4. SITE 204

The Shipboard Scientific Party[1]
With Additional Contributions From
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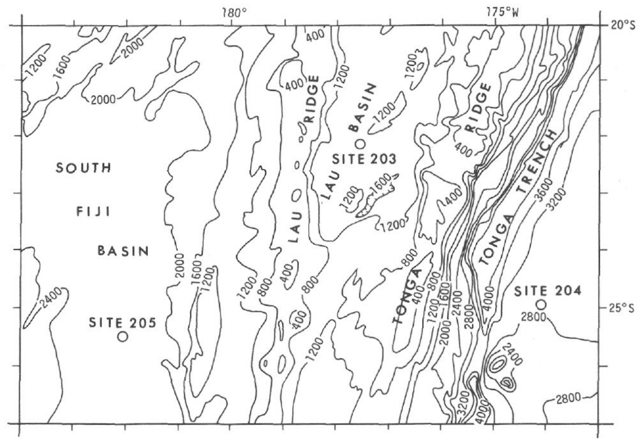
Location: Pacific plate east of Tonga Trench
Position: 24°57.27′S, 174°06.69′W
Water Depth: 5354 meters
Total Penetration: 160 meters



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: The section (dated from Quaternary to late Oligocene-early Miocene) consists of silty and iron-oxide clays with glass-shard ash unconformably overlying a fossil-barren volcanogenic sandstone and conglomerate of probable Late Cretaceous age.

BACKGROUND AND OBJECTIVES

General

One of the general objectives of the Pacific drilling program has been the examination of oldest Pacific crust. Earlier efforts to examine old crust had been made at Sites 59 (Fischer et al., 1971) and 61 (Winterer, et al., 1971) in the area of the Marianas Trench. Leg 21 provided an opportunity to determine the age and the biostratigraphy of the oldest Pacific crustal section in the region immediately east of the Tonga Trench. From the magnetic anomaly dating of crust eastward of the Tonga-Kermadec Trench, the age has been inferred as "older than anomaly 32 (>75 m.y.)" but exact age cannot be determined from the magnetic anomalies alone. The late Cretaceous age indicated by the sites at the marianas Trench was inconclusive since one (Site 59) stopped short of basement and the other (Site 61), although stopped in extrusive basalt, has seismic reflection profiles nearby that indicate the possibility of additional sediment beneath the basalt.

Several alternate sites were proposed on the basis of information available from *Conrad*, *Eltanin*, and others. The objectives at Site 204 were to get biostratigraphic data as well as to reach the oldest section possible.

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

Site Survey

The area around Site 204 was surveyed during August 1971 by R/V *Kana Keoki.* The sea floor (Figure 1) has a gentle regional slope to the west which steepens westward into the Tonga Trench. Three small hills with 300 to 400 meters relief occur within the survey area. These appear to

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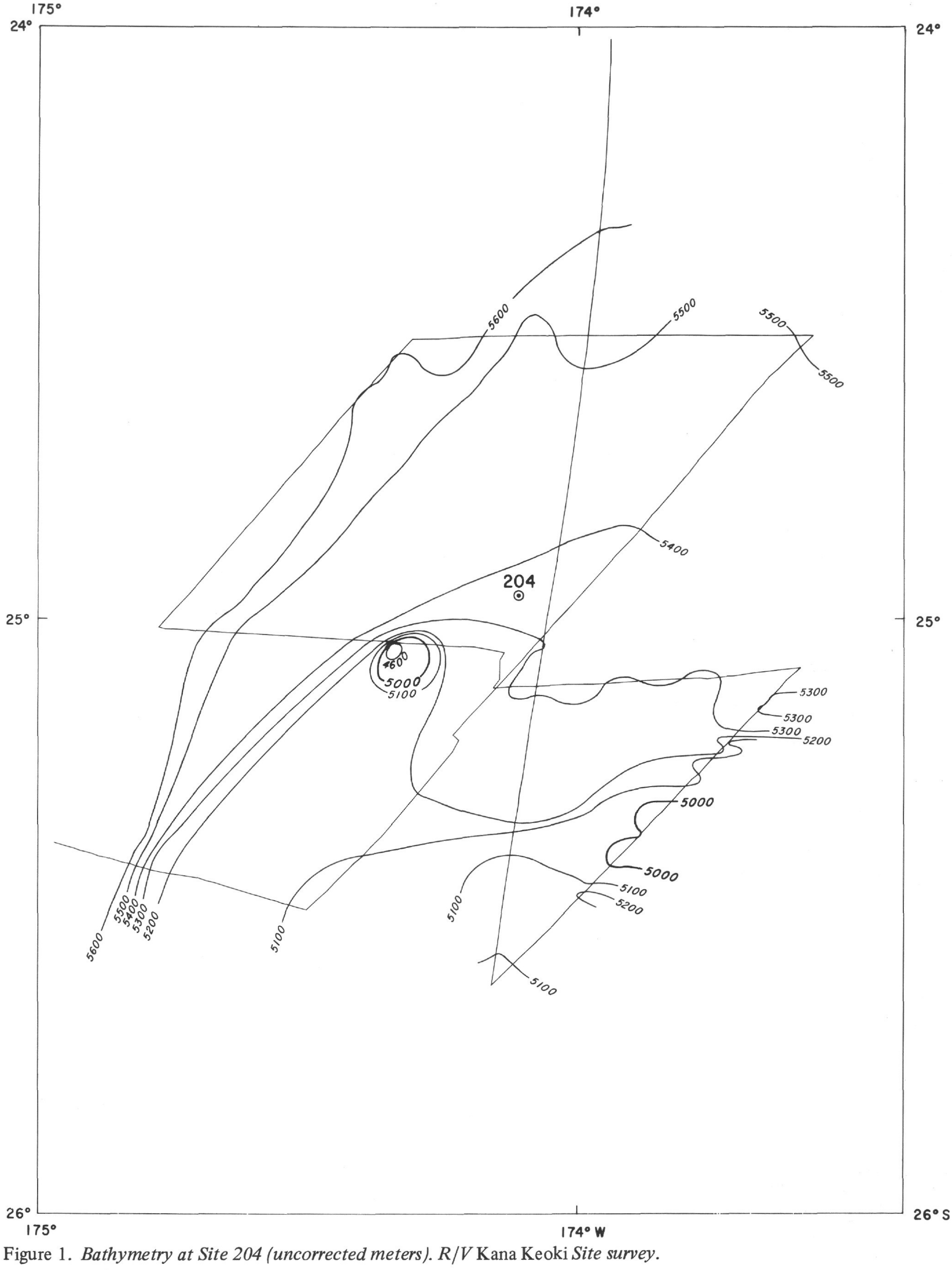

Figure 1. *Bathymetry at Site 204 (uncorrected meters). R/V* Kana Keoki *Site survey.*

be typical of the sea floor east of the trench, and the survey did not define any lineation in these hills.

To the west of the site the sea floor drops more steeply into the Tonga Trench, and seismic profiles (Figure 2) show normal faulting as evidence of crustal tension and possible evidence of subduction. The acoustically very transparent sediments range in thickness from 0.25 to 0.35 sec (round-trip travel time) on all survey profiles (Figure 3). The acoustic basement on the underway profiles is a diffuse and broad band (about 0.1 sec) whose general appearance suggests a series of horizons, with vague and intermittent reflectors continuing the pattern to depths reaching as much as 0.5 sec. This suggested that the apparent basement did not represent the top of the oceanic second layer (i.e., basalt), and this was confirmed by the subsequent drilling.

OPERATIONS

Site Approach

The drilling site was selected on the basis of the survey data and was approached directly from the previous site on a southeasterly course. The approach typified all later approaches in which survey data were available. The selected site was crossed for verification of structure on the seismic profile, course was reversed, and the beacon dropped. Sediment thickness at the site was 0.14 sec above the broad basement reflector. To minimize structural complications, the site was located at a point removed from the hills in the region (Figure 4).

Sonobuoy

The on-site sonobuoy profile (Figure 5) confirmed the impressions of the survey and approach profiles. Table 1 summarizes the reflector depths (round-trip travel times), characteristics, estimated sonic velocities, and originally estimated depths (meters). Two weak to moderate reflectors (upper surface to 0.14 sec) appear above a succession of signals up to 0.35 sec thick. Individual bands can be picked out within this band at 0.18, 0.22, 0.25, 0.29, 0.32, 0.36, 0.4, and 0.5 sec subbottom. Picking records to 0.1 sec provides 7.5 meters resolution at typical clay/ooze velocities (1500 m/sec). At these velocities the acoustic basement was estimated at 105 meters (1500 m/sec), and the deepest reflector was at a minimum of 555 meters.[2]

Drilling Program

Intermittent coring had been approved by the Panel on Safety and Pollution Prevention, and the coring program (summarized in Table 2) was conducted in an attempt to obtain samples of the several units and the contacts indicated by the seismic reflection profiles and by the on-station vertical section obtained with the sonobuoy.

Cores 1 through 7 were obtained in the normal manner by advancing the drill for 9 meters with the core barrel in place. Cores 8 and 9 were obtained by advancing 18 meters with the core barrel in place. These latter two cores were in the lithified volcanogenic sandstone and conglomerate, and the coring actually took place over the entire 18-meter interval. However, for notation, these two cores were logged as though they were obtained at the upper portions of the intervals sampled, and the assumption is that 9 meters were cored and the rest of the interval was drilled. Core 3 was taken in conjunction with a temperature (heat-flow) measurement.

Following Core 9, a decision was reached that it would not be profitable to continue drilling the lithified material in an attempt to reach basement. Prior to departure from the site, a supplementary hole (204A) was drilled to 86 meters and cored to 95 meters, specifically to obtain a second temperature (heat flow) measurement at this site. Following this, the equipment was recovered and the site was abandoned at 0730 on 22 November.

[2]Final correlations of sonobuoy profiles using laboratory-measured velocities, other physical properties, and lithologic boundaries are presented in Part II of this Initial Report.

LITHOLOGY

General

Ten cores were taken at Site 204 before the slow penetration rate forced termination of the hole before the objective of reaching basement was accomplished. Nine of the cores were from Hole 204 and one from 204A. Summaries of each of the cores are given in the Appendix.

The sequence at Site 204 can be divided into the following three lithologic units:

1) Unit 1 (0 to 103 m)–abyssal clay and ash from latest Quaternary to early Miocene or Oligocene in age.

2) Unit 2 (103 to 126.5 m)–tuffaceous sandstone and conglomerate of ?Cretaceous (Early?) age.

3) Unit 3 (126.5 to 147 m)–vitric tuff of unknown age.

Unit 1 (Abyssal Clay and Ash)

Cores 1 and 2 from the sea floor to a depth of 16 meters are mostly dark brown clays composed of montmorillonite, plagioclase (andesine), mica, quartz, augite, phillipsite, amorphous iron oxide, and glass shards. One or more of these lithologic components may be particularly abundant in one sample and absent in another. For example, several light brown or gray layers of glass-shard ash occur sporadically throughout the interval. The refractive index of clear to light brown glass shards near the top of the interval is greater than Canada balsam. The entire interval probably accumulated in waters beneath the carbonate compensation depth near a region of active, dominantly andesitic volcanism.

Core 3, from 48 to 57 meters below the sea floor, is mainly dark greenish gray, glass-shard ash with some clayey silt. Crystalline phases present include montmorillonite, potash fledspar, plagioclase, augite, quartz, and analcime. Five 1 to 2 cm in diameter manganese? nodules occur from about 49 to 50 meters depth. This interval also accumulated beneath the compensation depth adjacent to active volcanism.

Core 4 and most of Core 5 (85 to nearly 103 meters) are principally dark reddish brown iron-oxide clays composed mainly of potash feldspar, quartz, montmorillonite, and

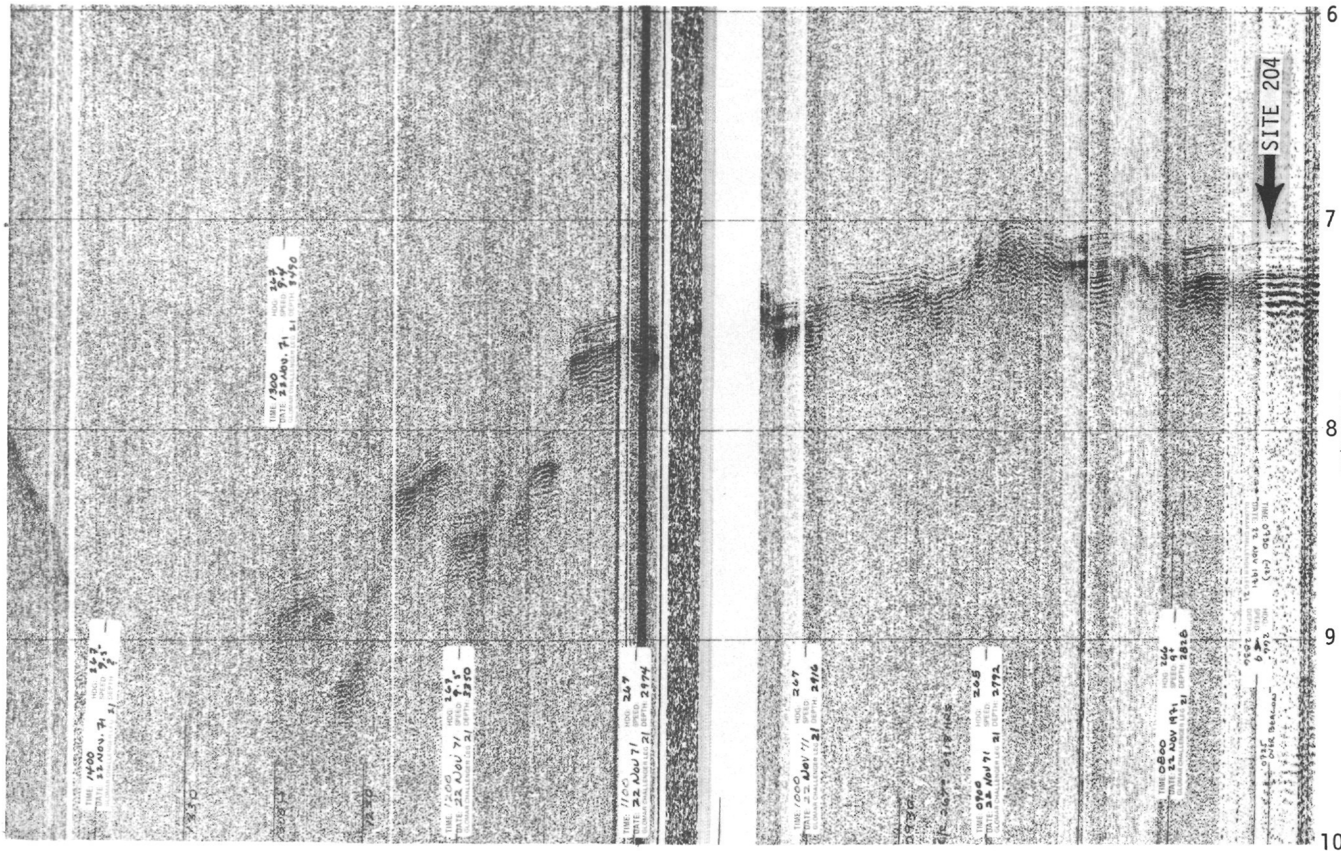

Figure 2. *Profile from Site 204*–Glomar Challenger. *Faulting at outer trench margin.*

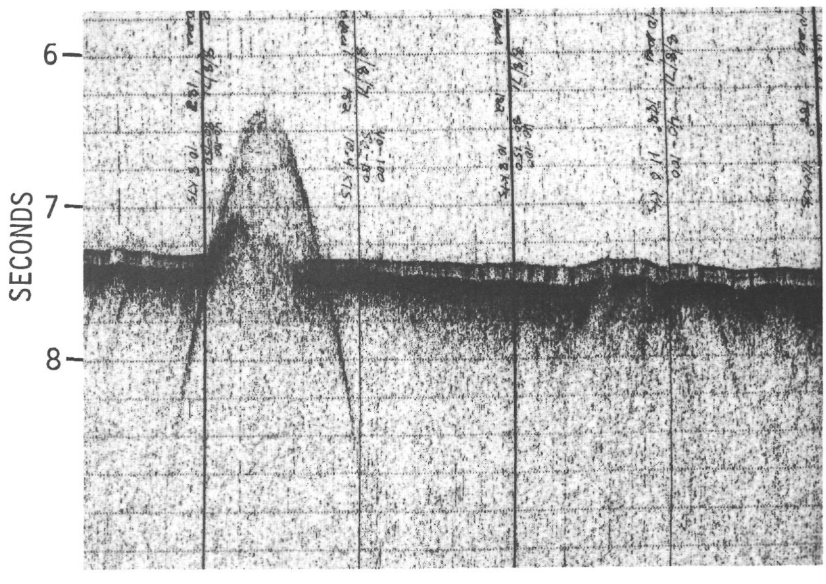

Figure 3. *Profile across small hill near Site 204. R/V* Kana Keoki *site survey. Time marks = 0.25 sec. Note thick acoustic basement.*

amorphous iron oxide. Some intervals are more red due to increased iron oxide content, whereas others are mainly brown glass-shard ash. The small amount of sand-sized material present commonly consists of fish teeth, bones, and otoliths. Rare arenaceous benthonic foraminifera indicate abyssal water depths. Near the bottoms of both cores are brown layers composed predominantly of calcite. Near the bottom of Core 5 (in the core catcher sample) is a sharp contact between an unindurated carbonate layer comprising the base of Unit 1 and indurated tuffaceous sandstone comprising the top of Unit 2. Core 1A is from essentially the same interval as Core 4.

Ages of Radiolaria suggest that the uppermost portion of Unit 1 is latest Quaternary, the middle portion (Core 3) is

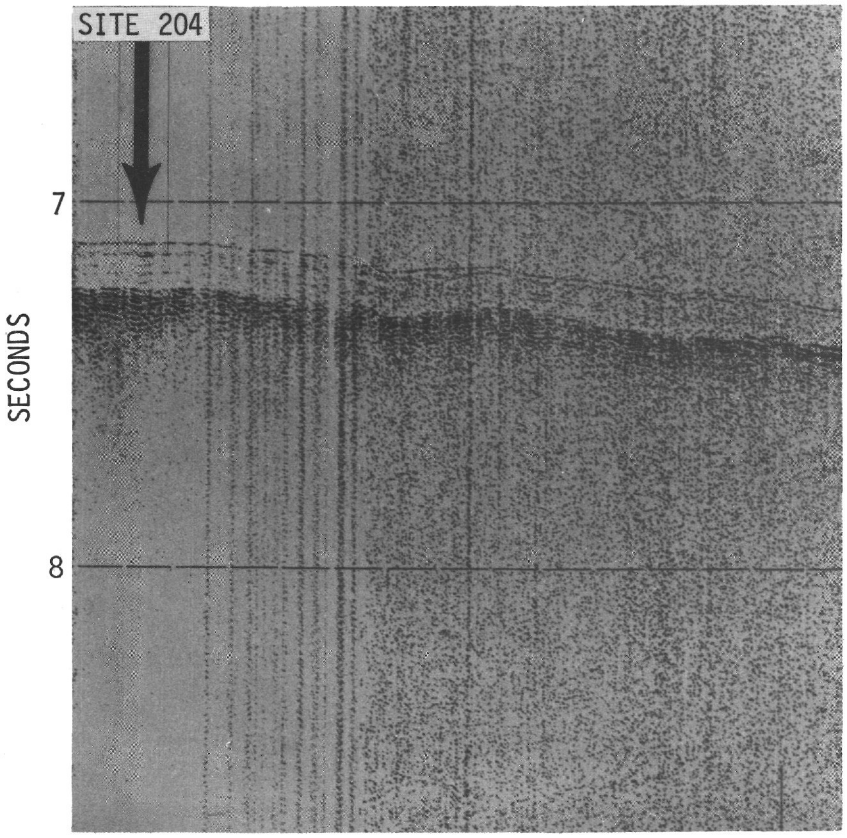

Figure 4. *Profile to Site 204*–Glomar Challenger.

middle Miocene, and the lower portion is Oligocene or early Miocene.

Unit 2 (Tuffaceous Sandstone and Conglomerate)

Unit 2 is mainly a yellowish brown, granular to pebbly, coarse tuffaceous conglomerate. In general, most of the larger clasts are subrounded, whereas most of the smaller ones are angular to subangular. Clast lithology includes calcite, andesine, pumice, glass shards, and andesitic and basaltic rock fragments. The matrix is mainly altered ash with secondary calcite, chloritic minerals, serpentine, epidote, zeolites, and amorphous iron oxide. Thin, white subhorizontal calcite veins occur sporadically throughout the interval. The finer-grained beds contain sedimentary structures including cross-bedding, graded bedding, reverse graded bedding, and contorted lamination indicating soft sediment deformation. White prismatic calcareous *Inoceramus*? sp. indet. fragments occur irregularly throughout. These beds are classified as tuffaceous sedimentary rocks rather than as tuffs or lapilli-tuffs because the rounded grains and the sedimentary structures suggest that the volcanic material underwent sedimentary transport after extrusion. The beds were probably deposited near an area of fairly high relief close to a volcanic source. The age of Unit 2 could be as old as middle Jurassic. However, because of the occurrence of questionable *Inoceramus* and the presence of reworked late Cretaceous microfossils in Unit 1, Unit 2 is possibly of Cretaceous (?Early) age.

Unit 3 (Vitric Tuff)

Unit 3 is dark greenish gray vitric tuff which occurs from 126.5 to 147 meters, the bottom of the recorded interval in the hole. The tuff is in sharp contact with the overlying yellowish brown basal conglomerate of Unit 2. As in the overlying unit, essentially all the constituents of Unit 3 are of volcanic origin. Although some vague stratification, somewhat resembling irregularly contorted "dish structures" is present, as well as a few angular to subrounded pebble-sized particles consisting of altered glass fragments, Unit 3 shows much less evidence of sedimentary transport than does Unit 2. The tuff is mainly composed of angular shards of devitrified basaltic to andesitic glass with some highly altered feldspar and pyroxene crystals in a pale greenish, fragmental, glassy matrix that is highly altered and weakly birefringent. Many of the glass shards have devitrified, producing spherulitic structures filled by secondary minerals including serpentine, chlorite, calcite, and ?epidote. There is, however, some relatively unaltered glass present. Thin white calcite veins occur sporadically throughout the entire interval, whereas only the upper portion of the interval contains calcite in the matrix.

Because drilling did not penetrate below the tuffs of Unit 3, it is difficult to determine if the cementing calcite in both Units 2 and 3 came from an underlying biogenic source or was derived from juvenile carbon dioxide and calcium leaching from within the beds themselves. Unit 3

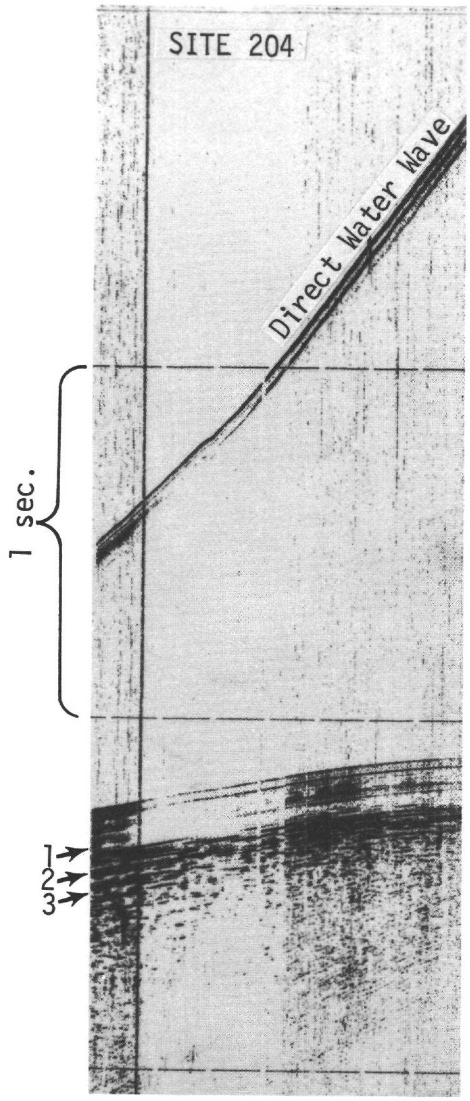

Figure 5. *On-site sonobuoy profile at Site 204.*

probably originated in close proximity to a volcanic source and formed directly from the extrusive activity with little or no sedimentary transport. The age of Unit 3 is unknown.

Sequence of Geologic Events Interpreted from Lithology

?Cretaceous or Older (Units 3 and 2)

The vitric tuff and tuffaceous sandstone and conglomerate of Units 3 and 2 accumulated from a nearby andesitic to basaltic source, most likely either the Louisville Ridge (now about 60 to 70 miles to the south) or the Tonga Ridge (now about 125 to 140 miles to the west).

If the Louisville Ridge was the source, Unit 3 may reflect uplift with concomitant volcanism that marks the birth of this topographic high, and the overlying Unit 2 may reflect continued volcanism with the culmination of ridge building near or above wave base. The rounding of clasts in Unit 2 indicates a high-energy environment, and clast size and sedimentary structures indicate sedimentary transport along a fairly steep, uninterrupted paleoslope to the site of deposition.

TABLE 1
Site 204 Sonobuoy Data

Reflector	Depth (sec)	Nature	Estimated Velocity Structure (m/sec)	Estimated Depth (m)
1	0.06	Faint	1500	45.0
2	0.09	Moderate	1500	67.5
3	0.14	Strong (possible intrusion)	1500	105
4	0.16	Decreasing intensity downward, no obvious 2nd-layer reflector	Increasing downward	
5	0.22			
6	0.25			
7	0.29			
8	0.32			
9	0.36			
10	0.40			
11	0.50			

If the Tonga Ridge were the source, then the present intervening Tonga Trench could not have come into existence until after deposition of Unit 2 (?Cretaceous time), and the ridge and Site 204 could not have been significantly further apart during accumulation of Units 3 and 2 than they are now. The crest of the Tonga Ridge would also have had to be near or above wave base during deposition of Unit 2. Although most of the Tonga volcanics are andesitic, pre-Upper Eocene basalt has been found on the Island of Eva in the Tonga group (Bryan et al., 1972).

Oligocene or Early Miocene to Present (Unit 1)

The abyssal clay and ash of Unit 1 accumulated in deep water below the carbonate compensation depth in a region of active volcanism (essentially the same tectonic conditions that exist now).

If the Louisville Ridge were the source of Units 3 and 2, then the time when Unit 1 deposition started probably represents a cessation of volcanic activity on the ridge and the beginning of subsidence to its present crestal depth of about 1800 meters (see Hayes and Ewing, 1971, for topography of the ridge).

If the Tonga Ridge were the source of Units 3 and 2, then the start of Unit 1 deposition probably marks the beginning of the formation of the Tonga Trench which would then act as a sediment trap for Unit 2-type sediments preventing them from reaching Site 204.

No matter which of the two hypotheses described above is more likely, the Tonga Ridge, presently being the nearest active volcanic area, is probably the source of the wind-transported glass shards in Unit 1. The reworked Cretaceous nannofossils in Unit 1 have no obvious geographic source—they may have come from the Louisville Ridge or any other topographic feature above the carbonate compensation depth in the Site 204 region east of the Tonga Trench.

TABLE 2
Coring Summary – Holes 204 and 204A

Core	Date	Time	Depth from Drill Floor (m)	Depth Below Sea Floor (m)	Cored (m)	Recovered (m)	Recovery (%)
1	11/20	1655	5364-5371.5	0-7.5	7.5	7.5	100
2	11/20	1845	5371.5-5380	7.5-16	8.5	5.1	60
3	11/20	2115	5412-5421	48-57	9.0	2.2	24
4	11/20	2310	5449-5458	85-94	9.0	5.7	63
5	11/21	0130	5458-5467	94-103	9.0	9.0	100
6	11/21	0420	5467-5476	103-112	9.0	5.3	59
7	11/21	0725	5476-5485	112-121	9.0	3.7	41
8	11/21	1150	5485-5494	121-130	9.0	5.2	58
9	11/21	1545	5505-5514	141-150	9.0	5.7	63
Total					79.0	49.4	62
1A	11/21	1920	5450-5459	86-95	9.0	4.3	48

Note: Echo sounding depth (to drill floor) = 5364 meters;
drill pipe length to bottom = 5364 meters.

BIOSTRATIGRAPHY

General

The age determination at Site 204 was a difficult task because of the paucity of calcareous and even siliceous microfossils in almost all cores recovered in the two holes drilled.

The first five cores of Hole 204 have been rather thoroughly investigated. A fairly rich radiolarian assemblage occurring at the top of Section 1-1 is the single certain fossil document recorded at this site. This assemblage can be dated as of latest Quaternary age (*Buccinosphaera invaginata* Zone).

In all other cores the only unreworked fossils are rare broken orosphaerid spines and, in Cores 4 and 5, arenaceous foraminifera and fish teeth. The presence of a particular type of orosphaerid spines in Section 3-1 suggests a middle Miocene age.

Very rare orosphaerid spines are sometimes present in samples from Cores 4 and 5, and the age of these cores is Oligocene or early Miocene. The presence of *Ammosphaeroidina* in Core 4 suggests an Eocene or younger age. The fish teeth are also of Cenozoic type.

Reworked, well-preserved late Cretaceous (≈Maastrichtian) radiolarians occur in the top of Section 1-1 and reworked, poorly preserved late Cretaceous radiolarians and calcareous nannofossils occur in Cores 4, 5, and 1A.

Rare prismatic shells of ?*Inoceramus* occur in Cores 6 to 8. A specimen from Sample 204-6-4, 131-138 cm, contains several of these fragments. These indicate the following:

1) The fragments, up to 12 mm long, are not in their death position (i.e., have been transported).

2) Identification with *Inoceramus* is by no means certain as thick-shelled bivalve taxa of the Pinnidae, Malleidae, and Isognomonidae have similar prismatic shell structures.

3) The indicated age range, prior to transportation, is mid-Jurassic to Recent.

On the basis of the above information and the presence of reworked Late Cretaceous microfossils in the overlying Cores 4 and 5, we conclude that a Cretaceous (?Early) age seems likely for Cores 6 to 8.

Foraminifera

As a result of the great water depth at this site, planktonic foraminifera and calcareous benthonic foraminifera are entirely absent throughout. Indeed, most samples examined are barren of all foraminifera although the following levels contain rare arenaceous abyssal forms:

Sample 204-4-2, 68-70 cm, includes *Rhabdammina* sp., *Miliammina* sp., *Ammodiscus* sp., *Glomospira* sp., *Saccammina* sp., and *Ammosphaeroidina* sp.

Sample 204-4-4, 70-72 cm, includes *Rhabdammina* sp., *Miliammina* sp., *Adercotryma* sp., *Glomospira* sp., *Ammodiscus* sp., and *Ammosphaeroidina* sp.

Samples 204-4, CC and 204-5-1, 45-47 cm, include a few fragments of arenaceous foraminifera.

Sample 204-5, CC includes *Ammodiscus* and *Haplophragmoides.*

The presence of *Ammosphaeroidina* in Core 4 indicates that these levels are no older than Eocene.

Residues at the following two levels consist almost entirely of fish teeth, bones, and otoliths: Samples 204-5-1, 45-47 cm and 204-5-5, 45-47 cm.

Calcareous Nannofossils

For a discussion of the calcareous nannoplankton of Site 204, see the report by Edwards (Chapter 18). In summary, the samples examined mostly lack nannoplankton, but parts of Cores 4, 5, and 1A yielded very small sparse floras of probable late Campanian to early Maastrichtian age. However, the Oligocene or early Miocene age determined from the associated radiolarians and arenaceous foraminifera implies that all of the nannoplankton are reworked.

Siliceous Microfossils

Nine cores were recovered in Hole 204 and one in Hole 204A at this site situated on the western margin of the Pacific plate. Because of the paucity of calcareous microfossils, all of the sections of the first five cores from Hole 204 have been thoroughly investigated for radiolarians and other possible biogenic remains. The results are tabulated in Figure 6.

Radiolarians are practically absent or very rare in most samples, so the ages of the cores are questionable. The only

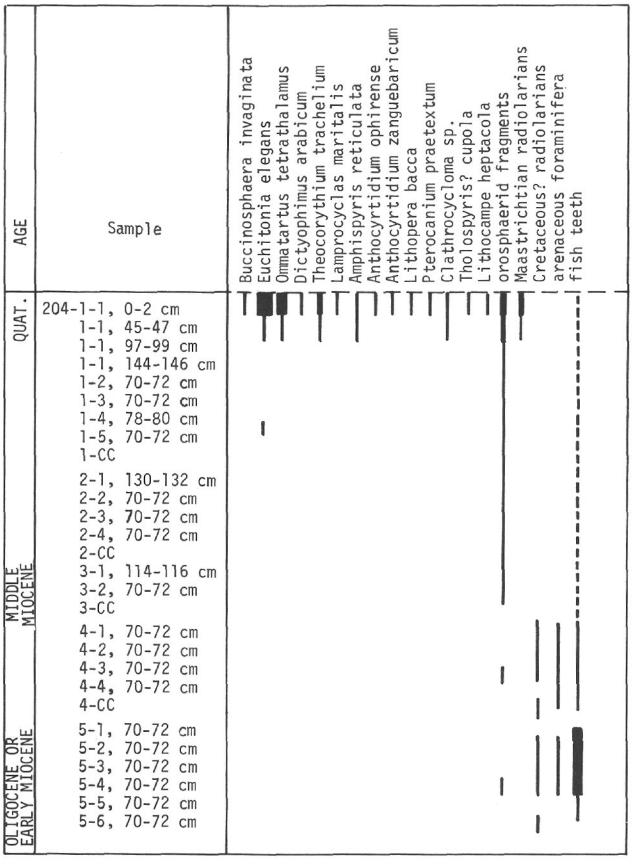

Figure 6. *Distribution of Radiolaria and other organic remains in cores recovered in Hole 204.*

rather abundant radiolarian fauna has been encountered at the top of Section 1-1. A few specimens of *Buccinosphaera invaginata* found in the interval 204-1-1, 0-2 cm, indicate a Recent or latest Quaternary age, corresponding to Zone 1 established by Nigrini (1971) in the equatorial Pacific sediments. *Euchitonia elegans* is one of the most frequent species of this assemblage.

Silicoflagellates are practically absent, only one specimen of *Dictyocha aculeata* being observed in the highest sample.

In Sample 204-1-1, 45-47 cm radiolarians are rare and partly destroyed and essentially disappear in Sample 204-1-1, 97-99 cm. The only radiolarian skeleton remains present in all the other sections of Core 1 and in almost all sections of Cores 2 through 5 are rare, corroded orosphaerid fragments.

Very well preserved reworked late Maastrichtian radiolarians and silicoflagellates accompany the Quaternary assemblage in the top two samples (204-1-1, 0-2 cm and 204-1-1, 45-47 cm), suggesting a nearby submarine outcrop of Maastrichtian sediments. Among the reworked late Maastrichtian forms the following were determined: *Staurodictya*(?) *fresnoensis, Saturnalis*(?) *latuformis, Lophophaena*(?) *polycrytis, Theocampe* cf. *vanderhoffi, Amphipyndax* sp., *Acanthocorys* cf. *cretacea, Diacanthocapsa ancus, Stichomitra*(?) *campi, Dictyomitra andersoni*, and *Lyramula furcula*.

The age of Core 2 and Section 1-2 through 1-5 cannot be established because of the absence of microfossils. In Sample 204-3-1, 114-116 cm, several curved flattened orosphaerid spines were found. They are similar to those illustrated by Friend and Riedel (1967) as *Oroscena* sp. and by Kling (1971) in the upper middle Miocene (approximately *Cannartus* ? *pettersoni* Zone). At Site 206 such spines were found within the same interval. We thus conclude that the age of Sample 204-3-1, 114-116 cm is middle Miocene.

No other distinct type of orosphaerid spine was observed in Cores 4 or 5, but the presence of rare orosphaerid remains in these cores indicates at least that the cores are not older than Oligocene. Poorly preserved reworked radiolarians of Cretaceous age also occur in these two sections.

Radiolarians are accompanied by fish teeth in almost all the cores, particularly Cores 4 and 5.

Core 1A, taken between 86 and 95 meters below the sea floor, does not contain spines of orosphaerids, but the depth and the poorly preserved Cretaceous radiolarians suggest a correlation with Sample 204-4, CC or 204-5, CC.

PHYSICAL PROPERTIES

Bulk Density

GRAPE density measurements that were taken on Cores 1 through 5 are shown in Appendix E. All of these are in the range of 1.28 to 1.48 gm/cc and do not show any clear systematic increase in density with depth. The chemistry laboratory aboard ship, by weighing small samples, obtained densities of 1.28 and 1.43 gm/cc that verify the GRAPE data.

Higher values of bulk density (2.0-2.5 gm/cc and averaging 2.2) were obtained on wet samples of lithified sediment from Cores 6, 8, and 9. These densities were obtained by weighing fragments of core and then submerging these in a water-filled measuring cylinder to determine the volume of each fragment.

In general, the abyssal clay sediments in the upper part of the hole have densities less than 1.5 gm/cc. This agrees with results obtained on unconsolidated clay muds from previous work aboard *Glomar Challenger.*

The bulk densities of lithified volcanic sandstones in the lower part of the hole, although only rough approximations because no correction was made for porosity, give values that are reasonable when compared to similar sediments examined on previous cruises.

Sonic Velocity

Sonic velocity measurements made on the unconsolidated clay sediments in the upper part of the hole were measured on cores split, but not removed from each half of the plastic liner. These clay samples gave velocities of about 1.48 km/sec. On the other hand, the velocity determinations on consolidated volcanoclastic sediments in the lower part of the hole average 2.64 km/sec.

Thermal Conductivity and Heat Flow

Thermal conductivity (K) was measured on core material recovered from Cores 1 through 5 at this site (see Appendix D to this chapter). Values ranged from about 1.8 through 2.0 m cal/°C cm sec (TCU) on Cores 1 through 4, uncorrected for temperature and pressure at the sea floor.

No significant systematic variation with depth down to Core 4 (85 to 94 meters) was discerned. Core 5 consisted of more indurated material, and values ranged from 2.4 to 2.8 TCU. Cores 6 through 9 (103 to 160 meters) were for the most part lithified; no conductivity measurements were attempted on the material.

Temperature measurements in the holes at this site were attempted at 48 meters (Hole 204) and at 86 meters (Hole 204A). The instrumentation performed well on both attempts. The temperature measurements have a precision of about ±0.01°C and an accuracy of ±0.02°C. A maximum temperature of 1.72°C was measured on the 48 meters attempt. The temperature of the probe during the 10-minute measurement in the bottom at 48 meters depth increased slowly towards the maximum. The gradient from the sea floor (bottom water temperature = 1.06°C, as measured by the instrument descending in the drill pipe) to 48 meters is about 0.14°C/m, a low value. These observations, together with the temperature measured at 86 meters, imply that the temperature measured at 48 meters is not in situ.

A temperature of 4.78°C was attained about 2 minutes after penetration at 86 meters and extended over a period of about 2 minutes. A subsequent slight increase in temperature, followed by a slow decrease, indicated a disturbance during the measurement. The gradient between the sea floor and 86 meters, based on the initial undisturbed part of the measurement, is about 0.043°C/m. An average thermal conductivity to this depth of 1.9 TCU, as measured on the cored material, results in a heat flow of about 0.8×10^{-6} cal/cm^2 sec (±10%). The error is estimated principally from the variation in conductivity measurements and the lack of continuous conductivity measurements to 86 meters depth. The heat-flow value is on the lower side of "normal" values, but is a reasonable one for old sea-floor crust near the subducting Tonga Trench.

SUMMARY AND CONCLUSIONS

Drilling at this site, approximately 72 miles east of the axis of the Tonga Trench, did not achieve its objective of sampling basaltic basement. Sonobuoy records on site show a series of prominent reflectors to a depth of at least 0.5 sec with no distinct lower limit. Drilling showed that the first of these strong reflectors at 0.13 sec (103 m), at the base of the "transparent" sequences of abyssal clay and ash, represents an abrupt transition to a lithified tuffaceous sandstone. The second of this series of reflectors at 0.16 sec (129 m) marks the top of a vitric tuff.

The lowest unit sampled is the vitric tuff with grain size similar to some of the ashes found in the higher unlithified sequence. (This material may have undergone submarine or subaerial transport.) The lithified tuffaceous sandstones and conglomerates which overlie the tuff are barren of fossils except for *Inoceramus* (?) fragments. The coarse grain size, granules, and abundant pebbles in this unit suggest nearby volcanic activity. The sedimentary structures, rounding, and sorting point to submarine transport after initial extrusion and deposition.

Overlying the lithified units is an abyssal clay and ash sequence probably no older than early Miocene or Oligocene, although it contains reworked Cretaceous radiolarians and nannofossils. The base of the abyssal clay and ash sequence appears to be an unconformity similar to that described by Johnson et al. (1972) in the Samoan Passage which may be related to the movement of Antarctic Bottom Water, and also possibly to the regional unconformity recognized at Sites 206 to 210. The reworked assemblages in the lower portion of the sequence may represent a decreasing effect of current activity due to circulation changes and subsidence of the Louisville Ridge. The occurrence of the reworked assemblages suggests that the oceanic crust is at least as old as Cretaceous in the vicinity of the drill site. This region of the Pacific does not have any clear sequence of magnetic anomalies that can be related to the East Pacific Rise. Tentative ages of "old", older than anomaly 20 (50 m.y. B.P.), and probably older than anomaly 32 (75 m.y. B.P.) (Pitman et al., 1968), have been suggested based on the assumption that this is part of the Pacific plate. Information obtained at Site 204 provides no conclusive determination of age of the oceanic crust, but the Cretaceous age suggested by the faunal sequence supports the concept that this locality is one of old oceanic crust.

The presence of reworked fossil assemblages implies that the volcanic detritus found in the abyssal clay and ash sequence may not be exclusively the result of Cenozoic volcanism, so that it is only possible to attribute generally post-Eocene abyssal depths to this portion of the sediment record.

Of possibly greater significance is the indication of extensive volcanism throughout the cored sequence. This site, east of the Tonga Trench, is located in an area tectonically similar to Sites 52, 59, and 61 (DSDP Legs 6 and 7) east of the Bonin and Marianas trenches. Lithologically, these four sites are similar in that a Cenozoic sequence of abyssal clay and ash overlies a sequence containing at least some lithified volcanogenic beds of Cretaceous age. This similarity, results from dredging of western Pacific seamounts, and the tuffaceous conglomerates at Site 204 suggest widespread Cretaceous volcanism throughout the western Pacific with at least some portion of it from volcanic sources not directly associated with the present Pacific plate boundaries (East Pacific Rise and western Pacific trenches).

A possible sequence of events resulting in the sediments at this site may be postulated for a region removed from the vicinity of the Tonga Trench. The vitric tuffs (Unit 3) were deposited during Mesozoic time as products of the growth of the nearby Louisville Ridge. As the volcanism died out and the ridge reached sea level, the tuffaceous sands of Unit 2 were laid down by submarine transport. As subsidence began along the ridge, pelagic sediments accumulated which were in part removed by surface currents. Bottom water circulation inhibited deposition and probably actively eroded sediments at the site until late Oligocene at which time intensity decreased to permit accumulation of clay as well as some of the winnowed ashes and pelagic materials from the Louisville Ridge. The clays of Unit 1 represent in situ accumulations with little input from the ridge near its present depth.

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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 204

Core, Section, Top of Interval (cm)	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Classification
1-2,76.0	2.3	8.2	53.2	38.6	Clayey silt

APPENDIX B
Carbon-Carbonate Determinations, Site 204

Core, Section, Top of Interval (cm)	Depth in Hole (m)	Carbon Total (%)	Organic Carbon (%)	$CaCO_3$ (%)
1-1,28.0	0.3	0.1	0.1	0
1-3,75.0	3.8	0.1	0.1	0

APPENDIX D
Thermal Conductivity Measurements, Site 204

Core, Section, Interval Below Top (cm)	Thermal Conductivity (mcal/°C cm sec)	Standard Deviation	Ambient Core Temperature (°C)	Remarks
1-3,75	0.001953	0.013192	23.75	
1-4,73	0.001953	0.011880	24.74	
1-5,77	0.001888	0.009501	24.61	
2-2,87	0.001988	0.008141	22.82	
2-3,87	0.001898	0.013637	22.01	
2-4,85	0.001882	0.012291	22.88	
3-1,95	0.001931	0.009554	23.01	
3-2,84	0.001902	0.008184	23.01	
4-1,85	0.001927	0.014916	22.90	Repeat
4-2,85	0.001715	0.008402	22.94	Repeat
4-3,85	0.002014	0.009996	22.85	Repeat
4-4,87	0.001865	0.007381	20.23	
5-4,84	0.002404	0.010171	24.31	
5-5,84	0.002456	0.014480	24.74	
5-6,84	0.002798	0.015541	24.82	

APPENDIX C
X-ray Mineralogy Determinations, Site 204

Core	Cored Interval Below Sea Floor (m)	Sample Depth Below Sea Floor (m)	Diff.	Amorp.	Calc.	Quar.	K-Fe.	Plag.	Mica	Chlor.	Mont.	Phil.	Anal.	Augi.	Magn.	U-1[a]	Anat.	Kaol
Bulk Sample																		
1	0.0-7.5	3.9	87.9	81.0	–	18.6	–	36.7	22.8	3.0	11.2	–	–	7.7	–	–	–	–
2	7.5-16.0	11.2	89.2	83.2	–	14.4	–	20.4	14.5	–	6.9	43.9	–	–	–	–	–	–
		11.3	93.4	89.7	–	6.7	–	12.9	7.2	2.3	70.9	–	–	–	–	–	–	–
3	48.0-57.0	49.4	89.2	83.2	–	4.8	–	33.4	–	–	34.3	–	2.1	24.7	0.7	–	–	–
4	85.0-94.0	86.1	87.0	79.6	–	18.5	61.1	–	5.7	–	12.0	–	–	–	2.7	–	–	–
		90.4	83.1	73.6	27.1	9.1	37.5	–	4.2	–	17.6	–	–	–	4.4	Trace	–	
		91.0	68.1	50.1	–	13.9	63.2	–	–	–	11.7	–	–	–	11.2	–	–	–
5	94.0-103.0	102.8	79.3	67.6	7.3	16.1	71.0	–	–	1.8	3.8	–	–	–	–	–	–	–
2-20μ Fraction																		
1	0.0-7.5	3.9	82.7	72.9	–	21.2	–	49.1	14.9	2.4	–	–	–	9.6	2.9	–	–	–
2	7.5-16.0	11.2	80.5	69.6	–	11.0	–	10.5	11.8	–	–	66.7	–	–	–	–	–	–
3	48.0-57.0	49.4	84.7	76.0	–	4.8	–	40.8	–	–	41.3	–	1.3	8.7	3.0	–	–	–
4	85.0-94.0	86.1	70.9	54.5	–	18.5	63.6	–	1.6	1.1	8.7	–	–	–	6.5	–	–	–
		90.4	78.5	66.5	–	15.4	68.4	–	–	–	4.9	–	–	–	11.3	–	–	–
		91.0	78.8	66.9	–	14.4	71.3	–	–	–	–	–	–	–	14.3	–	–	–
5	94.0-103.0	102.8	68.2	50.3	–	17.8	72.4	–	–	1.0	–	–	–	–	8.9	–	–	–
<2μ Fraction																		
1	0.0-7.5	3.9	80.9	70.2	–	16.2	–	20.1	17.6	3.5	42.6	–	–	–	–	–	–	–
2	7.5-16.0	11.2	80.1	68.9	–	5.9	–	8.1	7.1	2.2	71.7	4.9	–	–	–	–	–	–
		11.3	73.7	59.0	–	2.3	–	2.7	2.1	–	91.7	–	–	–	–	–	1.2	–
3	48.0-57.0	49.4	80.4	69.3	–	0.5	–	7.4	–	–	82.0	–	10.2	–	–	–	–	–
4	85.0-94.0	86.1	80.6	69.7	–	19.6	65.7	–	7.2	–	–	–	–	–	3.5	–	–	4.0
		90.4	76.1	62.6	–	3.6	15.0	–	–	–	78.1	–	–	–	3.3	–	–	–
		91.0	82.9	73.3	–	5.3	22.9	–	–	–	66.0	–	–	–	5.9	–	–	–
5	94.0-103.0	102.8	87.0	79.7	–	8.8	36.2	–	–	2.9	52.0	–	–	–	–	–	–	–

[a]U-1 Peak at 12-1 Å

Site 204 Hole Core 1 Cored Interval: 0-7.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
QUATERNARY		R R R R	C R + +	G M P P	1	0.5 1.0	EMPTY	4	CC	[0% $CaCO_3$] ZEOLITE AND IRON OXIDE RICH SILTY CLAY dark brown — 45% clay minerals, 20% iron oxide, 20% zeolites, 10% glass shards increasing in glass 10YR3/3
		R	+	P	2				GZ	+ IRON OXIDE RICH GLASS SHARD SILTY CLAY dark brown [8% sand, 53% silt, 39% clay] — 45% clay minerals, 30% glass shards, 20% iron oxide, 2% phillipsite, 2% feldspar, 1% pyroxene 10YR6/3
		R	+	P	3				CC XM	10YR3/3 10YR3/3 & 10YR2.5/1 10YR3/3 10YR4/4 Sections 3, 4, & 5 vary from darker brown areas richer in iron oxide to lighter brown areas richer in glass shards [0% $CaCO_3$] FELDSPAR BEARING GLASS SHARD RICH IRON OXIDE SILTY CLAY dark brown — 63% iron oxide, 25% glass shards, 10% feldspar, 2% pyroxene 10YR3/3 grading occasionally to 10YR4/3 X-ray - 81% amorphous, 19% crystalline: 19% quartz, 3% chlorite, 37% plag., 11% mont., 23% mica, 8% augite
		R	R	P	4			3		
		R	+	P	5					5Y7/1 GLASS SHARD ASH light gray — 90% glass shards, 2% feldspar, 2% pyroxene 10YR3/3
		N R	- R	- P	Core Catcher					PHILLIPSITE AND GLASS SHARD BEARING IRON OXIDE RICH CLAY — 57% clay minerals, 24% iron oxide, 10% glass shards, 4% phillipsite, 2% feldspar, 1% pyroxene, 1% amphibole, 1% foraminifera

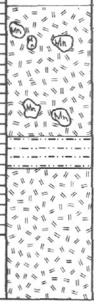
Site 204 Hole Core 2 Cored Interval: 7.5-16 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
?	?	R	+	P	1	0.5 1.0	EMPTY			10YR3/3
		R	+	P	2			3 to 4		FELDSPAR AND GLASS SHARD BEARING ZEOLITE AND IRON OXIDE RICH SILTY CLAY dark brown — 55% clay minerals, 20% iron oxide, 11% zeolites, 6% glass shards, 6% feldspar, 2% pyroxene X-ray - 83% amorphous, 17% crystalline: 14% quartz, 7% mont., 20% plag., 44% phillipsite, 14% mica
		R	+	P	3				XM	GLASS SHARD ASH Several 2-3 cm thick patches of light gray ash composed almost entirely of glass shards occur throughout the barrel.
		R	+	P	4					
		N R	- +	- P	Core Catcher					ZEOLITE IRON OXIDE SILTY CLAY

Site 204 Hole Core 3 Cored Interval: 48-57 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	?	R	+	P	1	0.5, 1.0	EMPTY	4	XM	5Y3/2 **IRON OXIDE AND FELDSPAR BEARING GLASS SHARD ASH** dark gray, contains 1-2 cm in diameter Mn? nodules. 80% glass shards, 8% feldspar, 6% iron oxide, 2% pyroxene, 2% zeolites, 2% clay minerals. 5Y4/1; 5GY4/1. X-ray - 83% amorphous, 17% crystalline: 5% quartz, 2% analcime, 33% plag., 25% augite, 34% mont., 1% magnetite
		R	+	P	2			3		10YR4/2; 5GY4/1 **FELDSPAR AND PYROXENE BEARING GLASS SHARD RICH IRON OXIDE CLAYEY SILT** dark grayish brown
		N R	- -	- -	Core Catcher					10YR4/2 **IRON OXIDE BEARING FELDSPAR RICH GLASS SHARD ASH** dark greenish gray to grayish brown
										5GY4/1 **IRON OXIDE BEARING FELDSPAR RICH GLASS SHARD ASH** dark greenish gray

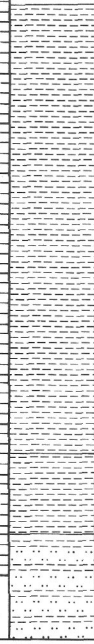
FOSSIL CHARACTER



Site 204 Hole Core 4 Cored Interval: 85-94 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
OLIGOCENE OR EARLY MIOCENE	?	R	R	P	1	0.5, 1.0	EMPTY	4 to 3	XM	**GLASS SHARD BEARING IRON OXIDE RICH CLAY** dark reddish brown streaked with lighter brown. 73% clay minerals, 12% iron oxide, 5% glass shards, 2% feldspar, 2% pyroxene, 2% zeolites, 2% fish debris, 1% forams (arenaceous), 1% rads. 5YR3/2
		F R	R R	M P	2					
		R	R	P	3					
		F R	R R	M P	4			3	XM	5YR3/3 & 10R4/6 Main lithology same as above. Four 1-2 cm thick beds of red IRON OXIDE CLAY occur in this interval. X-ray - 74% amorphous, 26% crystalline: 27% calcite, 4% mica, 9% quartz, 18% mont., 38% K-feldspar, 4% magnetite
		N N R F	R R R R	P P P M	Core Catcher				XM	5YR3/3 & 10R4/6 & 7.5YR4/2 Alternating beds of two above mentioned lithologies plus beds of brown CARBONATE SILT. Same colors and composition as three above mentioned lithologies.

FOSSIL CHARACTER



Site 204 Hole Core 5 Cored Interval: 94-103 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
OLIGOCENE OR EARLY MIOCENE		F	R	M	1	0.5				
		R	-	-		1.0				
		R	R	P	2					
		R	R	P	3			4		
		R	R	P	4					
		R	-	-	5					
					6			3	XM	
? CRETACEOUS		N	R	P*	Core Catcher					
		F	R	M						

5YR3/2 to 5YR3/3 to 5YR3/2

IRON OXIDE CLAY
dark reddish brown
smooth, creamy

43% iron oxide
43% clay minerals
2% fish debris
2% rads
2% feldspar
2% pyroxene
2% glass shards
2% zeolites
2% forams (arenaceous)

A few patches of dark brown (10YR3/3), dark grayish brown (10YR4/2), and light gray (10YR7/1) (10YR7/1). IRON OXIDE RICH GLASS SHARD ASH are scattered throughout the interval.

GLASS BEARING IRON OXIDE RICH CALCIC SILTY CLAY
brown with scattered pebble size dark red (2.5YR3/6) chips of iron oxide clay (includes upper 6 cm of CC)

70% authigenic carbonate
15% iron oxide
10% glass
2% feldspar

Lower 22 cm of core catcher is TUFFACEOUS MEDIUM SANDSTONE (19 cm thick) with sharp upper contact with above and sharp inclined (40°) lower contact with 3 cm of TUFFACEOUS PEBBLY COARSE SANDSTONE lithologically similar to Core 6.

5YR3/2 mixed with 7.5YR5/2 mainly 10YR3/3 with other shades of brown & 10R4/6

richer in carbonate and feldspar

5YR4/6

10YR4/3

X-ray - 68% amorphous, 32% crystalline:
7% calcite 2% chlorite
16% quartz 4% mont.
71% K-feldspar

*Top of core catcher

Site 204 Hole Core 6 Cored Interval: 103-112 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
? CRETACEOUS	?				1	0.5	EMPTY			
						1.0				
					2			1		
					3					
		M*	R	M	4					

5YR4/4

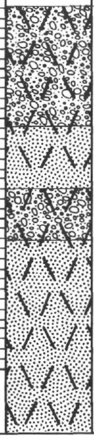
TUFFACEOUS PEBBLY COARSE SANDSTONE and TUFFACEOUS COARSE SANDSTONE
Overall color is yellowish brown but by numerous thin (mostly 2-4 mm), mostly subhorizontal calcite veins. Pebbles are up to 5 cm in diameter. Most granules and pebbles are subrounded granules, pebbles, and calcite veins occur irregularly throughout the interval. Clast lithology includes pumice, ash, glass, iron oxide, and vesicular basalt. Cement is calcite. Uppermost reddish brown 4 cm is cross bedded.

matrix grain size increases downward

TUFFACEOUS PEBBLY GRANULE CONGLOMERATE
Lower 62 cm of interval contain a few scattered white calcareous prisms (*Inoceramus*?) up to 15 mm in length.

*M = Mollusca

Site 204 Hole Core 7 Cored Interval: 112-121 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
? CRETACEOUS	?	N	-	-	1, 2, 3, Core Catcher	0.5, 1.0	EMPTY 		1	see below

Entire core is volcanogenic, has an overall yellowish brown color, and is indurated.

TUFFACEOUS PEBBLE CONGLOMERATE
lithologically similar to Core 6.

TUFFACEOUS GRANULAR COARSE SANDSTONE
In Section 2:
- 59 - 62 cm - clayey silt
- 62 - 64.5 cm - sandy silt, cross bedded
- 64.5- 73 cm - fine sand at bottom to granules at top (reversely graded), cross bedded
- 73 -107 cm - very coarse sand and granules at bottom to medium sand at top (graded bed)
- 107 -120 cm - coarse sand to granular gravel, cross bedded

In Section 3:
- 70 - 80 cm - coarse sand, cross bedded?
- 80 -105 cm - coarse sand, some granules, disturbed bedding (soft sediment deformation?)
- 130 -150 cm - coarse sand, vague inclined bedding with sporadic white calcareous (*Inoceramus*?) prisms

TUFFACEOUS GRANULAR COARSE SANDSTONE
yellowish brown, 10 cm piece

Site 204 Hole Core 8 Cored Interval: 121-130 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
? CRETACEOUS	?				1, 2, 3, 4, Core Catcher	0.5, 1.0	EMPTY 		1	see below

TUFFACEOUS MEDIUM TO COARSE SANDSTONE
Overall color is yellowish brown cut by numerous thin (2-4 mm) mostly sub-horizontal calcite veins. Occasionally granular to pebbly (mostly subrounded). Calcite cemented. Occasionally iron stained. Lower 50 cm is coarser, more granular and pebbly, and contains a few scattered white calcareous (*Inoceramus*?) prisms. Clasts lithologically similar to Cores 6 and 7.

TUFFACEOUS FINE SANDSTONE grading down into VOLCANOGENIC COARSE SANDY PEBBLE CONGLOMERATE
lithologically similar to above

5G4/1 VITRIC TUFF
dark greenish gray
Sharp contact with yellowish brown conglomerate above. Sandstone contains zeolites, iron oxide and pyrite, altered glass, and pyroxene. Calcite cemented.

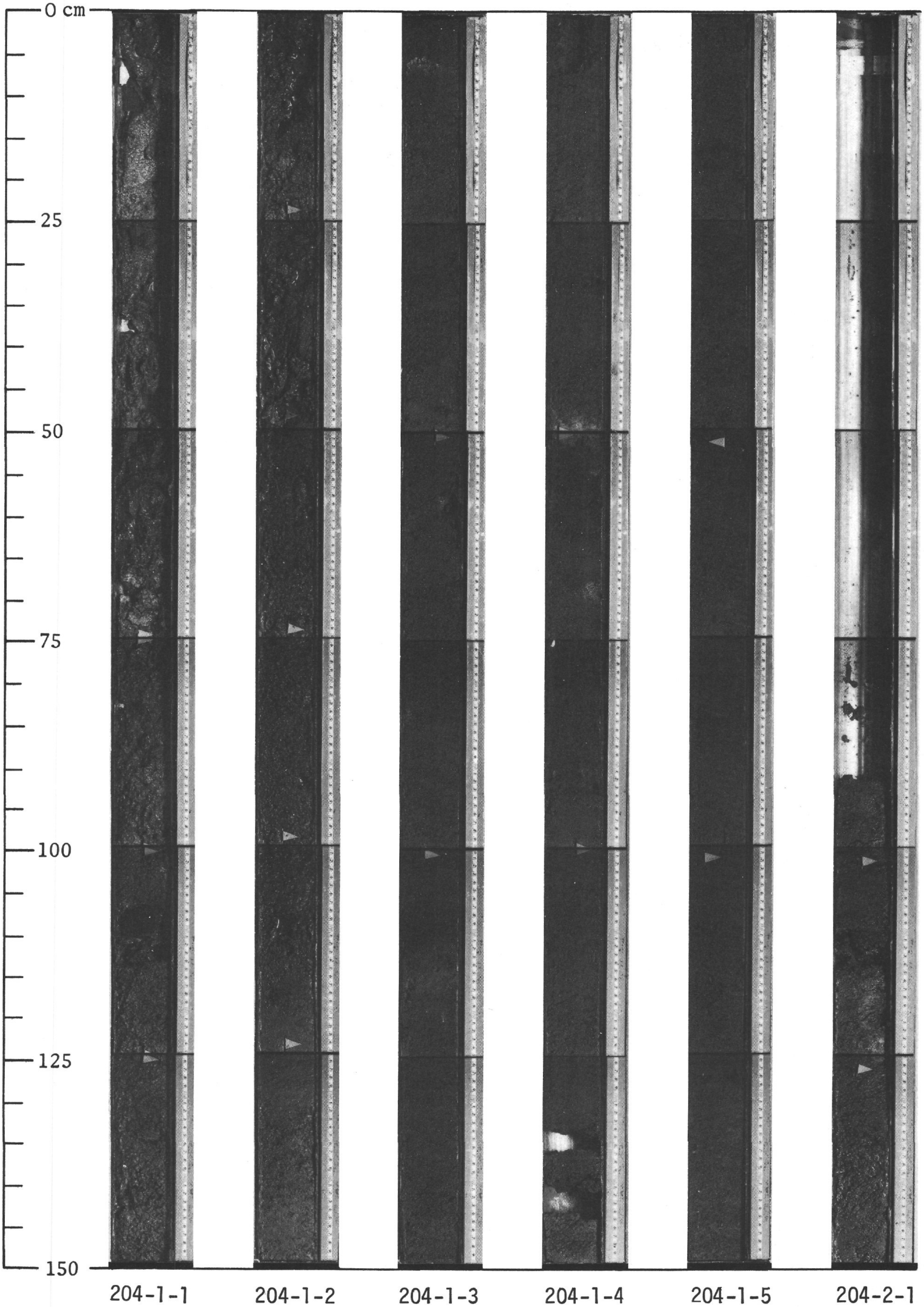
5G4/1 VITRIC TUFF
as above

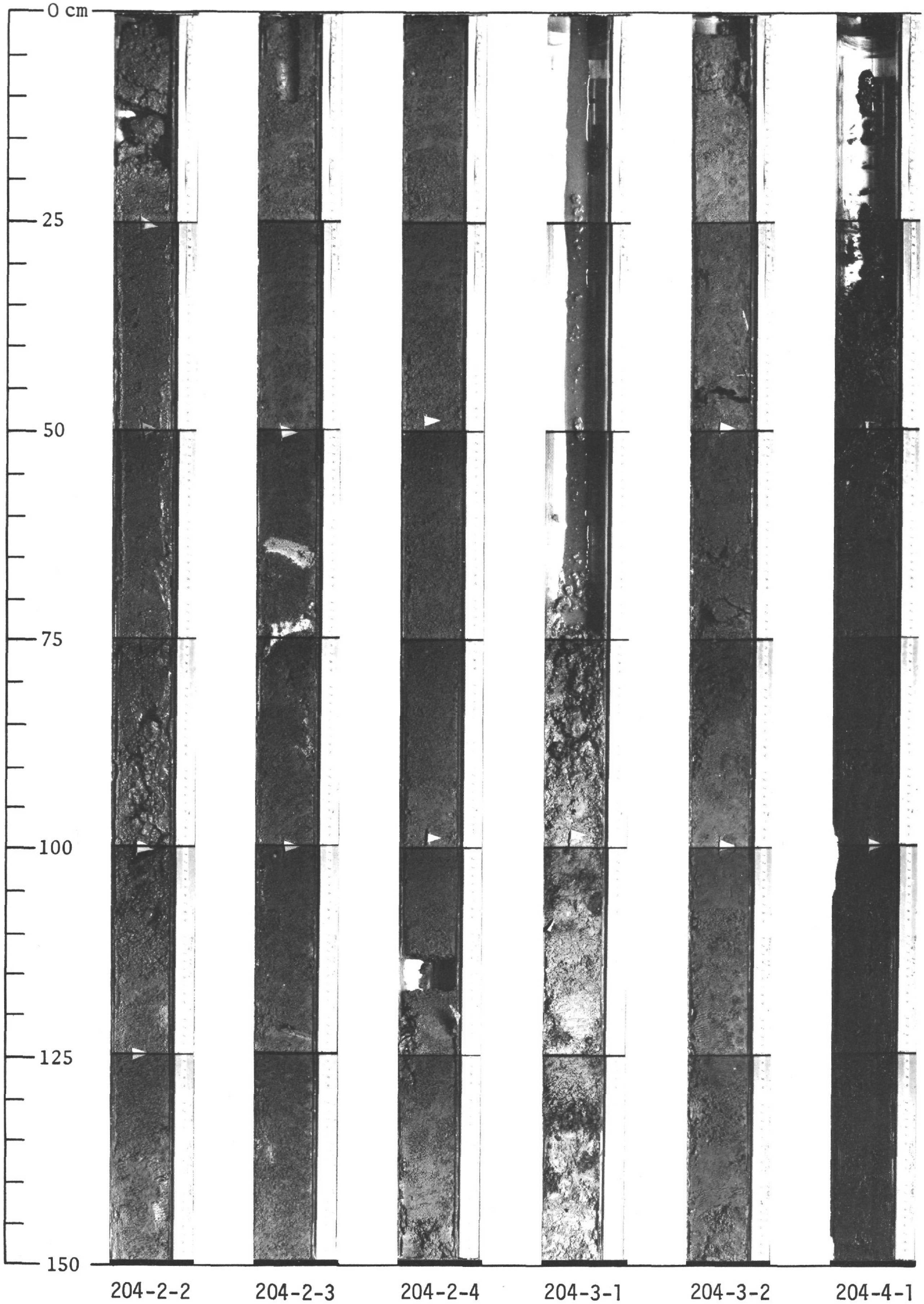
Site 204 Hole Core 9 Cored Interval: 141-150 m

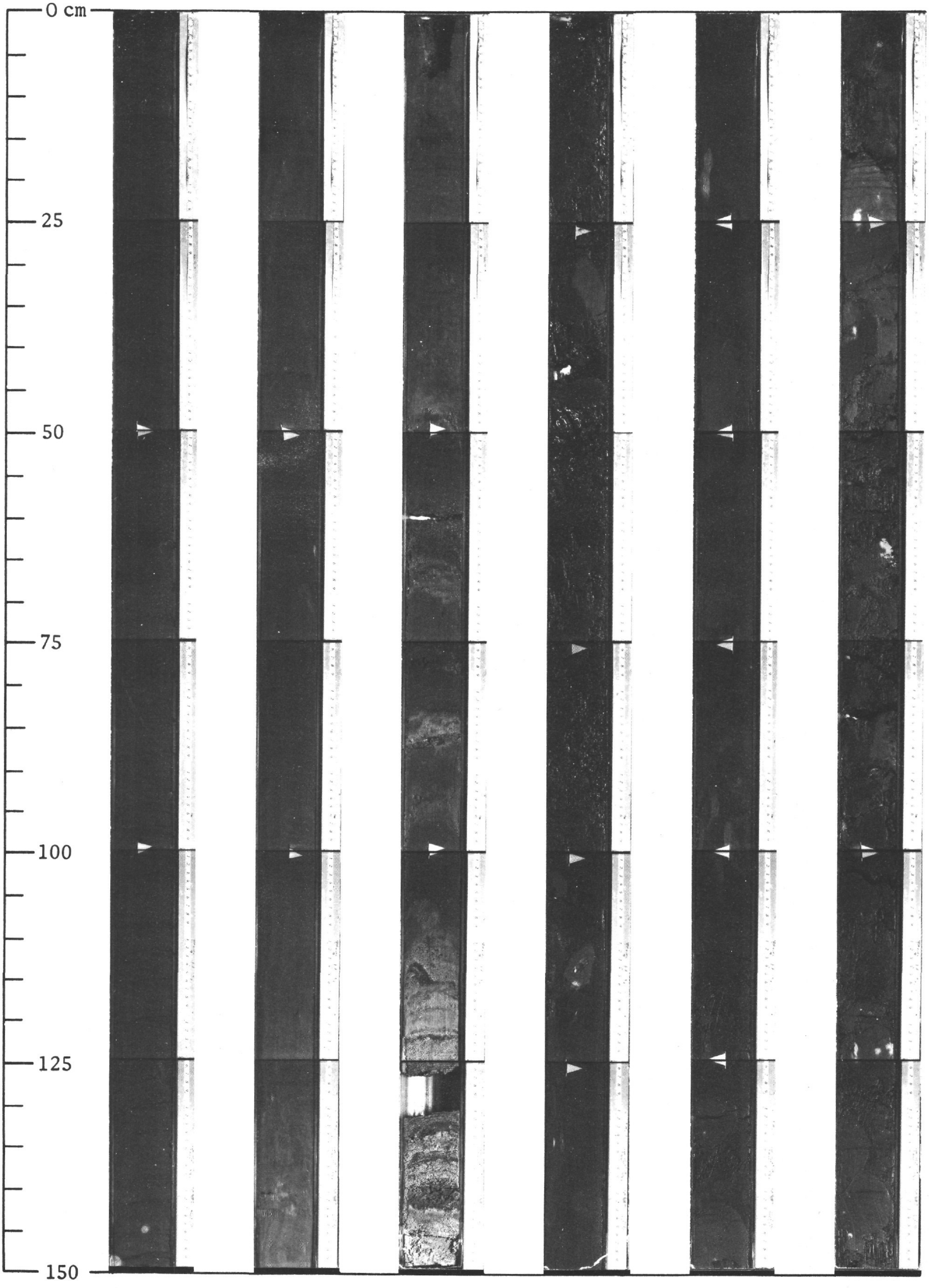
AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
?	?				1	0.5 1.0				VITRIC TUFF dark greenish gray Similar to bottom of Core 8. Sporadic dark gray to black angular to subrounded pebbles of altered glass. Vague stratification throughout most of the core, often irregular (soft sediment deformation?). Lower 50 cm cut by thin calcite veins. Probably not calcite cemented.
					2			1		
					3					5G4/1
					4					
					Core Catcher					5G4/1 VITRIC TUFF as above

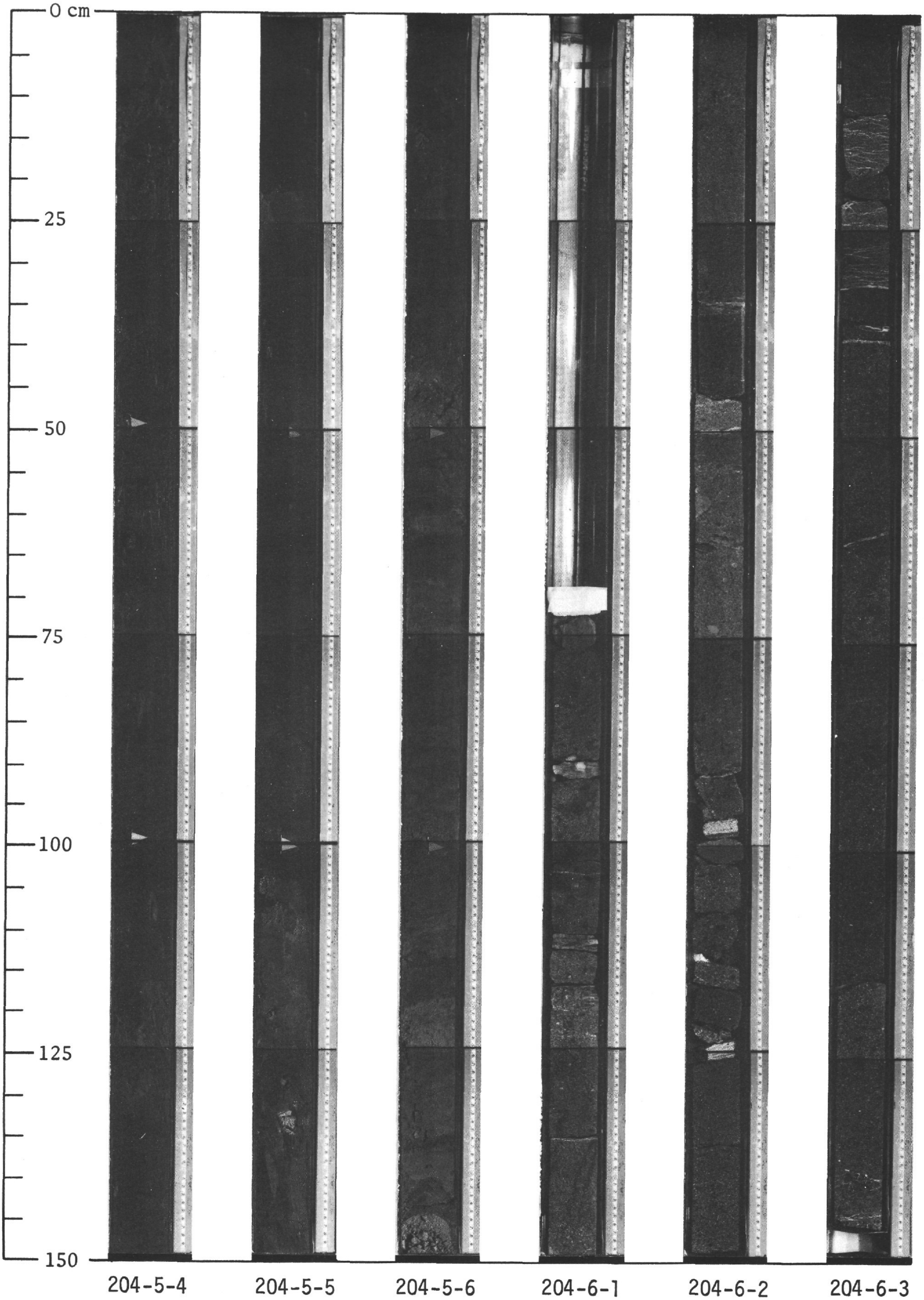
Site 204A Hole Core 1 Cored Interval: 86-95 m

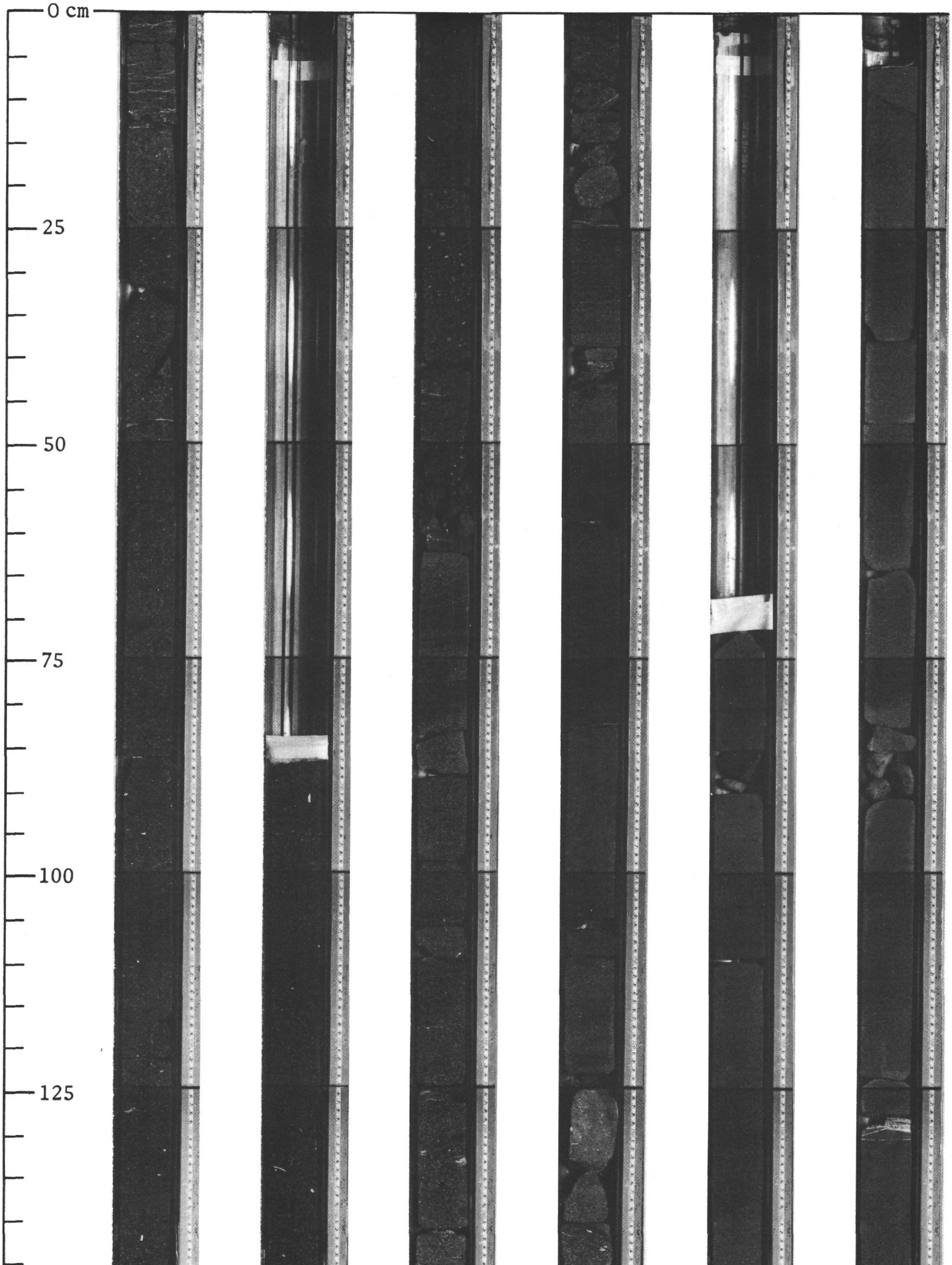
AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
? OLIGOCENE OR EARLY MIOCENE	?				1	0.5 1.0	EMPTY	4		10YR3/1 — Upper 65 cm of core disturbed by heat probe. Entire core more disturbed and mixed than same interval in Hole 204 (Core 4). 10YR3/2 — Same three lithologies present listed in decreasing abundance: 5YR3/1 mixed with 5YR3/3 — IRON OXIDE RICH CLAY - dark grayish brown to dark reddish brown IRON OXIDE CLAY - dark red CARBONATE SILT - brown
					2					layers of 7.5YR3/2 2.5YR3/6 10YR4/3 — See Hole 204, Core 4 for more details on this interval. On the basis of lithologically similar carbonate silt beds, the basal portion of 204A-1-3 is correlative with the basal portion of 204-4-4.
		N	R	P	3			3		
		N R	- R	- P	Core Catcher					Mixture of 3 above mentioned lithologies.

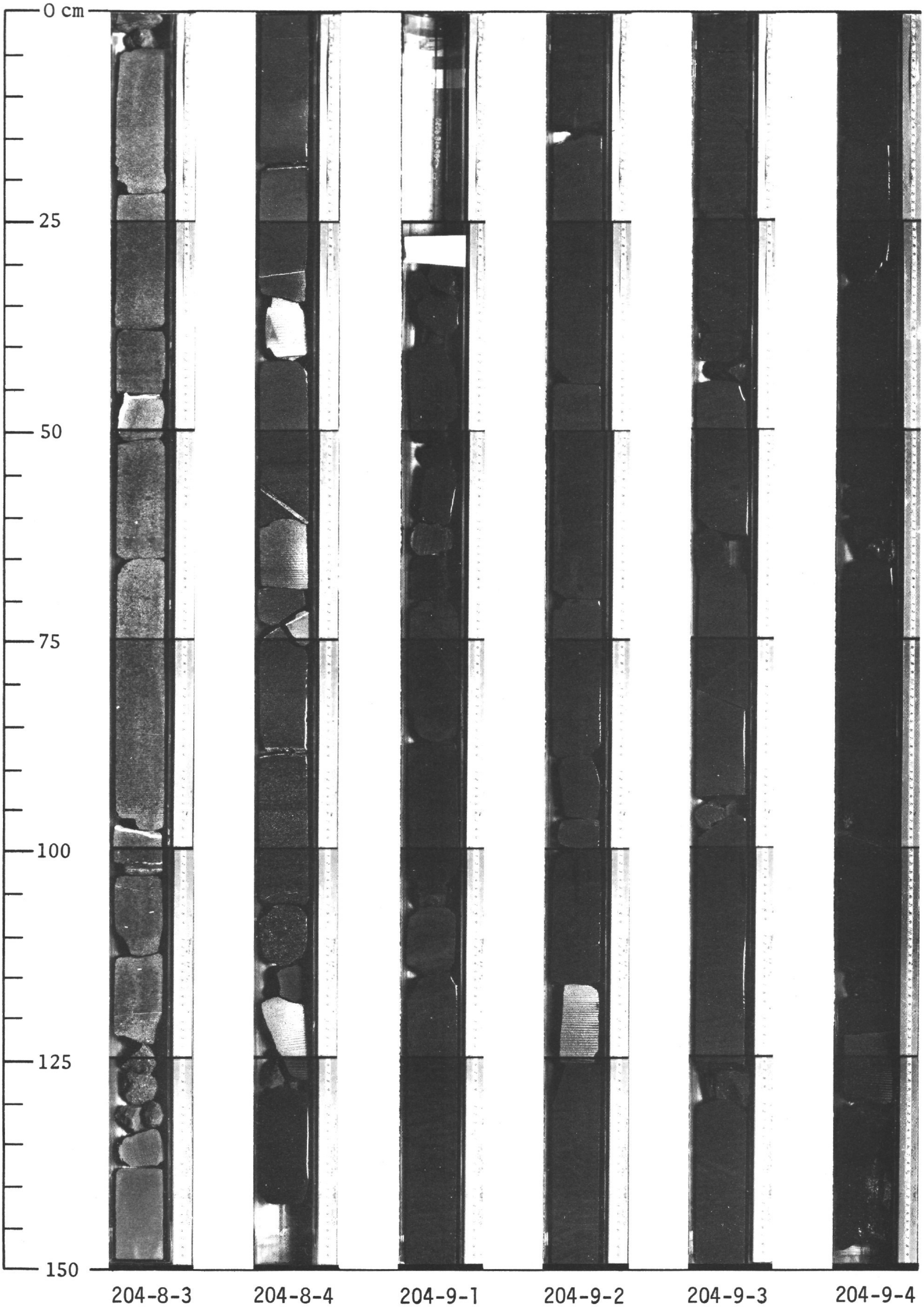

0 cm
25
50
75
100
125
150
204-1-1
204-1-2
204-1-3
204-1-4
204-1-5
204-2-1

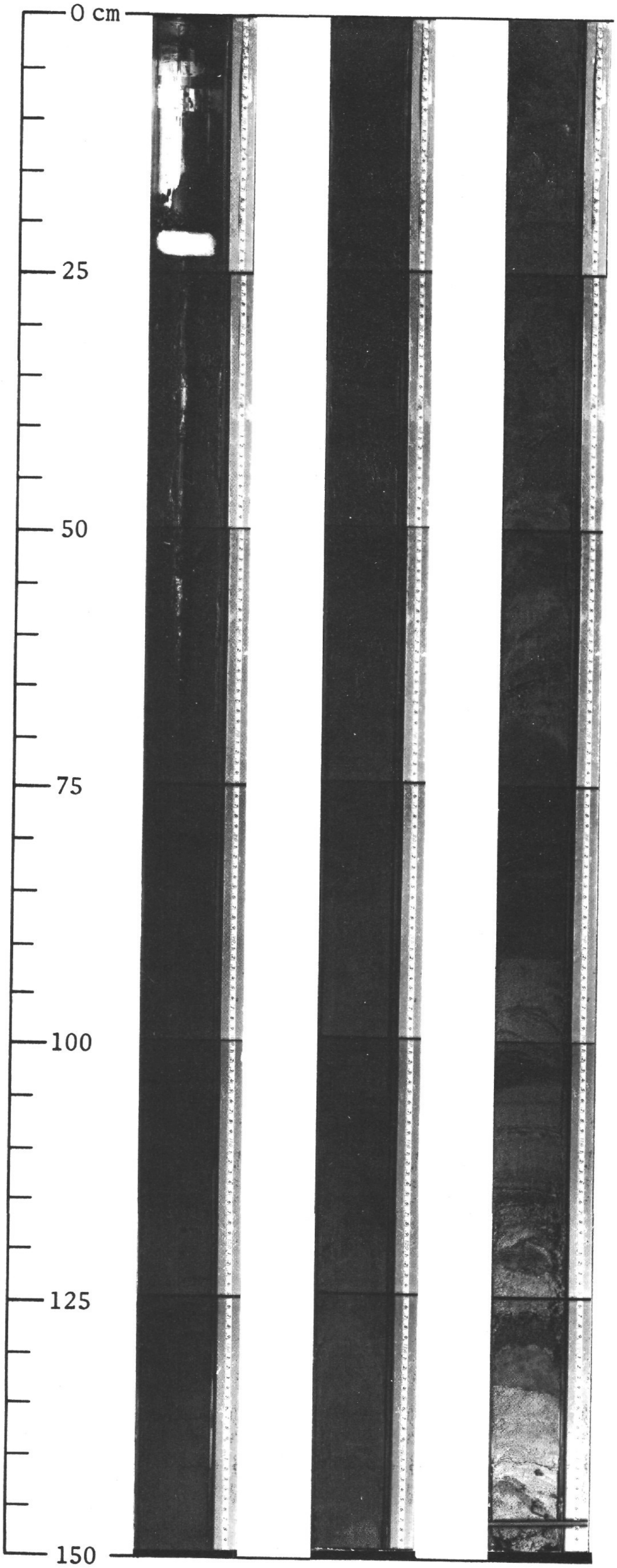

0 cm
25
50
75
100
125
150
204-2-2
204-2-3
204-2-4
204-3-1
204-3-2
204-4-1


0 cm
25
50
75
100
125
150
204-4-2
204-4-3
204-4-4
204-5-1
204-5-2
204-5-3

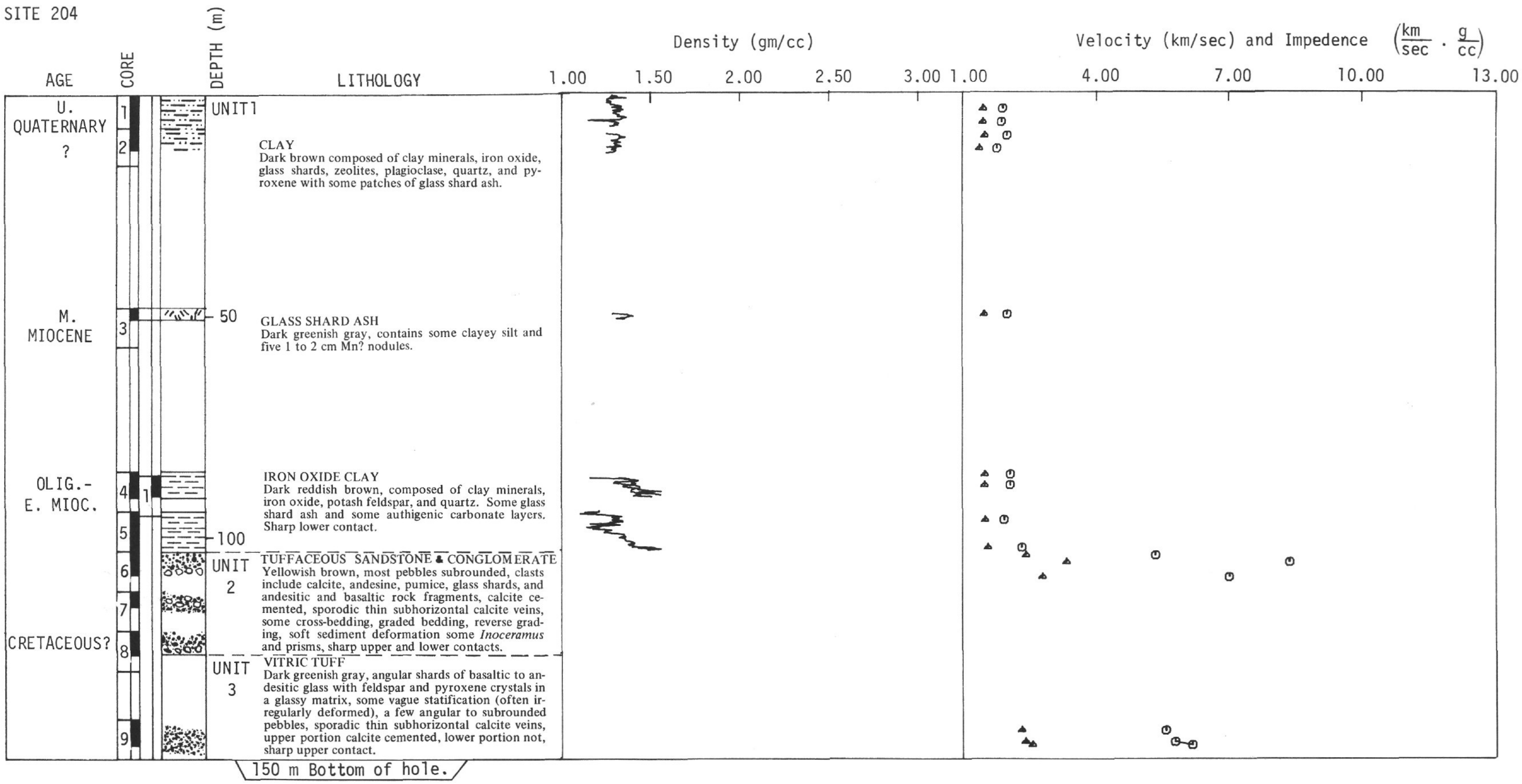

0 cm
25
50
75
100
125
150
204-5-4
204-5-5
204-5-6
204-6-1
204-6-2
204-6-3


0 cm
25
50
75
100
125
150
204-6-4
204-7-1
204-7-2
204-7-3
204-8-1
204-8-2


0 cm
25
50
75
100
125
150
204-8-3
204-8-4
204-9-1
204-9-2
204-9-3
204-9-4



204A-1-1 204A-1-2 204A-1-3


SITE 204
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
U. QUATERNARY ?
M. MIOCENE
OLIG.- E. MIOC.
CRETACEOUS?
1
2
3
4
5
6
7
8
9
1
UNIT1
50
100
UNIT 2
UNIT 3
CLAY
Dark brown composed of clay minerals, iron oxide, glass shards, zeolites, plagioclase, quartz, and pyroxene with some patches of glass shard ash.
GLASS SHARD ASH
Dark greenish gray, contains some clayey silt and five 1 to 2 cm Mn? nodules.
IRON OXIDE CLAY
Dark reddish brown, composed of clay minerals, iron oxide, potash feldspar, and quartz. Some glass shard ash and some authigenic carbonate layers. Sharp lower contact.
TUFFACEOUS SANDSTONE & CONGLOMERATE
Yellowish brown, most pebbles subrounded, clasts include calcite, andesine, pumice, glass shards, and andesitic and basaltic rock fragments, calcite cemented, sporodic thin subhorizontal calcite veins, some cross-bedding, graded bedding, reverse grading, soft sediment deformation some *Inoceramus* and prisms, sharp upper and lower contacts.
VITRIC TUFF
Dark greenish gray, angular shards of basaltic to andesitic glass with feldspar and pyroxene crystals in a glassy matrix, some vague statification (often irregularly deformed), a few angular to subrounded pebbles, sporadic thin subhorizontal calcite veins, upper portion calcite cemented, lower portion not, sharp upper contact.
150 m Bottom of hole.