General features of sediment cores collected in the Okhotsk Sea and the adjacent area during the MR00-K03 cruise

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Multiple and piston cores were collected at three sites in the Okhotsk Sea and the adjacent area in the northwestern North Pacific during the R/V MIRAI MR00-K03 (May 9 - June 10, 2000) cruise.

This paper reports basic data on coring site locations and some geological data: visual core descriptions, color reflectance spectra, magnetic susceptibility, and gamma ray attenuation density, which were obtained on board.

Keywords : R/V MIRAI, Okhotsk Sea, sediment core, visual description, physical property

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1. Introduction

The North Pacific is ventilated today at relatively shallow depths by cooling and mixing in the Okhotsk Sea and the Gulf of Alaska[1) 2) 3)]. The ventilated seawater, called North Pacific Intermediate Water (NPIW), penetrates at depths of 600-900m[4)]. Ventilation at such intermediate depths is sensitive to large-scale climate variability, such as the El Niño/Southern Oscillation[5)]. In addition, today's NPIW is supposed to actively accumulate CO_2. Thus, understanding the behavior of NPIW is indispensable in clarifying the mechanisms of global climate change and the biogeochemical cycle through the geological period. Not only with NPIW but also with the surface and deep water of the North Pacific, there still remain major unknown factors concerning behaviors and roles through the geological period. Furthermore, considerable speculation still remains, for example, that modern processes generating NPIW could produce Pacific Deep Water in glacial times[6)].

The sediment coring was undertaken during the MR00-K03 cruise from May 9 to June 10 in 2000, as an investigation of a JAMSTEC project on "Biogeochemical Study of the Northern North Pacific and its Adjacent Seas." The main objective was to understand the past environmental change in the northwestern North Pacific and the Okhotsk Sea throughout the late Quaternary period (ca 150,000 yr), as follows: (1) the sea surface temperature, (2) the paleo flux of biogenic particles, (3) deep-water circulation, (4) paleo distribution of nutrients in deep water, (5) how far the terrigenous materials and ice rafted debris (IRD) were transported from the Okhotsk coast to the Pacific, and (6) what amount of terrigenous materials and IRD were transported. Furthermore, paleomagnetic study is carried out to determine the geological age and the magnetic field reversal events.

This paper reports geological routine data of sediment cores obtained onboard and on land, as follows.

- Visual core descriptions - To obtain geological information, such as sedimentation structure, micro fossil assemblage, and past volcanic activity.
- Color reflectance spectra - To understand (i) component materials, such as pelagic clay and biogenic materials, (ii) the past change of the redox condition, and amount of transition metals, such as manganese and iron.
- Magnetic susceptibility - To understand (i) paleo flux of magnetic minerals, such as terrigenous materials, and (ii) past volcanic activity.
- Gamma ray attenuation - To estimate bulk density of sediment.
- Volume - To estimate dry bulk density of sediment.

These data provide valuable information on past phenomena and environmental changes, which are further investigated by radioisotope and stable isotope analyses, cosmogenic nuclides analysis, micro fossil assemblage analysis, and analyses of inorganic and organic geochemistry.

2. Sampling Location

Four pistons and four multiple cores were obtained in the northwestern Pacific and the Okhotsk Sea (Table 1 and Fig.1). MC-01 was collected at the southwestern site in the pacific side of the Kulzenshutana Strait (45°52.77'N, 151°33.15'E, water depth 1121m). PC-01 and the MC-02 were collected at the southeastern site in the pacific side of the Kulzenshutana Strait (46°18.65'N, 152°32.16'E, water depth 2796m). PC-02, PC-03, and MC-03 were collected at the northeastern area of Kuril Basin (48°15.00'N, 151°59.95'E, water depth 3244m; 48°15.00'N, 151°59.89'E, water depth 3244m; 48°14.96'N, 151°59.94'E, water depth 3245m, respectively). PC-04 and MC-04 were collected at the south-eastern site in the Okhotsk Sea, off Kamchatka peninsula (49°22.03'N, 153°00.63'E, water depth 1821m; 49°22.02'N, 153°00.64'E, water depth 1822m, respectively).

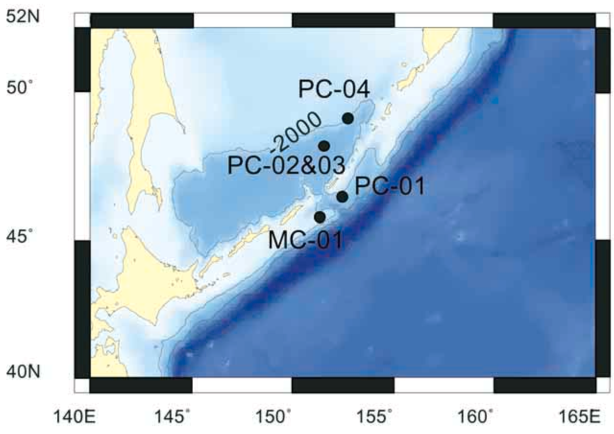

Fig. 1 Location map of multiple and piston cores collected in MR00-K03 cruise.

Table 1 Summary of sediment samples during the MR00-K03 cruise (R/V Mirai)

Core	Date	Equipment	Latitude	Longitude	Water Depth	Cored length excluding flow-in	Core depth below sea floor
					(m)	(cm)	(cmbsf)
MC-01	18.May.00	multiple corer	45-52.77'N	151-33.15'E	1121	6.5	0-6.5
MC-02	21.May.00	multiple corer	46-18.65'N	152-32.16'E	2796	27.5	0-27.5
MC-03	30.May.00	multiple corer	48-14.96'N	151-59.94'E	3245	35.5	0-35.5
MC-04	31.May.00	multiple corer	49-22.02'N	153-00.64'E	1822	37	0-37
PC-01	21.May.00	piston corer-10m	46-18.61'N	152-32.23'E	2793	865.9	-
PC-02	30.May.00	piston corer-20m	48-15.00'N	151-59.95'E	3244	482.5	-
PC-03	30.May.00	piston corer-20m	48-15.00'N	151-59.89'E	3244	461.5	-
PC-04	31.May.00	piston corer-20m	49-22.03'N	153-00.63'E	1821	2060	

*The core location (latitude and longitude) is the hitting point of corer.
*Positioning system: WGS84

3. Sampling Procedures on board and chemical properties analyzed on land

Sampling manner and analytical procedures of physical properties were almost same as those reported in Harada *et al*. (2000)[7]. Therefore, we explain only different or additional procedures for the last cruise (MR98-05).

After the gamma-ray attenuation (GRA) and the magnetic susceptibility measurements, all whole cores were split into working and archive halves. The archive halves were sub-sampled, for soft X-ray analysis, using a plastic case of 20 cm length and 3 cm width. Then, sub-samples for organic geochemical analysis, such as total carbon, organic carbon, total nitrogen, alkenone, sterol, hydrocarbon, and fatty acid, were taken, using glass bottles.

The working halves were also continuously sub-sampled for future analysis following: (1) microfossil assemblage analysis, such as planktonic foraminifera and benthic foraminifera, (2) $\delta^{18}O$, ^{14}C, and trace metal (Cd/Ca, Mg/Ca) analyses of microfossils, (3) biogenic silica analysis, radioisotope and stable isotope analysis (C, U, Th, Pa, Po, Pb etc.), (4) particle size distribution analysis of terrigenous materials, (5) paleo magnetic analysis.

Cube samples whose paleo magnetic analysis had been finished were used for volume analysis, with a Penta-Pycnometer (Quantachrome Inc.). Wet and dry densities of sediment were estimated based on volume and weight values of the cube samples (Fig. 7). The standard deviation of triplicate analysis was less than 1%.

4. Results

Visual core descriptions of multiple and piston cores are summarized in Fig. 2. Visual core description was executed to represent lithologic features, components, and sedimentary stratigraphy. For the piston core samples, the working half was used for visual core description. For multiple corer samples, the longest core, which was recovered in one cast, was used.

Down core variations of MSCL data (GRA density and magnetic susceptibility) and color reflectance indices are shown in Figs. 3 to 6. The color reflectance data are indicated as color parameters of L*, a*, and b* (L*, black and white; a*, red and green; b*, yellow and blue). The color indices were only the depth of 5 m measured for PC-03, because the samples, which are 5 m below, were flow-in.

Raw data of magnetic susceptibility and gamma ray attenuation are generally inversely correlated, and thus volumetric magnetic susceptibility and gamma bulk density are directly correlated to each other (Figs. 3 to 6). Such patterns of profiles imply that high bulk density (low gamma ray attenuation) intervals are associated with high content of magnetic materials. From the core top to several tens of cm downward, drastic increasing of gamma density and magnetic susceptibility are generally observed, due to quick decreasing of water contents. These drastic changes are recognized in the vertical profiles of not only PC core but also MC core. It is important information to construct a composite profile of MC and PC cores.

4.1. MC-01

A multiple core, MC-01 was 6.5 cm long and was mainly composed of medium～coarse grain sand (Fig. 2). Dark gray colored pumice grains, and well-rounded sandstones up to 2 cm wide, were scattered through the core. Sandy silt was included in the depths from 5.5 to 6.5 cmbsf (centimeters below the sea floor). Some biological sand pipes were identified at the core top.

L*, a*, and b* varied from 37 to 41, from 0.4 to 0.8, and from 1.5 to 3 through the core (Fig. 3).

4.2. PC-01&MC-02

A piston core, PC-01 was 865.9 cm long and was chiefly composed of dark olive colored homogeneous diatomaceous silt (Fig. 2). At the core top, the oxygenated layer had been lost. Medium grain pumiceous sand was scattered through the core. A lenticular grayish colored tuff zone was observed at 334.5 cmbsf, in the middle part of section 4. Four pumiceous sand layers 4 to 10 cm in thickness, were intercalated below sections 6-7. A slight biogenic disturbance was developed through the core. Olive black (5Y3/1) colored fine～very fine sand layers occurred at sections 1, 3 and below section 6. Upward fining and coarsening structures were identified at sections 6, 7, and 8.

A multiple core, MC-02 was 27.5 cm long and was mainly composed of dark olive (7.5Y3/2) colored diatomaceous silty clay with sandy silt (Fig. 2). An oxygenated layer was shown at 0 to 5 cmbsf. A fine sand layer of 2 cm thickness, bearing foraminifera, occurred at 13～19 cmbsf. A slight biogenic disturbance existed in the whole sections. Shell fragments existed at 26 cmbsf.

L*, a*, and b* varied from 30 to 55, from -2 to 0.5, and from 0.2 to 11.8, respectively (Fig. 4). The highest L* value: 55, was found at a depth of 3.3 m and corresponded with the relatively high gamma density. The vertical profiles of three parameters showed relatively small fluctuation compared with those of the PC-02, 03, and 04.

Most peaks and troughs of magnetic susceptibility were correlative with those in gamma density profile (Fig. 4). Several unique patterns, however, occurred in PC-01. For example, small magnetic susceptibility peaks at about 7.6 m in depth were correlated to the prominent troughs in the gamma ray attenuation variation. The peak corresponded to a pumiceous layer identified by visual core descriptions. Pumiceous fragment of porous texture and high contents of magnetic minerals might cause such a pattern. In the case of a glassy ash layer at a depth of 3.3 m, a different pattern, showing high density and low magnetic susceptibility, was recognized.

Wet bulk density was from 1.2 to 2 (g/cm^3). Although the density slightly increased with depth from the surface to 800 cmbsf, no increasing was found below about 800 cmbsf (Fig. 7). The wet density was relatively high, at about 340~370 cmbsf. Dry bulk density varied from 2 to 2.5 (g/cm^3), without a drastic change, throughout the whole core (Fig. 7).

4.3. PC-02, 03 & MC-03

Piston cores PC-02 and PC-03 were 482.5 and 461.5 cm long, respectively, and they were composed of grayish olive (7.5Y4/2) foraminifera-bearing diatomaceous clay and very fine sand layers (Fig. 2). Sections 1 and 2 were composed of purely diatomaceous clay. Normally graded olive black (5Y3/1) colored fine～very fine sand layers occurred at sections 1, 3, and 5. An upward fining structure was identified at sections 1 and 3. According to Ternois *et al*. (2000)[8], the Siberian permafrost meltwater event, and melting water pulse 1-A (MWP-1A, Bard *et al*., 1997[9]) were identified at 8k～10k yrBP and 14k～15k yrBP from the alkenone paleo SST profile of a core obtained near PC-03. It seems likely that the graded fine sand layers at sections 1 and 3 are evidence of these melting water events, since the depths of the sand layer of PC-03 almost corresponded with those at which melt water events were identified in the core or by Ternois *et al*. (2000). Flow-in sediment (mainly composed of fine sand) occurred probably below section 5. For PC-02, the lithological feature was the same as that of PC-03, and therefore a figure of the visual description of PC-02 was omitted.

A multiple core MC-03 was 38.5 cm long and was composed of olive black (5Y 3/2) colored homogeneous diatomaceous dull clay (Fig. 2). A brownish black～black (10YR2/2～10YR17/1) colored oxygenated layer occurred at the top～5 cmbsf. Moderate bioturbation was developed in the whole core. Isolated pumices existed at 29 and 36 cmbsf. The core bottom (2 mm in thickness) was slightly disturbed.

L*, a*, and b* of PC-02, 03, and MC-03 varied from 24 to 45, from -2 to 3.7, and 2 to 14, respectively (Fig. 5). The variation pattern of vertical profiles between PC-02 and 03 was very similar for each color parameter. The variation of L* profile corresponded to that of the b*, but was the opposite trend of the a* profile. The L* was a relatively low value (less than 30) at the depths of 0.8, 2.3, and 4.4 m. It seems likely that the cyclic low value of L* would relate to the geological events, such as one melting water event.

The figures of the physical properties were also omitted for PC-02 core. The PC-02 and 03 cores included three distinctive sand layers. The layers showed sharp spikes in magnetic susceptibility and gamma density. Magnetic susceptibility spikes were tenfold larger than the background value, and grain density was several-fold larger than the background. In the second sand layer of PC-02, spikes of magnetic susceptibility at intervals of 2.5m, indicated a unique pattern, which was a sharp increasing at the bottom, and gradual decreasing in the top of the spike. This pattern suggested that the sand layer was derived by a turbidite. Visual inspection also identified an upward grading structure in this horizon.

Wet bulk density of the PC-03 core was from 1.4 to 2.2 (g/cm^3) throughout the whole core (Fig. 7). Relatively high values of 2 (g/cm^3) were found at the depths of 0.8, 2.3, and 4.4 m. These depths corresponded to those having low L*, and these high densities at these depths might be evidence of melting water events. Dry bulk density varied from 2 to 3.2 (g/cm^3) throughout the whole core. A relatively large change was found at a layer from 280 to 320cm, and corresponded to the coarser sand layer rather than its above and below layers.

4.4. PC-04 & MC-04

PC-04 was 2060.0 cm long and was composed chiefly of olive black (7.5Y3/2) colored homogeneous diatomaceous silt (Fig. 2). The core top～50 cm in depth was a grayish olive (5Y4/2) diatom-rich layer. Biogenic disturbance weakly developed in the whole sections. A few species of foraminifera were included. Many pumices (3 mm～3 cm in size) occurred in this core. Well-rounded pebbles (probably basaltic rock) were in the whole sections. Faintly laminated coarse - fine sand layers were identified at sections 1, 4-5, and 16-18.

MC-04 was 39.0 cm long and was composed of olive black (7.5Y3/2) colored homogeneous diatomaceous dull silt with very fine sand (Fig. 2). An oxygenated layer was identified at～1 cmbsf. Silt～very fine sand was observed in the whole length. Biogenic disturbance weakly developed about 20 cmbsf below the oxygenated layer.

L*, a*, and b* of PC-04 and MC-04 varied from 30 to 44, from -3 to 0.8, and from 4 to 12.5, respectively (Fig. 6). There was no correlated variation trend among L*, a*, and b* profiles.

Peaks and troughs of magnetic susceptibility well correlated with those of gamma density. The patterns of both profiles imply that high bulk density (low gamma ray attenuation) intervals are associated with high content of magnetic materials. Although there was no large spike in the profile, very unlike PC-01 and 02, variations of magnetic susceptibility and gamma density showed a periodic pattern.

Wet bulk density varied from 1.4 to 1.8 (g/cm^3), with a narrower variation range than the other two piston cores (Fig. 7). Dry bulk density varied from 2.2 to 2.8 (g/cm^3), without a drastic change throughout the whole core, and its variation pattern is very similar as those of wet density.

5. Acknowledgment

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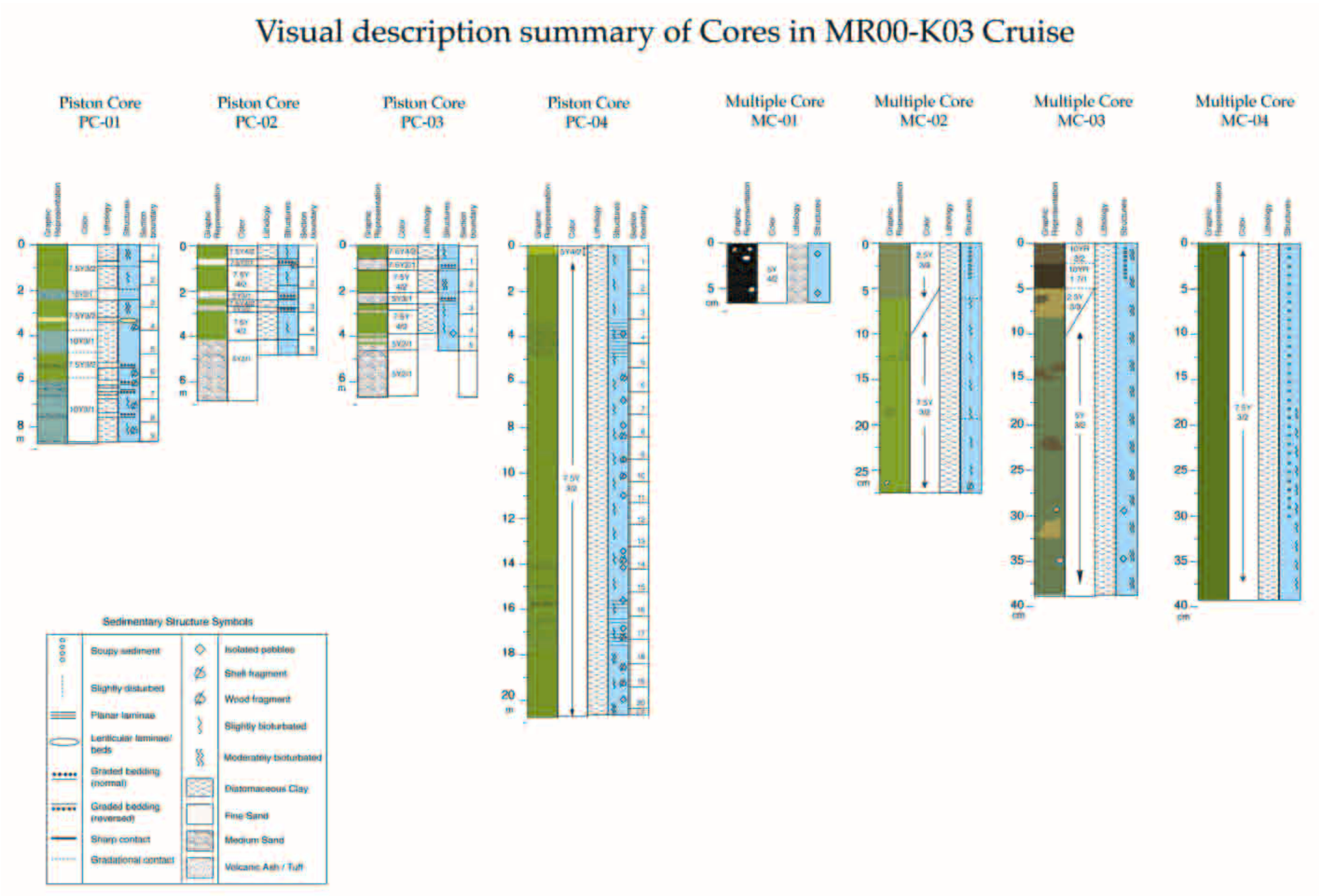

Fig. 2 Down core variations of visual description of multiple and piston cores.

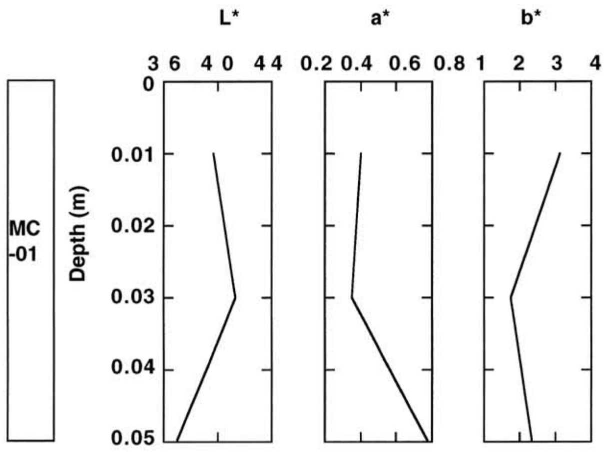

Fig. 3 Vertical distribution of color indices, L*, a*, and b* of MC-01 core.

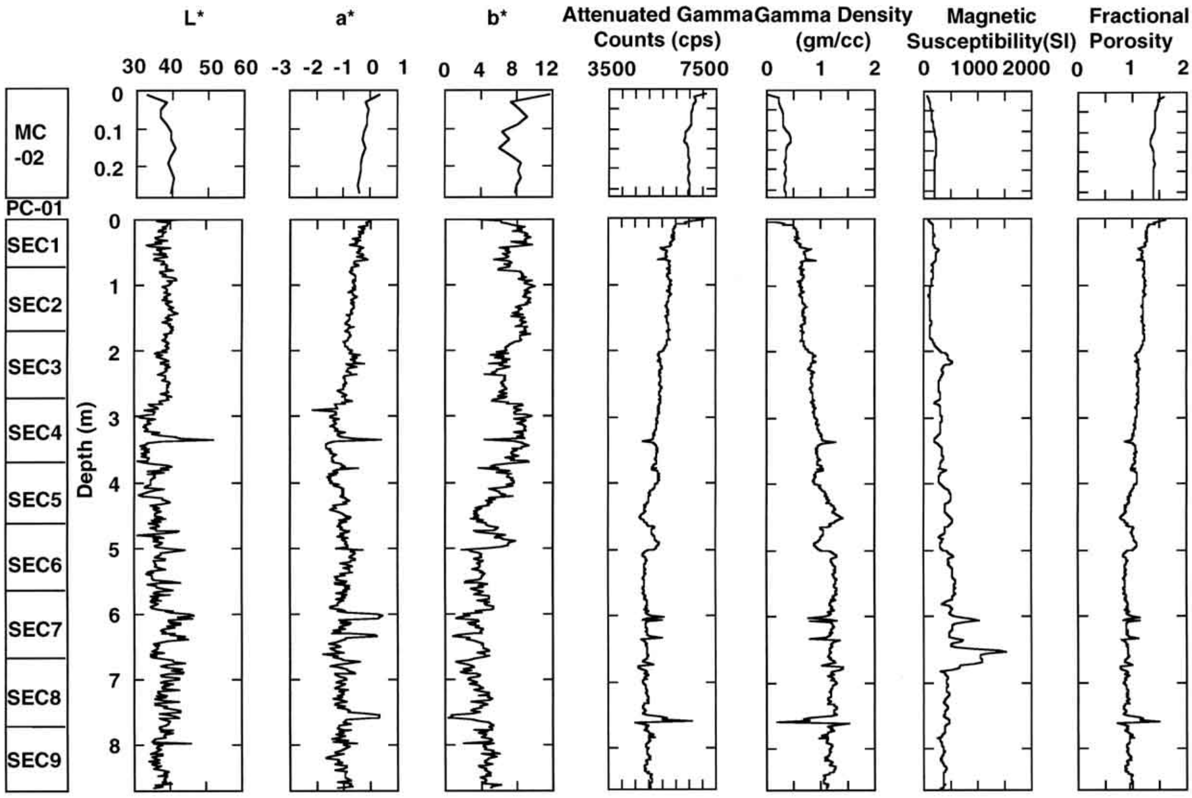

Fig. 4 Vertical distribution of gamma density, magnetic susceptibility, L*, a*, and b* of MC-02 and PC-01 cores.

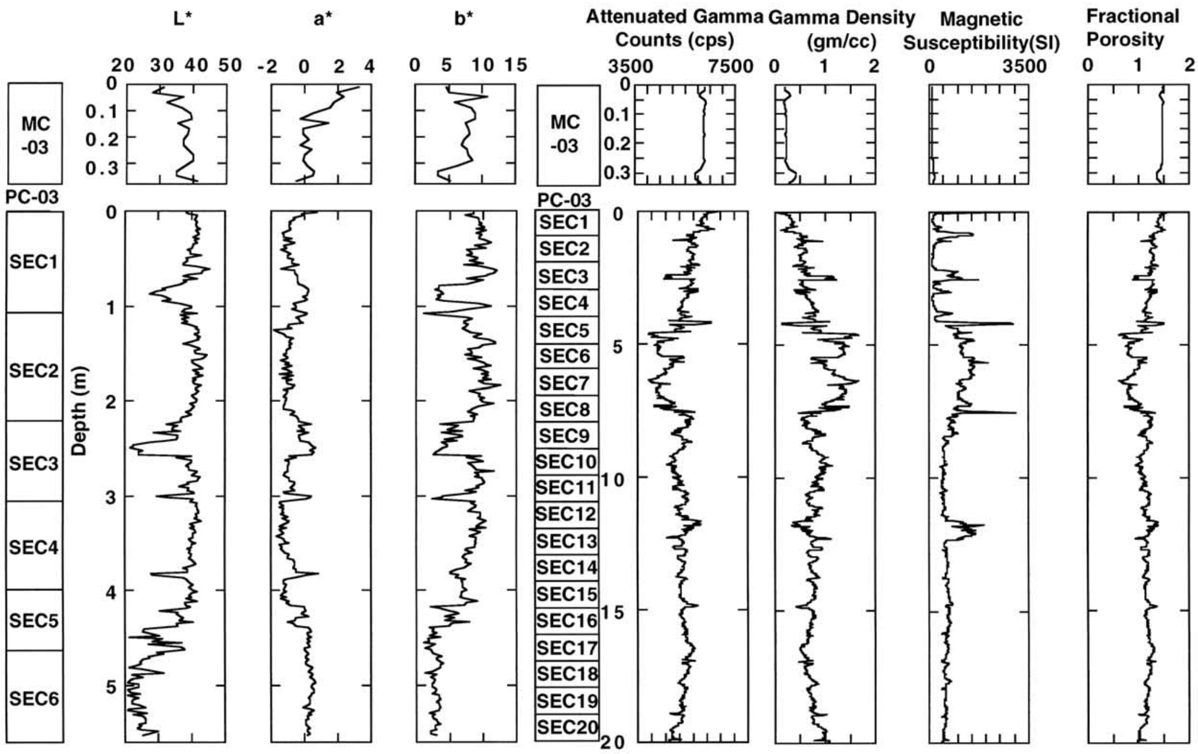

Fig. 5 Vertical distribution of gamma density, magnetic susceptibility, L*, a*, and b* of MC-03 and PC-03 cores.

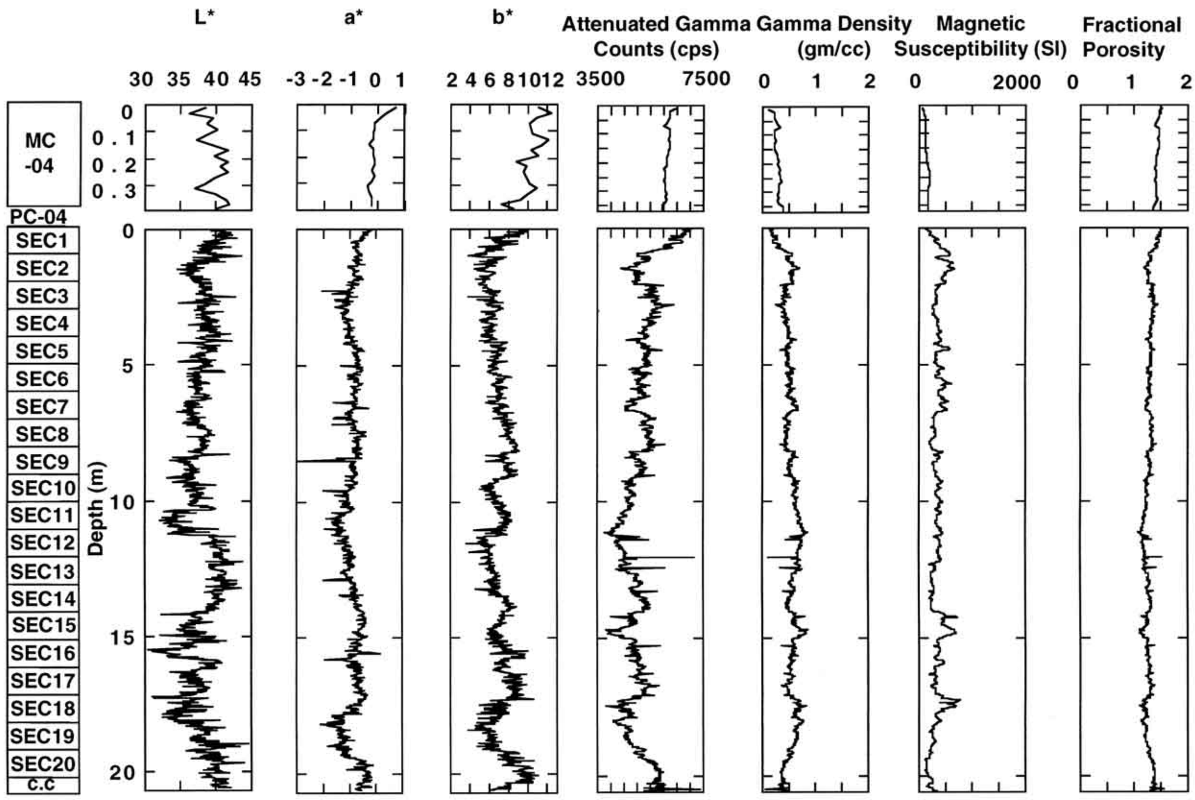

Fig. 6 Vertical distribution of gamma density, magnetic susceptibility, L*, a*, and b* of MC-04 and PC-04 cores.

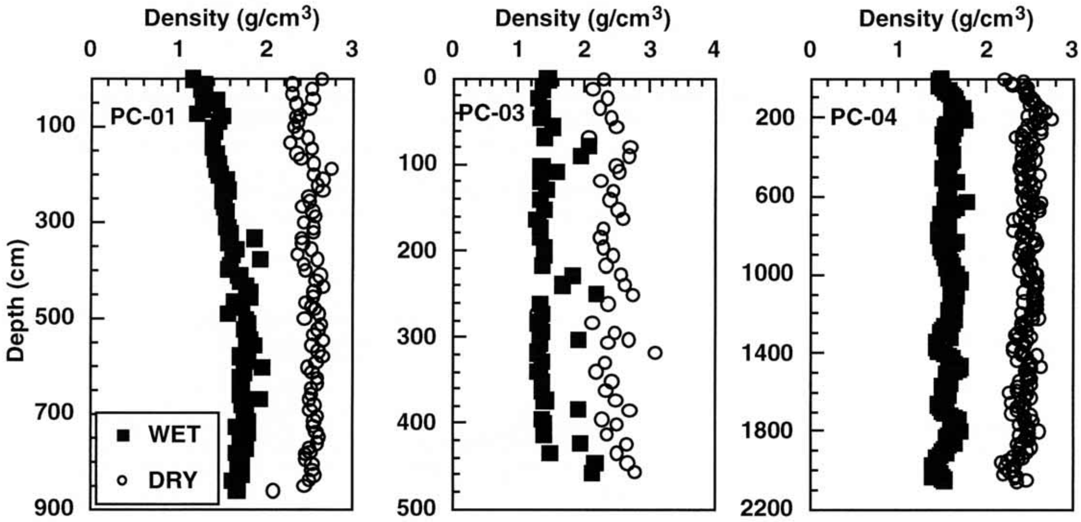

Fig. 7 Vertical profiles of wet and dry bulk densities of PC-01, 03 and 04 cores.