable to granules of iron oxide throughout the sediment. These occur as radiating aggregates up to 25μ in diameter.

Apart from the abundant coccoliths, other organic debris present includes foraminifera, Radiolaria, diatoms, silicoflagellates, and holothurian remains. Small, circular, brown organic bodies up to 5μ in diameter are also present.

Core 3 (108 to 117 meters) of early Pleistocene age consists of an upper 6.9 meters of ash in sharp contact with an underlying 2.1 meters of nannofossil ooze. The ash is silty throughout most of its thickness but coarsens to sandy in its basal 20 cm. The ash is composed predominantly of clear, colorless glass with a small proportion of pale brown glass together with minor clinopyroxene and plagioclase feldspar. Nannofossils are present in small proportions in nearly all samples, but reach 30% in places. Foraminifera are also present in some samples, but siliceous fossil remains are absent. Bulk X-ray results from Sample 203-3-4, 120-122 cm, give 45% calcite, 5% quartz, 36% plagioclase, 4% chlorite, and 11% montmorillonite in the crystalline fraction. A specimen from the base of the ash (Sample 203-3-5, 86 cm) contains colorless glass with a refractive index range of 1.514 to 1.54, pale brown glass with a refractive index of 1.54 to 1.57, and plagioclase with a range of refractive indices from 1.55 to 1.57. These data

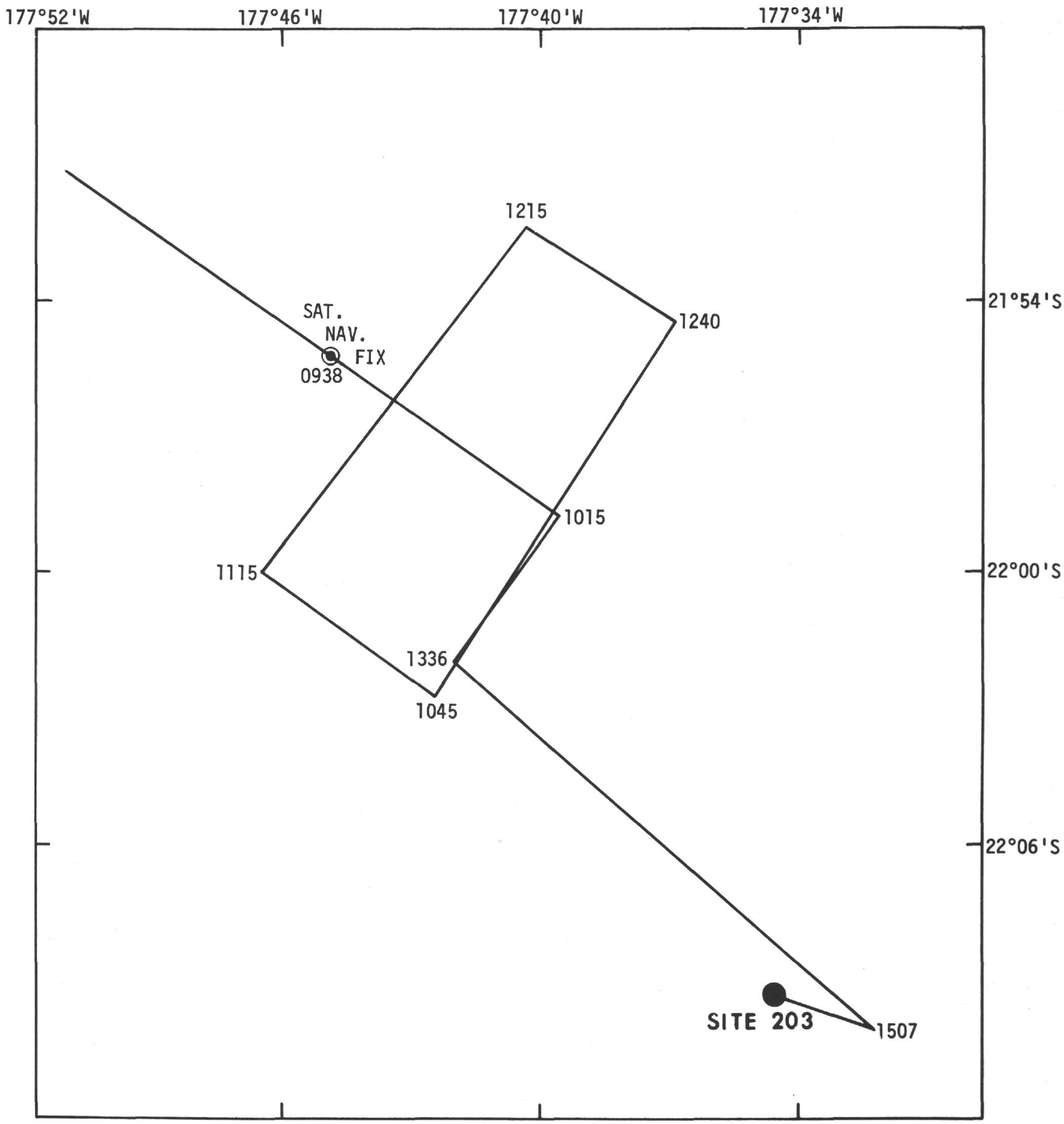

Figure 1. Glomar Challenger *track 17 November 1971. Survey for Site 203.*

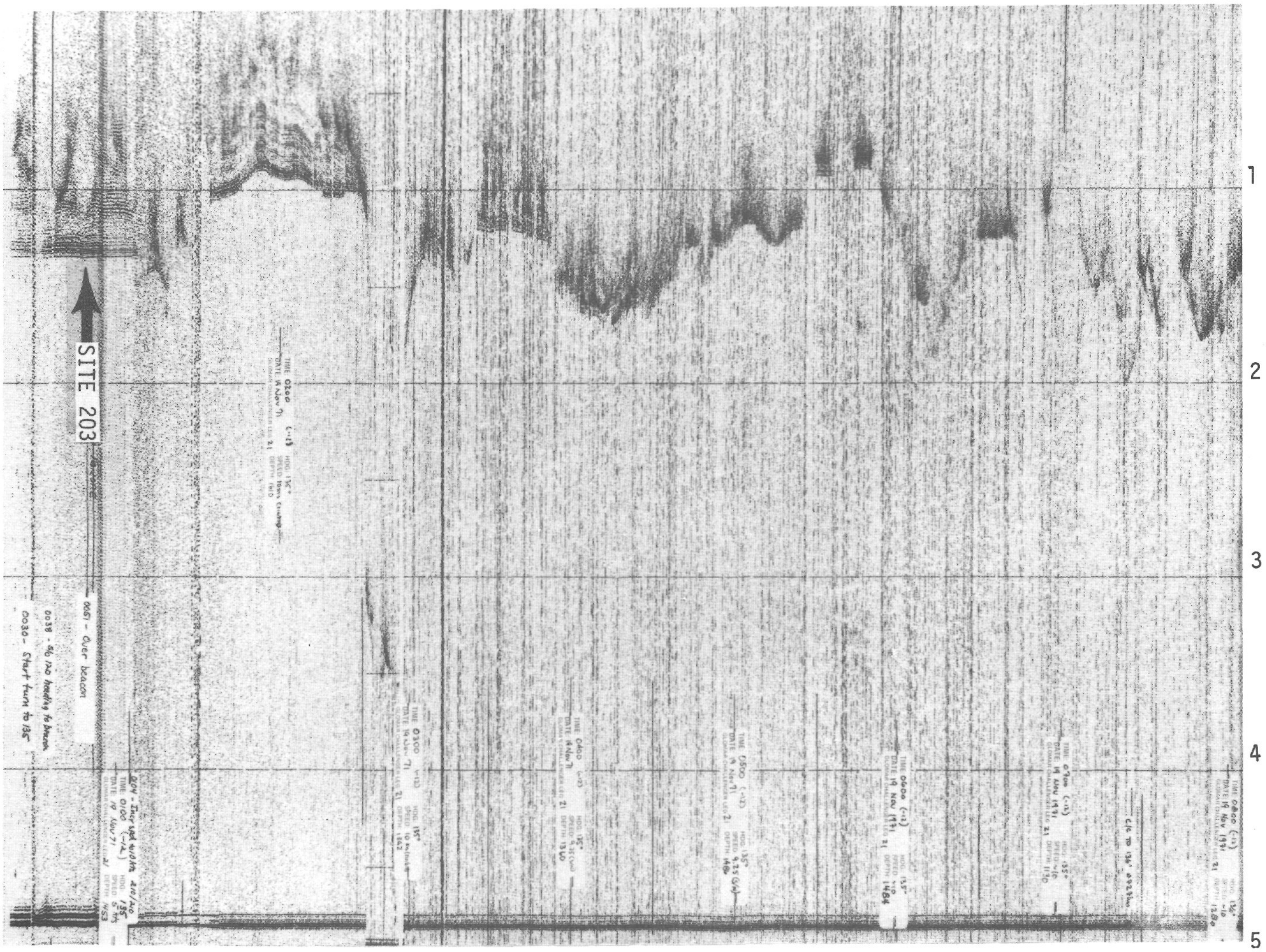

Figure 2. *Reflection profile of sediment pond drilled at Site 203 and adjacent pond showing extensional deformation in the Lau Basin.*

TABLE 1
Coring Summary, Site 203

Core	Date	Time	Depth from Drill Floor (m)	Depth Below Sea Floor (m)	Cored (m)	Recovered (m)	Recovery (%)
1	11/18	0310	2730-2736	0-6	6	5.4	90
2	11/18	0402	2736-2745	6-15	9	2.0	22
3	11/18	0645	2838-2847	108-117	9	9.0	100
4	11/18	1028	2959-2968	229-238	9	2.4	27
5	11/18	1422	3130-3139	400-409	9	1.5	17
Total					42	20.3	48

Note: Echo sounding depth (to drill floor) = 2727 meters; drill pipe length to bottom = 2730 meters.

suggest a silica range of 56% to 66% for the colorless glass, 52% to 56% for the pale brown glass, and a broad possible range of plagioclase composition from andesine to bytownite. The presence of quartz is in keeping with the more sodic plagioclase than that found in samples from Core 2.

The lithology of the nannofossil ooze in the basal part of Core 3 is similar to that of Cores 1 and 2, except that siliceous fossil remains are absent. Volcanic glass is present in quantities estimated in smear slides from 7% to 15%.

Cores 4 and 5 sampled more indurated parts of the section and consist of separate pieces of rock up to 10 cm in length. Recovery was poor, amounting to 2.4 meters in Core 4 and 1.5 meters in Core 5. Both cores consist of layers of gray ash alternating with layers of paler gray and yellow nanno ooze. Volcanic glass is present in all the oozes except the basal 44 cm of Core 5. Both cores are moderately to intensely mottled. Burrows include *Chondrites* and *Zoophycos* types.

Core 4 (229 to 238 meters) straddles the Pliocene-Pleistocene boundary. The percentage of nannoplankton has been estimated from smear slides to range from about 5% to over 60%. Abundant foraminifera were noted in one layer (Sample 203-4-1, 80 cm) where they were estimated at 35%. Clay is present but difficult to estimate from smear slides, but up to 30% is suggested for the ash-poor layers. Iron oxide granules are present in these same layers in the range of 1% to 5%. Bulk X-ray data from a sample of one of these beds revealed a composition of calcite 25%, quartz 7%, chlorite 4%, plagioclase 46%, augite 8%, montmorillonite 6%, and magnetite 4% for the crystalline phases. The plagioclase in this sample has a range of refractive index from 1.56 to 1.57, suggesting a labradorite to bytownite composition. Nearly all the glass in this sample is pale green and altered. The volcanic ash horizons in the core show some variety, in some the glass is a clear type with a low refractive index, while in others green to greenish brown glass is the predominant type. The degree of alteration of the darker glass is much greater than in the higher cores. The refractive indices of the dark glasses are close to that of the mounting medium (Caedex), i.e., about 1.56 and therefore probably basaltic.

Core 5 (early to middle Pliocene), from 400 to 409 meters, shows the effects of volcanism most strongly; it consists of volcanic ash overlying nanno ooze. The top of the core consists of unconsolidated black sand, containing glass with a refractive index of 1.58 and olivine, overlying a silty moderately indurated gray, glass-shard ash. The glass in this latter sediment is mainly colorless with a low refractive index. A specimen from Sample 203-5-1, 78 cm, shows this pale glass to have a range of refractive indices from 1.518 to 1.534 with most falling in the range of 1.526 to 1.530. These values suggest a silica percentage of about 58% using the curve of George (1924) in contact with 50% silica for the glass in the overlying sand. The plagioclase in the same sample has a refractive index range from 1.564 to 1.578 with most grains between 1.568 and 1.574, indicating a calcic labradorite to bytownite composition. No quartz was detected by X-ray diffractometry, but minor quantities of clinopyroxene are present. In other samples, up to one-third of the glass is dark and usually altered. Interbedded paler beds are richer in nannofossils (up to 40% of the sediment). Foraminifera are present in minor quantities, but no siliceous organisms were noted.

Within the ash layer are two rounded cobbles of highly vesicular olivine basalt. There are no marks on the basalt to suggest that the rounding is the result of abrasion by the drill bit so that the rounded cobbles and the black sand might suggest that at the time of deposition volcanic activity was taking place nearby and in shallow water. However, the sand consists of freshly broken fragments of green glass and olivine and is reasonably well sorted. The basalt fragments are highly altered. It is possible that the sand and the basalt are of quite unrelated origins. The sand may be material which has caved down the hole either from a sand layer somewhat above the level of Core 5 or, alternatively, is the result of the pulverizing of a thin layer of basalt by the drill bit.

The lower part of the core, beneath the ash layer, consists of nannofossil ooze. The lower part of this ooze is brown in color, whereas the upper part is yellow. The boundary between the two parts is quite sharp and, although it is inclined, the structure of the sediments does not seem to be disturbed. This suggests that the boundary is secondary in nature and may represent a front of iron enrichment associated with volcanism in a lower part of the section beneath that part sampled (cf. Boström and Peterson, 1969). The suggestion of some kind of diagenetic alteration is enhanced by the presence of about 40% of material identified as clay in the smear slides about 10% of iron oxide in the lower (brown) part and the absence of recognizable glass shards.

Sample 203-5, CC contained a cobble of highly vesicular basalt. Another basalt cobble was found jammed in the opening of the drill bit after recovery of the entire string. The vesicles comprise about half of the basalt from the core catcher; the remainder consist mostly of highly altered glass with thin needle-like feldspars, small crystals of pale green clinopyroxene, and large fresh olivine phenocrysts.

A large quantity of black volcanic sand was found jammed in the core barrel after recovery of the string. This is the same as the sand at the top of Core 5 and is probably cavings from higher up in the hole, since the drill had not advanced at all beyond the depth of Core 5 before becoming stuck in the hole.

Discussion

Site 203 lies on the western side of the Lau Basin in a depth of 2730 meters of water. The Lau Ridge to the west is unexposed in the region except for a few shoals and reefs, shows no sign of recent volcanic activity, and is thus not regarded as a source of the volcanic ash found at Site 203. By contrast, the western side of the Tonga Ridge to the east of the basin is characterized by an active series of exposed volcanic islands and submarine volcanoes. The line of strike of these volcanic features lies about 150 km east of Site 203, and they are the most likely source of the bulk of the volcanic debris found in the cores.

A recent study of the chemistry and petrography of the late Cenozoic volcanics of the western side of the Tonga Ridge by Bryan, Stice, and Ewart (1972) reveals that the volcanics there have similar features. They comprise basaltic andesites, andesites, and dacites, and contain bytownite to calcic labradorite as their feldspar. Basalts are absent. The presence of small amounts of quartz in samples from Cores 3 and 4 is also compatible with an origin on the Tonga Ridge. Pigeonite and hypersthene occur in the volcanics on the islands along with augite. Unfortunately, the only pyroxene seen in the sediments at Site 203 is pale green clinopyroxene, presumably diopsidic augite.

The basaltic debris which is present in larger quantities in Core 4, and more especially in Core 5, may have a different origin, since late Cenozoic basalts have not been found in the western Tonga Ridge volcanics. The basaltic debris may be similar to the material which comprises the sea floor of the Lau Basin; Sclater et al. (1972) have found this to be tholeiitic basalt. The shallow water origin suggested for the highly vesicular basalt and perhaps the glass-olivine sand in Core 5 is difficult to explain because it appears that deposition of the whole sequence sampled at Site 203 took place at about the present depth. This is indicated by the foraminifera which are typical of lower bathyal assemblages throughout all the cores.

BIOSTRATIGRAPHY

General

The five cores obtained from Site 203 represent a sequence ranging in age from the middle Pliocene to Recent.

Cores 1 and 2, consisting of nanno ooze, contain abundant, well-preserved foraminifera and calcareous nannofossils indicative of late Pleistocene to Recent. Also present are a few Radiolaria having Pleistocene and Recent affinities. The first upward appearance of the nannofossil *Emiliania huxleyi* in Sample 203-1-1, 60 cm, is indicative of a latest Pleistocene age. The presence of the silicoflagellates *Dictyocha aculeata* and *D. messanensis* without *D. lingi* or *Mesocena elliptica* throughout Cores 1 and 2 indicates a post middle Pleistocene age, i.e., younger than the Matuyama paleomagnetic epoch (top = 0.7 m.y. B.P.). Abundant reworked older Pleistocene calcareous nannofossils were observed in the volcanic ash horizons of Core 1.

Core 3, essentially a nannofossil-rich ash, contains abundant, moderately well preserved early Pleistocene foraminifera and calcareous nannofossils. No Radiolaria were found in this and subsequent cores.

Core 4, consisting essentially of an ash-rich nannofossil ooze, contains few to common moderately well preserved foraminifera and calcareous nannofossils. The Pliocene-Pleistocene boundary occurs between Samples 203-4-1, 87-89 cm, and 203-4-2, 45-47 cm, based on the transition between *Globorotalia truncatulinoides* and *G. tosaensis.* The last appearance of discoasters in reasonable numbers occurs between Samples 203-4-1, 75 cm, and 203-3, CC. In Core 3 they are exceedingly rare, and hence, almost certainly reworked. Even in Sample 203-4-1, 75 cm, the presence of some battered *Discoaster brouweri* among many undamaged specimens indicates at least some reworking.

Core 5, consisting mostly of nannofossil-rich ash and clay-rich nannofossil ooze, contains common to abundant moderately well preserved calcareous nannofossils and foraminifera. The foraminifera are indicative of middle Pliocene age (N20), whereas the nannofossils indicate a basal late Pliocene age (NN16). For the purposes of this report a middle Pliocene age is adopted.

Benthonic foraminifera indicate deposition in lower bathyal depths throughout, and calcareous nannofossils of neritic habitat are absent. The planktonic assemblages are of tropical affinity throughout.

An average sedimentation rate for the Pleistocene is 120 m/million years, although the thickness of nannofossil Zone NN21 suggests a drastic decrease in deposition rates in the upper part of the section.

Foraminifera

Planktonic foraminifera are abundant and moderately well preserved in all five cores obtained from Site 203. The assemblages show that a sequence of high sedimentation rate was drilled, ranging in age from the Recent to the middle Pliocene (Zone N20).

Core 1 contains a well-preserved fauna of Recent or latest Pleistocene age, including *Globorotalia truncatulinoides, Globorotalia crassaformis, Globigerinoides ruber, Globorotalia menardii, Globigerina digitata,* and *Globigerina dutertrei.* The absence of *Globorotalia menardii flexuosa* and yet the presence of *G. menardii* suggest a postglacial or Recent age. Volcanic ash is important.

Core 2 contains a similar fauna except that the presence of *Globorotalia menardii flexuosa* indicates greater age within the late Pleistocene (Zone N22). Pumice fragments are conspicuous in this core in addition to volcanic ash.

Core 3 contains a well-preserved fauna of earliest Pleistocene age (lowest N22) as indicated by the common occurrence of *G. truncatulinoides* and the rare to uncommon occurrence of *Sphaeroidinella dehiscens, Globorotalia inflata,* and *Globigerinoides fistulosus.*

Core 4 contains moderately well preserved, rare to common planktonic foraminifera. The Pliocene-Pleistocene boundary occurs between Samples 203-4-1, 87-89 cm, and 203-4-2, 45-47 cm, based on the first appearance of *Globorotalia truncatulinoides* in moderate numbers in Sample 203-4-1, 87-89 cm. A late Pliocene age (N21) for specimens below Samples 203-4-2, 45-47 cm, is indicated by an association of *Globorotalia tosaensis, Globigerina decoraperta, Globigerinoides quadrilobatus, Globorotalia hirsuta, Sphaeroidinella dehiscens,* and *Globigerina humerosa.*

Core 5 contains a poor to moderately preserved, common assemblage of planktonic foraminifera of middle Pliocene age (N20) based on an association of *Globorotalia crassaformis, Sphaeroidinella subdehiscens, Sphaeroidinella seminulina, Globigerinoides obliquus, Globoquadrina altispira, Globigerina decoraperta, Globigerina humerosa, Globorotalia cibaoensis,* and *Pulleniatina obliquiloculata precursor.*

Benthonic foraminifera are rare throughout and virtually absent in Core 5. All forms noted were typical of the lower bathyal environment.

Calcareous Nannofossils

The biostratigraphy of Site 203, as deduced from the calcareous nannofossils, is summarized in Figure 3. For a detailed discussion of the floras, see the report by Edwards (Chapter 18).

Siliceous Microfossils

Radiolarians and silicoflagellates are rare to few and well preserved in Samples 203-1, 0-6 cm, and 203-2, 6-15 cm, and absent in the underlying cores, except for Samples 203-3-6, 80-82 cm, and 203-3, CC, which contain very rare corroded orosphaerid spines. The delicate skeletons of most radiolarians and the abundance of collosphaerids in the first two cores suggest a near-surface tropical water mass origin.

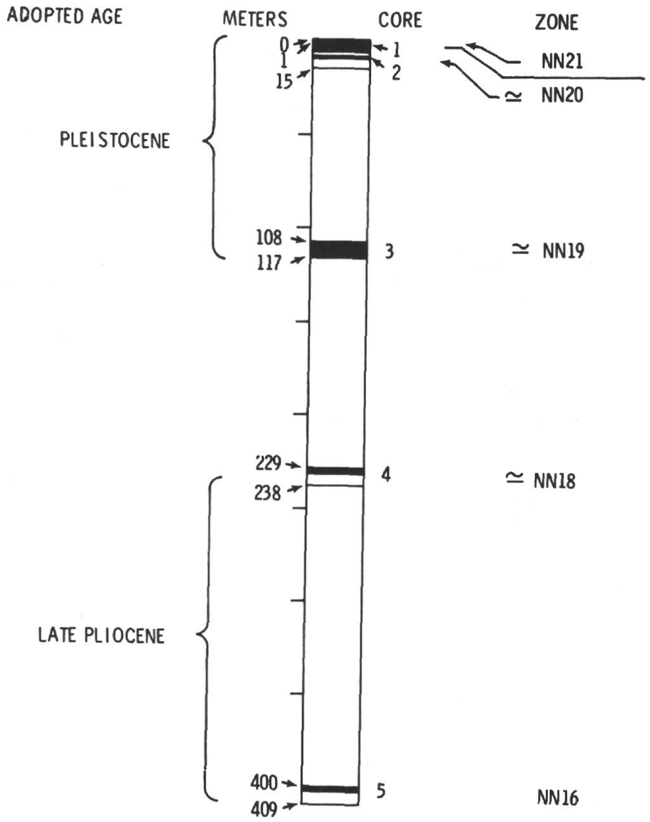

Figure 3. *Biostratigraphy of Site 203 as deduced from the calcareous nannofossils.*

The absence of the silicoflagellate *Distephanus speculum* in the assemblages supports this conclusion.

The assemblages are rather uniform through the two cores. Among other taxa they contain: *Ommatartus tetrathalamus, Anthocyrtidium zanguebaricum, Theocorythium trachelium, Lamprocyclas maritalis, Lithopera bacca, Lithocircus reticulata, Tholospyris acuminata, Tholospyris*(?) *cupola, Acanthodesmia vinculata,* etc. Frequently found were well-preserved phaeodarians such as *Porospathis holostoma, Castanidium*(?) *fenestratum, Protocystis xiphodon, P. thomsoni, P. harstoni, Lirella marina, L. melo, L. inauris, Euphysetta elegans, E. lucanii* plus fragments of *Aulographis taumorpha, Aulographonium candelabrum, A. pulvinatum,* dichotomous coelodendrid spines, and many other remains. Phaeodarians are generally only found in surface sediments, and hence, their presence throughout the upper 15 meters is surprising. There is no evidence of dissolution of the hollow skeletons of the phaeodarians with depth in sediment. This might be mainly due to the intense volcanic activity that saturated the seawater with silica and thus prevented dissolution of the siliceous skeletons of phaeodarians as Riedel (1959) and Stadum and Ling (1969) suppose.

There is no clear evidence among the radiolarians in Cores 1 and 2 for a precise age determination, although their Quaternary age is evident. In this respect the silicoflagellates, which are infrequent, give much more precise data. Two species occur throughout: *Dictyocha messanensis* and *D. aculeata.* The absence of *D. lingi* and *Mesocena elliptica* from this assemblage supports a post-middle Pleistocene age (*D. aculeata* Zone) or the Brunhes Normal Paleomagnetic Epoch.

PHYSICAL PROPERTIES

Introduction

At Site 203, bulk densities were determined by the standard Gamma Ray Attenuation Porosity Evaluation (GRAPE) device. Calculations for porosity were made using an assumed grain density of 2.65 gm/cc, but the results are not discussed here since they have not been fully analyzed.

Sonic velocities were measured, using the Hamilton frame device, and thermal conductivity (K) of the cores was measured using the heated needle probe method.

Bulk Density

GRAPE density measurement was made by linear interpolation between the two calibration samples; distilled water with a true density of 1.00 gm/cc and aluminum with a density of 2.60 gm/cc.

Bulk densities for Cores 3, 4, and 5 are shown on the graph at the end of this chapter. Cores 1 and 2 were not tested because of the liner size, unfilled cores, and sloppy material. The range of GRAPE densities for each core, based on section averages and excluding obviously spurious values, is given in Table 2.

Readings on the standards were run for each core barrel, but very little drift was noticed. In Core 3 a gradual increase from a density of 1.4 gm/cc at its top to 1.5 gm/cc at the bottom of the core was observed. This increase in density with depth is most likely due to the greater compaction of sediment at the bottom of the core barrel during coring and not an original density variation. In the lowermost core, Core 5, the most indurated sediment in the hole gave a wide range of density values (1.17 to 1.59 gm/cc). This is probably due to the short lengths of core separated by empty spaces and to the space between core sample and liner wall which is common in cores of indurated material.

TABLE 2
Range of Bulk Density in Cores from Site 203

Core	Bulk Density (gm/cc)
3	1.406-1.514
4	1.291-1.444
5	1.169-1.588

Sonic Velocity

Sonic velocity measurements made on the split half of Core 3 ranged from 1.54 to 1.56 km/sec. On the more consolidated sediments of Cores 4 and 5 sonic velocity was measured on individual rock fragments and had values ranging from 1.66 to 2.24 km/sec for the indurated ashes and oozes and 4.20 km/sec for the basalt (assuming a basalt density of 2.80 gm/cc). The basalt value is low, but this can probably be accounted for by the vesicular character of the basalt samples recovered.

Thermal Conductivity and Heat Flow

Thermal conductivity values were measured at 10 points on Cores 1 through 4 at this site. Results are tabulated at the end of this chapter. Values range from approximately 1.8 to 2.2 m cal/°C cm sec (TCU), uncorrected for in situ sea-floor conditions. The highest value was measured in Core 4, which was sufficiently indurated to require drilling a small hole completely through this sample in order to insert the needle probe. The limited data do not appear to vary systematically with either depth or appearance of the sediment.

No in situ temperature measurement was attempted at this site, and hence no heat-flow data were obtained.

SUMMARY AND CONCLUSIONS

The Lau Basin site was drilled in an attempt to learn more of the history and role of marginal basins in the pattern of sea-floor spreading and global tectonics. The site occupies a somewhat anomalous, small sediment pond within the Lau Basin in terms of structure and thickness of the sedimentary section encountered. The section is not appreciably disturbed except in the deeper layers. Sediments encountered in the hole were volcanic-rich oozes and clays and volcanic sands. Drilling was terminated at 409 meters when sands slumping into the hole jammed the bottom hole assembly. Two sonobuoys malfunctioned at this site so that no vertical reflection data are available for stratigraphic correlation.

Sedimentation rates calculated on the basis of the Pliocene/Pleistocene boundary and also Zone N21 (Bolli) give rates of 120 m/million years and 80 to 120 m/million years, respectively. These high rates and the coarseness of the volcanic sands (ashes) suggest proximity to the source. In the latter part of the Pleistocene, nannofossils suggest a slowing to about 50 m/million years.

The cored sand layers and also supplementary Sample 5 (cored during attempts to free the drill string, and representing slumped sands rather than in situ deposits) contain volcanic glass with fresh surfaces and a high degree of sorting which suggests transport from a nearby source with little or no reworking, but which may be the result of drilling activity. The bottom of Core 5 contained a 5-cm fragment of highly vesicular olivine basalt with olivine phenocrysts. The fragment is rounded, though not by drilling activity.

Volcanic debris at the site is generally more acidic higher in the section and may well be derived from the Tonga Ridge, while the basalt at the base of the hole suggests possible foramation of new sea floor in the extension of the basin (e.g., Sclater et al., 1972).

The oldest material dated is middle Pliocene. At the sedimentation rates indicated this would suggest sedimentation was initiated close to the Miocene-Pliocene boundary, based on 1.5 sec of sediment with a minimum velocity 1.5 km/sec, a rate supported by measurements on the cores.

Unfortunately, it is not possible to derive definitive conclusions from the data available. Basement was not reached, so maximum age is an extrapolation, and the hole was not continuously cored so that the sedimentary record recovered is very incomplete. The suggested age would indicate that the Lau Basin is much younger than the Tonga Ridge or the sea floor to the east of the Tonga Trench. The lack of sediment disturbance throughout the upper three quarters of the section suggests that extension has not been important in this local basin since early in its history. Nannofossil data suggest that basin depths have remained similar to those at present. On the other hand, seismic reflection profiles across an adjacent sediment pond immediately to the east of the one drilled by Site 203 show considerable folding and marginal faulting which would indicate that the basin has been undergoing at least some extension to the present time. The rugged structure of the Lau Basin floor and the different structural patterns of adjacent sedimentary basins within it point to continuing extension and opening of the Lau Basin, at least since the Miocene, but also show that this has not been uniform or symmetrical, occurring instead irregularly across its width at various times and places.

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NOTE CONCERNING THE APPENDICES

The appendices consist of tables of shore laboratory determinations of grain size, carbon content, and mineralogical composition, summary visual descriptions of the cores recovered from the site, photographs of the cores and, finally, an overall summary of the results of drilling at the site. The symbols used to represent lithology in the core summary forms are explained in Chapter 2 of this volume. The lithologic description of each core contains typical results of shipboard examination of smear slides of each lithology. In order to make the lithologic descriptions more complete we have also included many of the shore laboratory results. These are identified by being placed in square brackets.

APPENDIX A
Grain Size Determinations, Site 203

Core, Section, Top of Interval (cm)	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Classification
1-4,113.0	5.6	13.8	41.6	44.6	Silty clay
3-3,40.0	111.4	0.0	78.3	21.7	Silt
3-5,56.0	114.6	2.0	79.9	18.0	Silt
3-5,88.0	114.9	62.4	30.7	6.9	Silty sand
5-1,10.0	400.1	92.7	4.7	2.6	Sand

APPENDIX B
Carbon-Carbonate Determinations, Site 203

Core, Section, Top of Interval (cm)	Depth in Hole (m)	Carbon Total (%)	Organic Carbon (%)	$CaCO_3$ (%)
1-1,119.0	1.2	7.6	0.0	63
1-2,90.0	2.4	7.6	0.0	63
2-2,10.0	7.6	7.7	0.0	64
3-4,10.0	112.6	0.5	0.0	4
3-6,45.0	115.9	7.7	0.0	64
4-1,91.0	229.9	5.7	0.0	47
4-2,134.0	231.8	0.5	0.0	4

APPENDIX C
X-ray Mineralogy Determinations, Site 203

Core	Cored Interval Below Sea Floor (m)	Sample Depth Below Sea Floor (m)	Diff.	Amorp.	Calc.	Quar.	Plag.	Chlor.	Mont.	Augi.	Magn.	Clin.
Bulk Samples												
3	108-117	113.7	97.6	96.3	44.8	4.9	35.5	3.8	10.9	–	–	–
4	229-238	230.1	84.6	75.9	25.4	7.1	46.1	4.3	5.9	7.6	3.6	–
2-20μ Fraction												
3	108-117	113.7	98.9	98.3	–	13.3	86.7	–	–	–	–	–
4	229-238	230.1	80.7	69.8	–	11.5	59.5	4.1	–	21.3	3.6	–
<2μ Fraction												
3	108-117	113.7	92.3	87.9	–	3.9	27.9	14.4	53.9	–	–	–
4	229-238	230.1	81.5	71.0	–	1.8	21.3	8.7	56.6	8.6	1.2	1.8

APPENDIX D
Thermal Conductivity Measurements, Site 203

Core, Section, Interval Below Top (cm)	Thermal Conductivity (mcal/°C cm sec)	Standard Deviation	Ambient Core Temperature (°C)	Remarks
1-2,70	0.002157	0.005935	25.17	Brown
1-3,70	0.001975	0.014463	25.37	Brown
2-2,70	0.001915	0.005161	0.00	Brown
3-1,70	0.001942	0.010625	24.14	Gray color
3-3,70	0.001824	0.009697	0.00	Gray color
3-4,70	0.001836	0.009060	0.00	Gray color
3-5,70	0.001970	0.007378	23.73	Lithological break 100 C
3-6,70	0.002228	0.007888	23.52	Brown
4-2,80	0.002232	0.013837	25.29	

Site 203 Hole Core 1 Cored Interval: 0-6 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
PLEISTOCENE	N23? ≈NN21	N R F	A F A	G G G	1	0.5 1.0	EMPTY	3	CC
	N22 ≈NN20	N R	A F	G G	2			1	CC
		N F R	A A R	G G G	3			1 4 1 3	
		N F R	A A F	G G G	4			4 3 4	GZ
PLEIST.	N22 ≈NN20	N F	A A	G G	Core Catcher				

LITHOLOGIC DESCRIPTION

10YR3/3 — FORAM IRON OXIDE NANNO OOZE
dark brown, slightly gritty
[63% $CaCO_3$]
67% nannos
20% iron oxide
10% forams
2% glass

10YR4/3 — IRON OXIDE RICH NANNO OOZE
[63% $CaCO_3$]
Increasing glass
↓
77% nannos
15% iron oxide
5% forams
1% rads
1% pyroxene
1% silicoflag.

10YR5/3
10YR4/3
10YR3/3

10YR4/3 — GLASS SHARD RAD AND FORAM BEARING IRON OXIDE RICH NANNO OOZE
dark brown, creamy
80% nannos
10% iron oxide
5% forams
2% glass
2% rads

2.5Y6/4 — IRON OXIDE BEARING NANNO GLASS SHARD ASH
yellow brown, slightly silty
2.5Y4/4 — Mixed zone.
72% glass
25% nannos
2% iron oxide
1% forams

2.5Y6/4
Mixed
2.5Y4/4
2.5Y5/2
2.5Y6/4 — RAD FORAM IRON OXIDE BEARING GLASS SHARD NANNO OOZE
medium brown, smooth with visible forams
44% nannos
40% glass
10% iron oxide
4% forams
2% rads

2.5Y5/2 — FELDSPAR BEARING NANNO RICH GLASS SHARD ASH
gray [14% sand, 42% silt, 45% clay]

2.5Y4/4 — SPONGE SPICULE GLASS SHARD BEARING RAD FORAM RICH IRON OXIDE NANNO OOZE
medium brown, smooth and creamy

FORAM AND IRON OXIDE BEARING GLASS RICH NANNO OOZE
70% nannos
15% glass
5% forams
5% iron oxide
2% rads

Site 203 Hole Core 2 Cored Interval: 6-15 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
PLEISTOCENE	N22 ≈NN20	F N R	A A F	G G G	1	0.5 1.0		4	CC
		F R N	A F A	G G G	2			4	
PLEIST.	N22 ≈NN20	F N	A A	G G	Core Catcher				

LITHOLOGIC DESCRIPTION

2.5Y4/4 — RAD GLASS SHARD BEARING IRON OXIDE FORAM RICH NANNO OOZE
brown, smooth and creamy texture
[64% $CaCO_3$]
50% nannos
16% forams
15% iron oxide
10% glass
5% rads
2% other siliceous fossils
2% minerals

FORAM BEARING IRON OXIDE AND GLASS SHARD RICH NANNO OOZE
olive brown, smooth with visible forams, no layering preserved
73% nannos
10% iron oxide
10% glass
5% forams
1% siliceous fossils
1% pyroxene

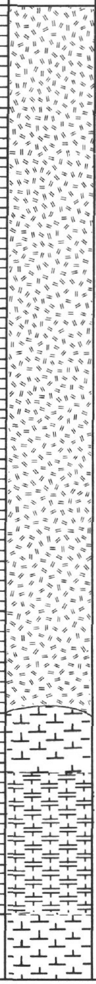
FORAM, IRON OXIDE AND GLASS BEARING NANNO OOZE
82% nannos
6% glass
6% iron oxide
3% forams
2% rads

Site 203 Hole Core 3 Cored Interval: 108-117 m

AGE: PLEISTOCENE
ZONE: N22 / =NN19

Section	Fossil	Abund.	Pres.	Deformation	Litho. Sample
1	F N R	- C -	G	3	
2	F R N	- - C	M	3	
3	F N R	- C -	M	3	GZ, CC
4	F R N	- - C	M	3	XM
5	F N	R C	G M	3	GZ, GZ
5	F	A	G		
6	F N R	A A VR	G M P	3	CC
Core Catcher	N F R	A A +	M G P		

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

5Y5/1 — NANNO RICH GLASS SHARD ASH: 80% glass, 17% nannos, 1% forams, 1% iron oxide, 1% pyroxene
gray, silty, no layering
Part of the core was very watery and lost in cutting. 115 cm in Section 1 disturbed yellow (5Y6/6) laminae

[78% silt, 22% clay]

[4% $CaCO_3$]

[2% sand, 80% silt, 18% clay]
[63% sand, 31% silt, 7% clay]

FELDSPAR, FORAM AND NANNO BEARING GLASS SHARD ASH
dark gray, medium sandy

2.5Y4/0, 5Y5/4 — FORAM AND CHLORITE BEARING NANNO OOZE: 80% nannos, 10% forams, 8% clay, 1% glass, 1% phillipsite

10YR5/4 — CLAY AND FORAM BEARING NANNO OOZE [64% $CaCO_3$]

10YR3/3 — IRON OXIDE AND GLASS SHARD BEARING NANNO FORAM OOZE: 50% forams, 40% nannos, 5% glass, 5% iron oxide
dark brown, slightly gritty, slightly mottled with material from above

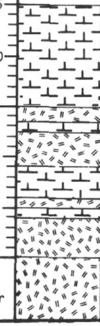
FORAM AND CLAY BEARING, IRON OXIDE AND GLASS SHARD RICH NANNO OOZE: 50% nannos, 20% glass, 15% iron oxide, 9% clay, 5% forams, 1% pyrite

Site 203 Hole Core 4 Cored Interval: 229-238 m

Age	Zone	Section	Fossil	Abund.	Pres.	Litho. Sample
PLEISTOCENE	N22	1	N F	C A	M G	CC, XM
UPPER PLIOCENE	N21 / =NN18	2	N F	C A	M G	CC
U. PLIOCENE	N21 / =NN18	Core Catcher	N F R	C C -	M M -	

METERS: 0.5, 1.0

LITHOLOGY: EMPTY



DEFORMATION: Slightly indurated pieces of rock.

LITHOLOGIC DESCRIPTION

2.5Y7/4, 2.5Y6/0 — GLASS SHARD BEARING CLAY RICH FORAM NANNO OOZE: 45% nannos, 35% forams, 16% clay, 2% glass, 2% other minerals
pale yellow, intensely mottled in parts, moderately mottled in others [47% $CaCO_3$]
Burrows are generally gray.
CHONDRITES type burrows 74-85 cm in Section 1.

5Y5/1, 5Y5/2, 5Y6/4, 5Y5/3, 5Y4/2, 5Y6/3, 5Y4/1 — Alternating layers of NANNO GLASS SHARD ASH and GLASS SHARD NANNO OOZE
The ash is dark gray or olive, the ooze is generally a paler gray and intensely mottled with pale yellow.
[4% $CaCO_3$]

Ash: 45% glass, 40% nannos, 9% forams, 2% siliceous fossils, 2% other minerals
Ooze: 44% nannos, 35% glass, 10% iron oxide, 5% clay, 5% forams

NANNO GLASS SHARD ASH
gray and brown

Site 203 Hole Core 5 Cored Interval: 400-409 m

Age	Zone	Section	Fossil	Abund.	Pres.	Litho. Sample
PLIOCENE	N19 / NN16	1	F N	R A	P M	GZ
PLIOCENE	N19 / NN16	Core Catcher	N F	A C	M M	

METERS: 0.5, 1.0

DEFORMATION: Pieces of slightly indurated rock.

LITHOLOGIC DESCRIPTION

5Y2.5/1, 5Y4/2 — [93% sand, 5% silt, 3% clay] OLIVINE GLASS SAND, green-brown to black

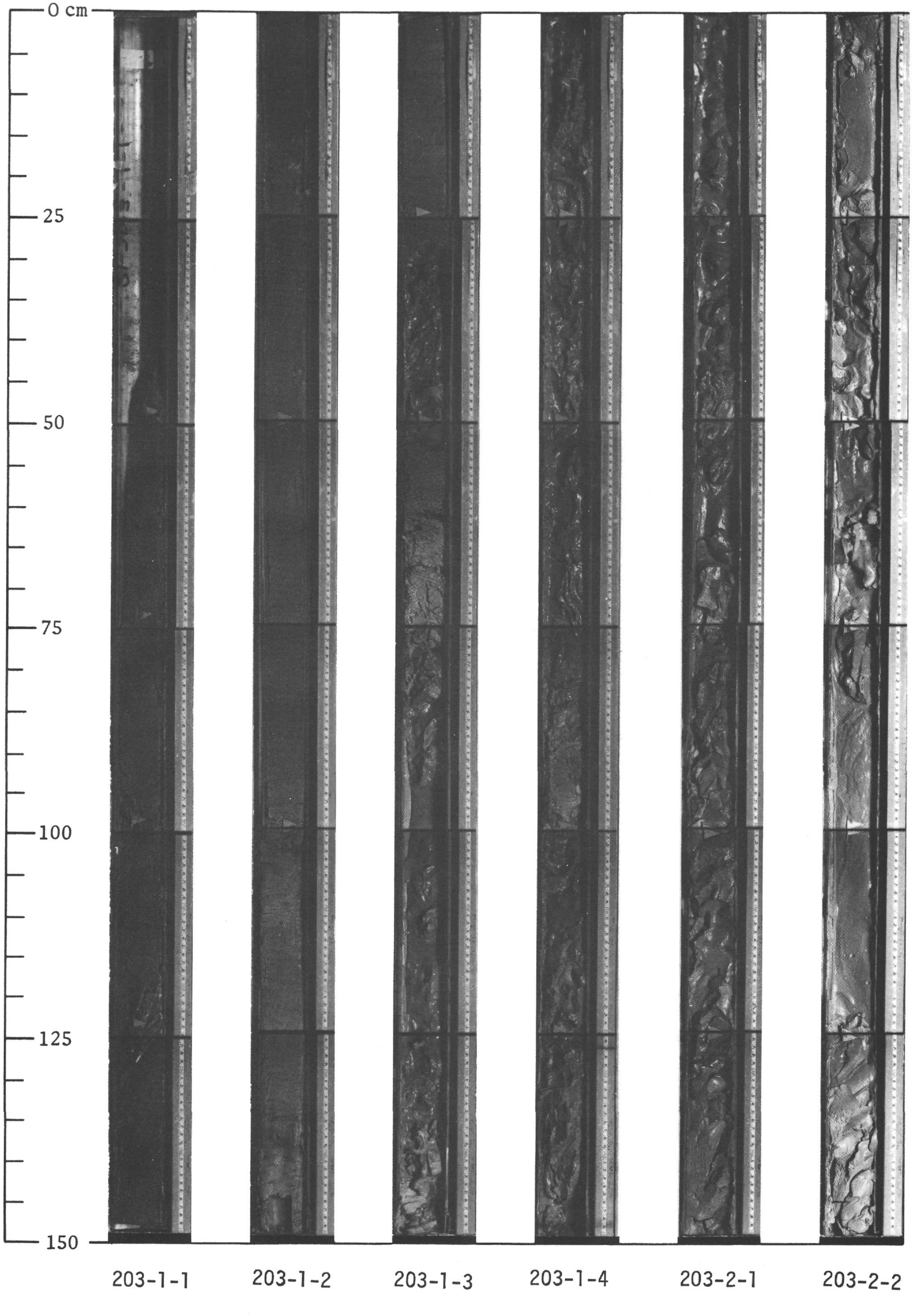
5Y6/3 — NANNO AND CLAY BEARING GLASS SHARD ASH: 80% glass, 10% nannos, 5% clay, 4% feldspar, 1% pyrite

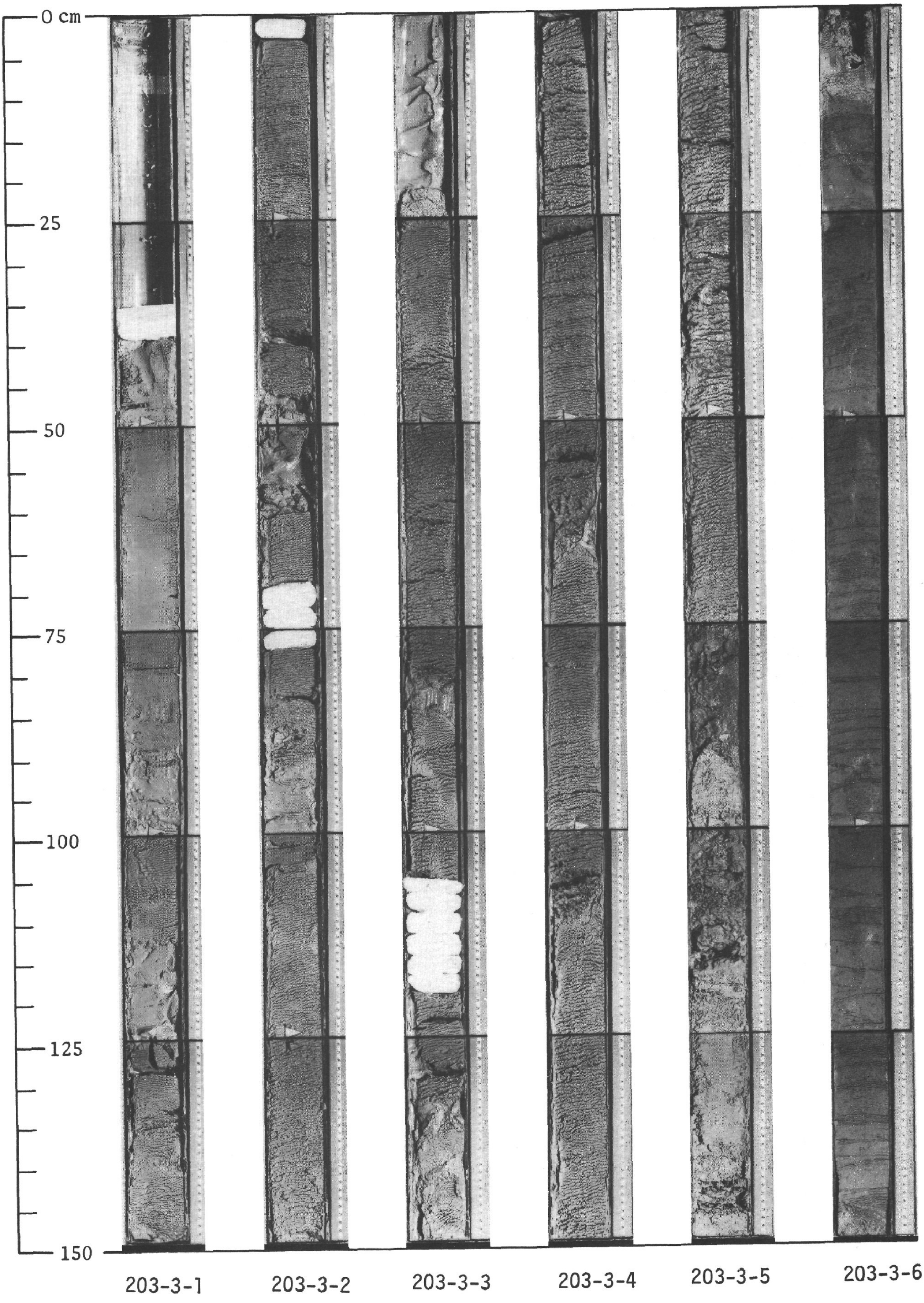
vesicular BASALT

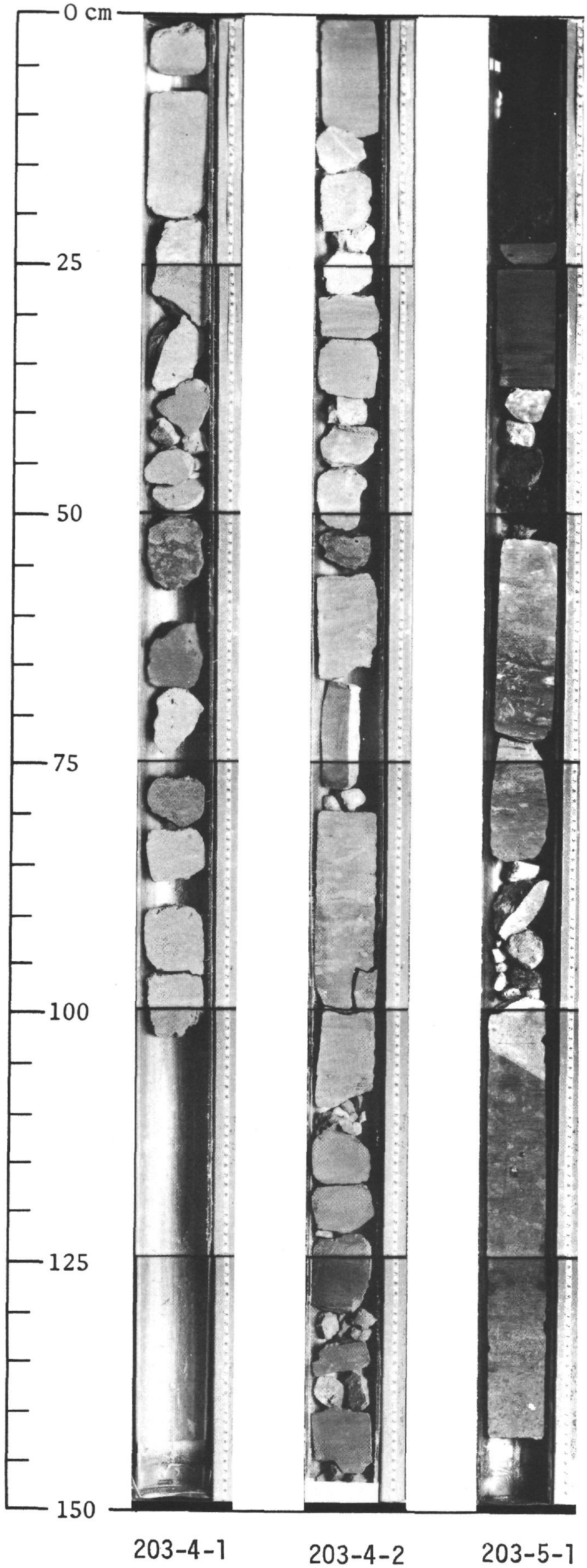
2.5Y6/4 — NANNO GLASS SHARD ASH
gray passing down into pale yellow, intensely mottled

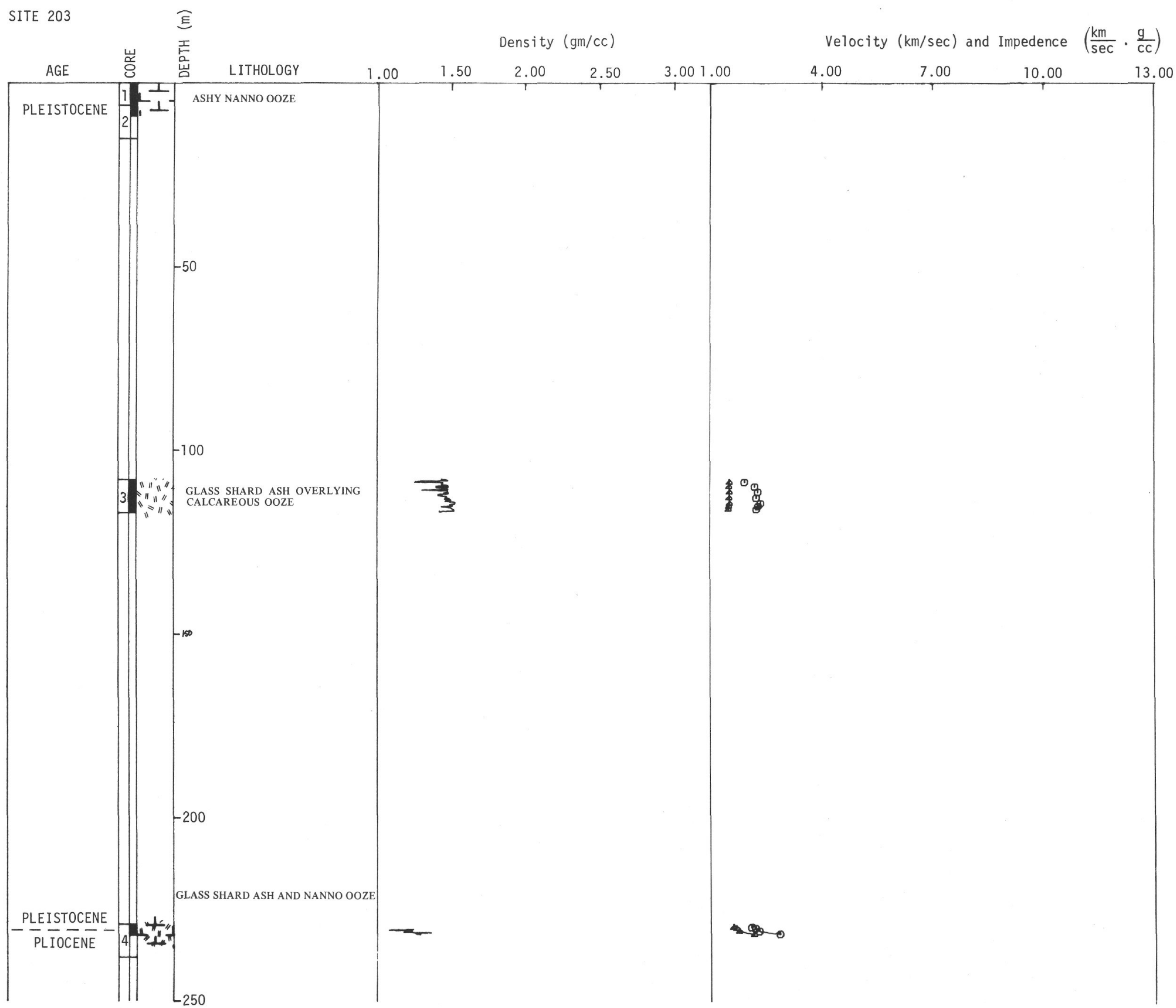
10YR8/8, 10YR4/3 — CLAY RICH NANNO OOZE
yellow overlying brown

CLAY RICH NANNO OOZE and highly vesicular OLIVINE BASALT

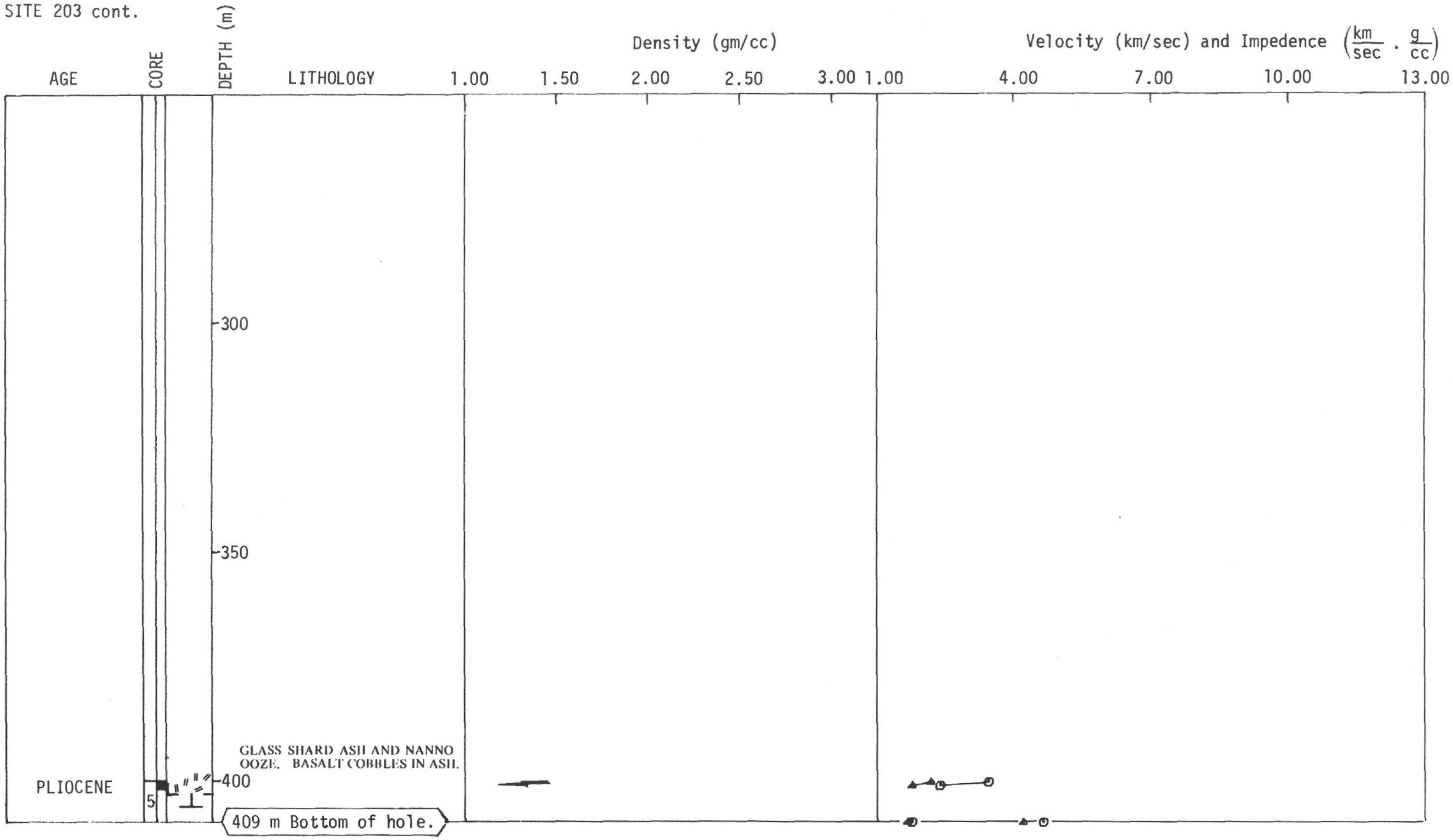

0 cm
25
50
75
100
125
150
203-1-1
203-1-2
203-1-3
203-1-4
203-2-1
203-2-2


0 cm
25
50
75
100
125
150
203-3-1
203-3-2
203-3-3
203-3-4
203-3-5
203-3-6


0 cm
25
50
75
100
125
150
203-4-1
203-4-2
203-5-1



SITE 203
AGE
CORE
DEPTH (m)
LITHOLOGY
Density (gm/cc)
1.00
1.50
2.00
2.50
3.00
Velocity (km/sec) and Impedence (km/sec · g/cc)
1.00
4.00
7.00
10.00
13.00
PLEISTOCENE
1
2
ASHY NANNO OOZE
50
100
3
GLASS SHARD ASH OVERLYING CALCAREOUS OOZE
200
GLASS SHARD ASH AND NANNO OOZE
PLEISTOCENE
PLIOCENE
4
250


SITE 203 cont.
AGE
CORE
DEPTH (m)
LITHOLOGY
Density (gm/cc)
1.00
1.50
2.00
2.50
3.00
Velocity (km/sec) and Impedence $\left(\frac{km}{sec} \cdot \frac{g}{cc}\right)$
1.00
4.00
7.00
10.00
13.00
300
350
400
GLASS SHARD ASH AND NANNO OOZE. BASALT COBBLES IN ASH.
PLIOCENE
5
409 m Bottom of hole.