— Report —

Geologic ages and magnetic fabrics of deep-sea sediments in the Sagami Trough, central Japan

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This paper describes in detail the deep-sea sediments along the Sagami Trough, which is an active subduction margin, mostly from the base of cliffs or knolls in the northern Sagami Bay area. Using Japan Agency for Marine Science and Technology (JAMSTEC) research vessels, we recovered 16 piston- and gravity-core samples of < 4 m in length. Six samples were collected from the knolls, four from the trough floor, and six from the landward trench slope. We determined the geologic ages using ^{14}C and tephra analyses, and the magnetic fabrics using paleomagnetism and anisotropy of magnetic susceptibility (AMS). The average sedimentation rates are ~1 cm/kyr on the upper terrace of the Sagami Knoll, 4–61 cm/kyr on the trough floor, and 40–79 cm/kyr on the landward trench slope. The main direction of magnetic particle arrangement (K_{max}) is largely constant in the upslope direction at the foot of Sagami Knoll, the Sagami Trough floor, and the landward trench slopes; in contrast, K_{max} is in the downslope direction in the upper terrace of Sagami Knoll.

Keywords : turbidite, Sagami Trough, anisotropy of magnetic susceptibility, tephra, average sedimentation rate

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1. Introduction

The Kanto region of Japan, which houses the capital, Tokyo, is one of the largest metropolitan areas in the world. The area is the central district of Japan in terms of politics, economy, and industry, and has experienced repeated great earthquakes at approximately 100-year intervals (e.g. Lallemand et al., 1996; Shishikura, 2003, 2014). These large earthquakes are closely related to the unique tectonic setting of the southeastern Kanto region, which is a trench–trench–trench type triple junction involving three oceanic plates (Ogawa et al., 2008). The Philippine Sea plate is subducting obliquely to the NW at a rate of ~3 cm/yr beneath the North America plate (on which Tokyo is located), and the Pacific plate is subducting to the west beneath these two plates at a rate of 9 cm/yr (Seno et al., 1989; Fig. 1A). This arrangement indicates that the subduction system produces a double-decker plate-boundary-type earthquake zone (e.g. Toda et al., 2008).

The pioneering studies of the Japanese–French KAIKO projects during the 1980s obtained many seismic images, bathymetric maps, and submersible observation data around the Sagami Trough subduction zone in Sagami Bay and off the Boso Peninsula (e.g. Nakamura et al., 1987; Pautot et al., 1987; Seno et al., 1989; Ogawa et al., 1989; Fig. 1B and C). Soh et al. (1988, 1990) described the morphology of the Awa and Boso canyons, and the Mogi fan (Fig. 1B) using detailed bathymetric data to verify the occurrence of rapid deformation on the subduction boundary. In addition, Lallemand et al. (1996), Ogawa et al. (2008), and Ogawa and Yanagisawa (2011) discussed the tectonic development of these areas and demonstrated that sedimentation and collapse of the slope occur along the subduction zone. They elucidated the sedimentary system of turbidity currents from Sagami Bay to the Mogi fan since the middle Miocene, and stated that sedimentation is likely to be controlled by both sea level change and crustal deformation along the subduction zone. Thus, these projects have outlined the sedimentation process along the Sagami Trough, but additional sediment cores are needed in this area to enable a specific and systematic discussion of the relationship between tectonics and sedimentation.

The recurrence interval of large earthquakes in this region has been investigated mainly using coastal terraces on land in the south Boso and Miura peninsulas, which have been uplifted repeatedly by subduction-type large

earthquakes over the past 7000 years (e.g. Shishikura, 2003, 2014). These earthquakes may also be recorded in marine sediments as seismo-turbidites (e.g. Ikehara, 2001), but it is difficult to determine whether a given deposit is a seismo-turbidite related to seismic movement or another type of deposit formed as a result of other geological processes. It is not always possible to identify explicitly paleo-earthquake records (e.g. seismo-turbidites) from deep-sea sediments.

In this study, we collected 14 piston core samples (PC in Fig. 2) and two gravity core samples (GC in Fig. 2) from Sagami Bay and off the Boso Peninsula, particularly from the trench (trough-slope) cliffs and basins, and the trough floor itself (Figs. 1 and 2). Bathymetric surveys were conducted alongside coring operations during recent several research cruises. We also analyzed the magnetic fabrics of these samples to determine their magnetic properties.

Determining the recurrence intervals of paleo-seismicity is a significant task for earth scientists in order to understand the history of hazardous earthquakes. Such intervals could be determined by conducting ^{14}C dating and dating tephra (volcanic glass) layers from cores. The sediment transport process in the deep sea provides clues to the nature of paleo-seismicity, if it were possible to identify sediments deposited as a result of earthquake shaking. Thus, it is necessary to analyze basin-filling processes to understand paleo-seismicity.

2. Description of cores

Core sediments were collected during four cruises; cruise KY07-14 by the R/V *Kaiyo* from 14 to 26 Nov. 2007; KR09-10 by the R/V *Kairei* from 10 to 20 Jun. 2009; KT-10-10 by the R/V *Tansei-maru* from 14 to 20 Jun. 2010; and KT-12-35 by the R/V *Tansei-maru* from 23 to 27 Dec. 2012 (Figs. 2 and 3; Table 1). In these cruises, piston-corer (PC) and gravity-corer (GC) systems were used. The outer barrels of the PC and GC were 8 and 20 cm in diameter, respectively.

2.1 Sagami Bay area

In Sagami Bay, we recovered 11 core samples from knolls as follows (Fig. 2 upper and lower left side; Table 1).

KY07-14 PC03 and GC01 were collected from the foot of a southern slope of the Sagami Knoll (Fig. 5). KY07-14 PC01 and GC02 were collected from the foot of

Fig. 1. **A:** Location of the study area. The plate convergence directions are indicated by black arrows. The names of the trenches in this figure are Kuril Trench (Kuril T.), Japan Trench (Japan T.), Izu-Bonin Trench (Izu-Bonin T.), Nankai Trough (Nankai T.) and Ryukyu Trench (Ryukyu T.). In the Sagami Trough, the Philippine Sea plate is subducting to the northwest at a rate of ~2.5 cm/yr (Seno et al., 1989). The subduction is generally parallel to the axis of the Sagami Trough.

B: Bathymetric map of the study area. Solid squares mark the locations of Figures 6–8. The dotted areas indicate deep-sea basins and fan as shown by Ogawa et al. (1989). Red, blue, and green lines are respectively thrust or fault lineaments, normal faults, and fold axes as illustrated by Ogawa et al. (2008) in the Sagami Basin area and by Nakamura et al. (1987) in the Middle Sagami Trough Basin area.

an eastern slope of the knoll (Fig. 6). Whole cores were sampled by the Center for Deep Earth Exploration (CDEX)

Table 1. Coring sites and core lengths. Lat. = Latitude, Lon. = Longitude, WD = Water depth, CL = Core length.

Cruise	Site	Lat. (N)	Lon. (E)	WD (m)	CL (cm)
KY07-14	PC01	35°05.91'	139°21.45'	1044	279
KY07-14	PC02	34°53.47'	139°15.89'	1212	94
KY07-14	PC03	35°09.22'	139°26.17'	908	252
KY07-14	PC04	34°49.11'	140°03.20'	2107	172
KY07-14	GC01	35°09.45'	139°26.32'	930	240
KY07-14	GC02	35°05.79'	139°21.49'	1059	212
KR09-10	PC01	34°42.56'	140°28.79'	2053	134
KR09-10	PC02	35°02.58'	140°48.55'	1186	215
KR09-10	PC03	34°42.21'	141°25.65'	4250	335
KT-10-10	PC-1	35°07.51'	139°20.51'	750	216
KT-10-10	PC-2	35°05.47'	139°25.53'	1000	194.5
KT-10-10	PC-3	35°07.16'	139°21.00'	790	225.5
KT-10-10	PC-4	35°04.43'	139°20.90'	1490	227
KT-12-35	PC01	35°04.01'	139°12.99'	991	159.5
KT-12-35	PC02	34°37.50'	140°01.25'	2449	248
KT-12-35	PC03	34°58.30'	139°13.40'	1235	293.5

of JAMSTEC as follows: PC03 at 120–150 and 215–245 cm from the sediment surface, GC01 at 190–220 cm, PC01 at 78–108 and 178–208 cm, and GC02 at 168–186 cm (Figs. 2 and 3). The whole cores were sampled for physical and mechanical properties.

KY07-14 PC03, which is 252 cm long, and GC01, which is 240 cm long, are composed of predominantly olive-black (7.5Y3/2) bioturbated silty clay containing foraminifers and scoria particles. There is a laminated silt layer at 156.4–157.4 cm in PC03 and very coarse scoria layers at 10–16 and 22.5–25.5 cm in GC01 (Figs. 2 and 3).

KY07-14 PC01 (279 cm long) and GC02 (212 cm long) are of similar lithofacies to PC03 and GC01, but contain many fine-medium scoriaceous sand layers at 20–21, 30–30.5, 50–51, 75–76, 130–135, 213–220, and 240–241 cm in PC01, and at 10–12, 93.5–94.0, 101.5–103, 113.5–117.5, 117.5–119.5, 121.5–125.5, 133.5–137.5,

Fig. 1. (Continued) C: Seismic profiles of Line A (the Sagami Basin area), Line B (the So-oh Trough area) and Line C (the Middle Sagami Trough Basin area). Line A is the seismic profile in Kato et al. (1983) with the interpretation as shown in Ogawa et al. (2008); lines B and C are from Nakamura et al. (1987). Seismic sequences A, B, and C in Lines B and C are 0–1.0, 1.0–3.5, and >3.5 Ma, respectively.

Fig. 2. Profiles of lithology and volumetric magnetic susceptibility (10^{-3} SI units) of cores collected from Sagami Bay (upper and lower left side) and off-Boso (lower right side) areas. PC = piston core; GC = gravity core. Whole cores were sampled by the Center for Deep Earth Exploration (CDEX) of JAMSTEC.

Fig. 3. Photographs of core sediments. The rulers are marked in cm.

143.5–145.5, 151.5–152.5, and 161.5–163.5 cm in GC02 (Figs. 2 and 3).

KT-10-10 PC01 and PC03 were collected from the upper terrace of the Sagami Knoll, and KT-10-10 PC02 was recovered from the Miura Knoll (Fig. 6). PC01 and PC03 are composed of predominantly olive-black (10Y3/2) bioturbated sandy clay. There are fine–medium scoriaceous sand layers at 20–22, 40–42, 60–62, and 78–80 cm, a fine–coarse graded scoriaceous sand layer at 143–216 cm in PC01, and fine–medium scoriaceous sand layers at 19–20, 98–99, 100–101, 110–111, 118–119, 121–122, 143–145, 177–178, 189–190, and 220–225.5 cm in PC03. KT-10-10 PC02 is olive-black (10Y3/2) silty clay with a fine sand layer at 143–144 cm (Figs. 2 and 3).

We recovered three core samples from the Sagami Trough floor: KY07-14 PC02, KT-12-35 PC01, and PC03 were collected from the western trough floor (Fig. 6). KY07-14 PC02 was bent and substantially deformed during the coring operation. We observed flow-in structures in the bottom 20 cm and therefore we could not reconstruct the original sedimentary sequence with certainty, but we infer the core to have been composed of black (2.5GY2/1) very

fine to medium sand that contains foraminifers (Figs. 2 and 3).

KT-12-35 PC01 is composed of silty clay with nannofossils. This core is interbedded with scoriaceous fine sand layers at 89.5–90.5 and 101.5–106.5 cm. PC03 is composed of silty clay with nannofossils interbedded with scoriaceous fine sand layers bearing foraminifers at 11–13, 36–38, 83–84, 123–128, 175–176, 198–198.5, 213–214, 231–235, and 289–293.5 cm, and a volcanic ash layer at 99–105 cm. We observed sporadic scoriaceous sandy clay bands of a few centimeters thickness throughout the cores (Fig. 2). These bands probably originated from Fuji or other volcanoes in the Izu Island Arc, as discussed below.

KT-10-10 PC04 was recovered from the Sagami Trough floor at the foot of the Sagami Knoll (Fig. 5). This core is composed of predominantly olive-black (10Y3/2) silt interbedded with a black (10Y2/1) very fine sand layer at 66–72 cm and black coarse sand layers at 164–175, 179–183, 188–189, 194–195, 202–203, and 221–222 cm (Figs. 2 and 3).

2.2 Area off the Boso Peninsula

From the off-Boso area, we recovered five core samples during cruises KY07-14, KR09-10, and KT-12-35 (Fig. 2 lower right side; Table 1).

KY07-14 PC04 was collected from a gentle slope at the foot of the Kamogawa Submarine Cliff, off the Boso Peninsula (Fig. 7). This core was bent and substantially deformed during the coring operation; thus, we could not reconstruct the original sedimentary sequence with certainty, but we assume that this core was composed of silty clay interbedded with scoriaceous sand layers containing small amounts of coral fragments at 8–21, 62–66, 83.2–87.2, and 99–172 cm (Fig. 2). The whole core at 32–62 cm was sampled by the CDEX of JAMSTEC (Figs. 2 and 3).

KR09-10 PC01, PC02, and PC03 were collected from gentle landward trench slopes (Fig. 8). PC01 is located at the western foot of the Dai-san Chikura knoll in the northern part of the Boso canyon. This core, which is 134 cm long, is composed mainly of olive-black (10Y3/2) nannofossil-bearing sandy to silty clay with diatoms. This sediment is well-bioturbated. A volcanic ash layer that is grayish-olive (7.5Y4/2) to gray (7.5Y5/2) in color is present at 74–82 cm: this layer grades from pumice to ash (Figs. 2 and 3).

KR09-10 PC02 was obtained from the southern

Fig. 4. Rates calculated for cores from tephra layers and ^{14}C analyses. The average sedimentation rate of KT-10-10 PC01 is ~1 cm/kyr from 0 to 30 cm, and ~17 cm/kyr from 30 to 146 cm depth. The average sedimentation rates of KT-12-35 PC01 and PC03 are calculated to be ~61 cm/kyr and ~4 cm/kyr, respectively. The average sedimentation rates of KR09-10 PC01, PC02, and PC03 are ~79, ~41, and ~65 cm/kyr, respectively.

Fig. 5. Washed samples for tephra analyses. A: KR09-10 PC01 74–82 cm depth, B: KR09-10 PC02 48–53 cm, C: KR09-10 PC02 126–127 cm, D: KR09-10 PC02 152–154 cm, E: KR09-10 PC02 170–175 cm, F: KR09-10 PC03 73–77 cm, G: KR09-10 PC03 170–174 cm, H: KR09-10 PC03 255–257 cm. The grids in the photographs are marked in 1-mm squares.

foot of the coastal area off Katsuura (Fig. 8). The core, which is 215 cm long, is composed mainly of olive-black bioturbated nannofossil-bearing sandy-silty clay with diatoms. A grayish-olive volcanic ash layer is observed at 48–53 cm and a gray volcanic ash at 126–127 cm. Black (10Y2/1) scoriaceous graded sand layers occur at 152–154,

170–175, and 177–178 cm. Faint sandy laminae are visible at 188–209 cm (Figs. 2 and 3).

KR09-10 PC03 was collected from the landward slope east of the Katakai Canyon (Fig. 7). The 335-cm-long core is composed of dominantly well-bioturbated, olive-black sandy-silty clay with diatoms. A nannofossil-rich pale

Fig. 6. Bathymetric map of the Sagami Basin area from the dataset compiled by Izumi et al. (2013). Solid stars mark coring sites. Gray lines represent faults and thicker gray lines crossing gray arrows denote anticlines (after Ogawa et al., 2008). Black arrows indicate presumed bottom-current directions. Lower-hemisphere stereographic projections show the AMS results. Squares, triangles and circles denote $K_{\max}$, K_{int} , and $K_{\min}$, respectively. The orange-colored rose diagrams overlain on the stereographic projections show the $K_{\max}$ direction, which is the dominant direction of alignment of the long axis of magnetic susceptibility. The magnetic susceptibility and AMS values are illustrated in the present north reference frame.

band occurs at 55–170 cm. A grayish-olive ash layer is present at 73–77 cm, and a grayish-olive pumiceous layer at 170–174 cm. Black scoriaceous sand layers are present at 77–80, 255–257, 283–288, and 312–313 cm (Figs. 2 and 3).

KT-12-35 PC02 is located upstream of the Awa Canyon (Fig. 7). The core, which is 248 cm long, is composed of olive-black (10Y3/2) silty clay. Burrows (a few centimeters in diameter) filled with fine to medium sand are disseminated throughout the core (Figs. 2 and 3).

3. Methods

3.1 ^{14}C age determination

We picked up shell samples from KT-10-10 PC01 and plant material and wood samples from KT-12-35 PC01 and PC03 for the ^{14}C age determinations. The ^{14}C dating has done at Beta Analytic Inc. They used accelerator mass spectrometry (AMS) technology, which gives the most accuracy for ^{14}C measurements.

For analyses of KT-10-10 PC01, they used acid-alkali-acid cleaning for the sample preparation, and determined the geologic age using Marine04 for the calibration issue. Depending on the age of the marine carbonate, a 200– to 500-year correction (i.e. global marine reservoir correction) is applied automatically for these marine carbonate samples (Beta Analytic Inc., 2016). This automatic correction means the radiocarbon date gets more recent in time due to the fact that it takes 200–500 years for present-day carbon dioxide in the atmosphere to be incorporated and distributed (equilibrated) through the ocean water column (Beta Analytic Inc., 2016).

For analyses of KT-12-35 PC01 and PC03, they used acid etching for the sample preparation, and determined the geologic age using Intcal09 for the calibration issue.

3.2 Tephra analyses

For the purpose of identification of time-marker tephras, we analyzed the refractive indices of some pumiceous deposits and deposits consisting of fine volcanic

Fig. 7. Bathymetric map of the off-Boso area. Solid stars indicate coring sites. Gray lines with triangles are thrust faults, gray broken lines are presumed faults, and gray arcuate lines are landslide scars (after Nakamura et al., 1987). Arrows show presumed bottom-current directions. The lower-hemisphere stereographic projection shows the AMS results. Squares, triangles, and circles denote $K_{\max}$, K_{int} , and $K_{\min}$, respectively. The rose diagram overlain on the stereographic projection shows the $K_{\max}$ direction. The magnetic susceptibility and AMS values are illustrated in the present north reference frame.

glass. Samples were washed in the laboratory, and volcanic glass shards and orthopyroxene and hornblende phenocrysts were gathered by hand-picking. Heavy minerals were crushed using an agate mortar to facilitate observation. These particles were enclosed within a glass cell with immersion oil. We measured the refraction indices of volcanic glass shards using a Refractive Index Measurement

System (RIMS 2000; Kyoto Fission-Track; Danhara, 1991). More than 30 glass shards were measured for each sample.

The tephra layers of KT-12-35 PC03 were analyzed by Palyno Survey as follows. The grains were washed using a 63- μm sieve to remove clay. At least 200 grains per sample were selected using a polarized microscope, after which the shapes of the glass shards were classified further

Fig. 8. Bathymetric map of the off-Boso area. The dataset was provided by JHOD-Japan Coast Guard and JAMSTEC (2011). Solid stars mark coring sites. Gray lines with triangles denote thrust faults, gray broken lines indicate presumed faults, and gray arcuate lines denote landslide scars (after Nakamura et al., 1987). Arrows indicate presumed bottom-current directions. The lower-hemisphere stereographic projections show the AMS results. Squares, triangles, and circles are $K_{\max}$, K_{int} , and K_{min} , respectively. The rose diagrams overlain on the stereographic projections show the $K_{\max}$ direction. The magnetic susceptibility and AMS values are illustrated in the present north reference frame.

following Yoshikawa (1976). Heavy minerals were separated using heavy liquid SPT (density 2.9 g/mL). The refractive indices of the glass shards were measured using a Refractive Index Measurement System (MAITO; Furusawa Geological Survey). More than 30 glass shards were measured per sample.

3.3 Magnetic fabric analyses

To obtain an indication of the sedimentary fabric, we measured the anisotropy of magnetic susceptibility (AMS) using the AGICO KLY-4S anisotropy magnetic susceptometer. Test specimens were encased in plastic cubes with a volume of 7 cm³. The obtained AMS values are represented by magnetic ellipsoids of which the maximum, intermediate, and minimum axes are denoted by $K_{\max} > K_{\text{int}} > K_{\min}$. In general, the magnetic ellipsoid indicates the degree of alignment of magnetic particles in sediment; i.e. the magnetic fabric (Tarling and Hrouda, 1993).

To measure the paleomagnetism we used a superconductive magnetometer (2G-Enterprises, CA, USA). We carried out step-wise alternating field demagnetization during the paleomagnetism measurements. Because the declination data are shifted gradually downward due to twisting during coring, magnetic north should be corrected accordingly by the least-square method to reconstruct the *in situ* north direction of the core.

4. Results

4.1 ¹⁴C and Tephra analyses, and calculated average sedimentation rates

4.1.1 KT-10-10 PC01

We measured the ¹⁴C ages of shells from three horizons in KT-10-10 PC01, as shown in Fig. 2 and Table 2. The age of the top of this core is estimated as ~22,000 cal. yr BP from ¹⁴C analysis of shells.

We detected a tephra layer (consisting of mainly

bubble-wall-type glass shards with a refractive index of 1.498–1.501) with an Aira-Tn (AT) of 30,009 ± 189 cal. yr BP (Smith et al., 2013) at 80 cm deep. Based on the four measurement results from the tephra layer and ¹⁴C analyses, we calculated the average sedimentation rate to be ~1 cm/kyr from 0 to 30 cm, and ~17 cm/kyr from 30 to 146 cm depth (Fig. 4).

4.1.2 KT-12-35 PC01 and PC03

We performed ¹⁴C age determinations of plant fragments at 136.5 cm in PC01 and a piece of wood at 172.5 cm in PC03 (Fig. 2; Table 2), yielding ages of 30,820 ± 210 and 2,850 ± 30 cal. yr BP, respectively (Table 2).

We detected two volcanic ash layers for age determination at 11.5–13.0 cm and 94.5–101.5 cm in PC03 (Figs. 2 and 3). These layers are correlated with the AD 1707 Fuji Hoei eruption and the AD 838 eruption at Kozushima Island, respectively, based on the particle morphologies and their stratigraphic position (Fig. 2; Table 3). On the basis of the three measurement results from the tephra layer and ¹⁴C analyses, the average sedimentation rate of KT-12-35 PC03 is calculated to be ~61 cm/kyr (Fig. 4).

The average sedimentation rate of KT-12-35 PC01 is calculated to be ~4 cm/kyr on the basis of the ¹⁴C analysis (Fig. 4).

4.1.3 KR09-10 PC01 to PC03

KR09-10 PC01 contains a volcanic ash layer at 74–82 cm depth. This layer is composed of rhyolitic pumice (max. ~1 mm) and fibrous volcanic glass shards with quartz, mica, and plagioclase phenocrysts (Fig. 5A). The refractive index of the volcanic glass is 1.495–1.498.

KR09-10 PC02 contains volcanic ash layers at 48–53 and 126–127 cm depth. The layer at 48–53 cm is composed of white pumice (max. ~1 mm) and fibrous volcanic glass shards with orthopyroxene, quartz, and plagioclase phenocrysts (Fig. 5B). The refractive index is 1.495–1.498. The layer at 126–127 cm is composed of

Table 2. Results of ¹⁴C age determinations. The measured radiocarbon ages are calculated simply as the BP year (from AD 1950) using ¹⁴C/¹²C data. We use conventional radiocarbon ages for the ¹⁴C age determination.

Cruise	Core	Depth	Sample	Measured radiocarbon age	Conventional radiocarbon age
KT-10-10	PC01	30 cm	shell	23590 ± 90 cal. yr BP	24030 ± 90 cal. yr BP
KT-10-10	PC01	104 cm	shell	28070 ± 120 cal. yr BP	28510 ± 120 cal. yr BP
KT-10-10	PC01	146 cm	shell	30320 ± 140 cal. yr BP	30740 ± 140 cal. yr BP
KT-12-35	PC01	136.5 cm	plant fragments	30780 ± 210 cal. yr BP	30820 ± 210 cal. yr BP
KT-12-35	PC03	172.5 cm	piece of wood	2810 ± 30 cal. yr BP	2850 ± 30 cal. yr BP

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fibrous volcanic glass shards and a small amount of bubble-wall-type volcanic glass shards with mica, quartz, and plagioclase phenocrysts (Fig. 5C). The refractive index of the shards is 1.494–1.498.

KR09-10 PC03 contains volcanic ash layers at 73–77 and 170–174 cm depth. The layer at 73–77 cm is composed of black scoria (max. ~0.5 mm) and fibrous, sponge-type and bubble-wall-type volcanic glass (Fig. 5F). The refractive index is 1.497–1.499. The layer at 170–174 cm is composed of gray-white pumice (max. grain size ~4 mm) and vesicular volcanic glass shards with clinopyroxene, orthopyroxene, and plagioclase phenocrysts (Fig. 5G). The refractive index of the shards is 1.510–1.520.

In these three core samples, we identified a volcanic ash layer (consisting of fibrous volcanic glass shards with refractive indices of 1.495–1.499) that indicate this layer was produced by the AD 838 eruption of Kozushima Volcano or the AD 886 eruption of Nijima Volcano (Fig. 2), both of which are located in the Izu island arc (Fig. 1).

Based on the tephra analyses, the average

sedimentation rates of KR09-10 PC01, PC02, and PC03 are ~79, ~41, and ~65 cm/kyr, respectively (Fig. 4).

4.2 Magnetic fabrics

We used the paleomagnetic north directions in each core under 200 G AF demagnetization conditions, because these directions are mostly stable. We corrected the $K_{\max}$ directions of the AMS using the paleomagnetic north in each core following the method of Kawamura et al. (2002). The corrected data, magnetic susceptibilities, and AMS data for each core are illustrated in Figs. 6–8 in the present north reference frame. Most of the magnetic susceptibility values in all cores are between 0.1×10^{-3} and 1.5×10^{-3} SI units. There are sharp peaks of $\sim 2.0 - 3.0 \times 10^{-3}$ SI units at ash layers in KR09-10 PC02 and PC03 (Fig. 2).

The corrected $K_{\max}$ directions show some consistency, as demonstrated by the rose diagrams in Figs. 6–8. For eight of the cores the directions are mostly constant, either to the west (KY07-14 GC01, and KR09-10 PC01 and PC03), to the north (KY07-14 PC03, KY07-14 GC02, and KT-10-10 PC04), or to the south (KT-10-10 PC01 and PC03).

5. Concluding remarks

We recovered 16 piston and gravity core samples of <4 m long from the Sagami Trough. Six samples were collected from knolls, four from the trough floor, and six from the landward trench slope.

On the basis of ^{14}C and tephra analyses, average sedimentation rates are calculated to be ~1 cm/kyr at the upper terrace of the Sagami Knoll, 4–61 cm/kyr in the Sagami Basin, and 40–79 cm/kyr in the off-Boso area.

The $K_{\max}$ direction of the anisotropy of magnetic susceptibility, as inferred from the orientation of magnetic particles, is mostly constant to the west (cores KY07-14 GC01, and KR09-10 PC01 and PC03), north (cores KY07-14 PC03, KY07-14 GC02, and KT-10-10 PC04), or south (cores KT-10-10 PC01 and PC03). These $K_{\max}$ directions are in the upslope direction at the foot of the Sagami Knoll, the Sagami Trough floor, and the landward trench slopes, and in the downslope direction on the upper terrace of the Sagami Knoll.

We think that a small basin on foot of the Kamogawa Submarine Cliff (Fig. 7) is one of the important

targets to study the paleo-seismicity in this study area. This basin is located on a small terrace being a high level from the trough floor. Around this basin, there are no submarine channels connecting directly into rivers. In addition, by considering the bathymetric map in the coring site that shows clear submarine arcuate-shaped scars for slide deposits to the terrace floor, it is suggested that the coarse scoriaceous and coral sand layers of KY07-14 PC04 should be supplied from the Kamogawa Submarine Cliff (Fig. 7). These topographical features indicate that this basin could be deposited with slope collapse sediments without flood sediments. Seismo turbidites and/or submarine landslides might deposit repeatedly in this basin with large earthquakes. We will further survey to provide good data of scientific drilling projects for subduction processes in much longer period in the future.

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