Earthquake Accompanied by Mudflow Observed by a Cabled Observatory off Hatsushima Island in Sagami Bay in April 2006

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Abstract – **Mudflow associated with an earthquake of magnitude 5.5 was detected with a cabled observatory on deep seafloor off Hatsushima Island in Sagami Bay in April 2006. Environmental fluctuations associated with the mudflow were observed. Water current 12m above the seafloor observed by ADCP was 27 cm/s at maximum and several millimeter sedimentation was recognized by video images. The fluctuation of electric potential difference between submarine cable ends indicates motional induction caused by the mudflow on the slope west of the observatory.**

I. INTRODUCTION

Since 1993, multi-disciplinary long term and real time observation on deep seafloor at a depth of 1175 m by a cabled observatory has been carried out in Sagami Bay, central Japan [1],[2],[3]. The place where the observatory is located is known as a cold seepage site that feeds one of the largest chemo-synthetic biological communities in Japan, which is mainly consisted of Vesicomyid clams (*Calyptogena*). In addition, the observatory faces the swarm earthquake area (Fig. 1) where swarm earthquakes have occurred almost every year until 1998. The aim of the observatory is to investigate the environmental fluctuation or phenomena of the cold seepage related to the swarm earthquakes and associated crustal deformation through long-term multi-disciplinary observation. For that purpose, the observatory is equipped with several kinds of sensors; two video cameras, a seismometer, a hydrophone, a CTD (Conductovity, Temperature and Depth of sea water) sensor, an ADCP (Acoustic Doppler Current Profiler) and so on.

Meanwhile, on April 21st in 2006, an earthquake of magnitude 5.8 (JMA scale) was occurred about 7 km apart from the observatory in the swarm earthquake area. The earthquake accompanied mudflow. Although swarm earthquakes have occurred repeatedly in that area, it was since 1998 that an earthquake as large as M 5 occurred. Mudflows associated with earthquakes were also observed in 1997 and in 1998. However, the observatory was replaced in 2000 and some of the installed sensors at those times were different from the present ones.

This paper shows a mudflow and associated environmental phenomena observed by the observatory that was accompanied by the earthquake on April 21st in 2006.

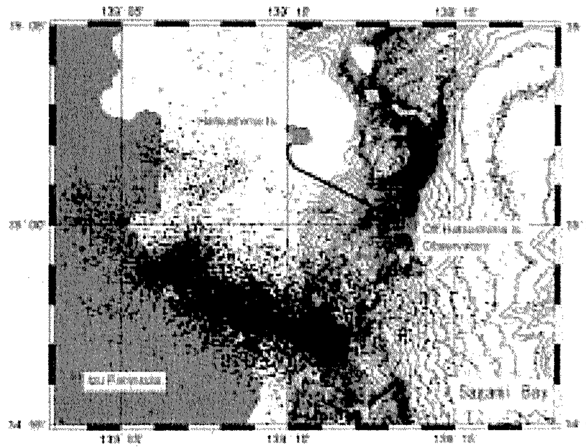

Fig. 1. Location of "off Hatsushima Island observatory" (red dot) and cable route.
Small dots are the epicenters of swarm earthquakes occurred during 1989-1999 (after JMA, Japan Meteorological Agency) and a blue dot is the epicenter of the earthquake occurred on April 21st in 2006 that triggered mudflow.

II. OBSERVATION OF MUDFLOW

A. Visual Observation

The earthquake of magnitude 5.8 (JMA scale) that triggered mudflow occurred at 02:50 JST on April 21st in 2006 about 7 km south of the observatory, where was the eastern edge of the swarm earthquake area east off Izu Peninsula in Sagami Bay (Fig. 1).

At this time, the observation was carried out by two video cameras, a seismometer, a hydrophone, a CTD sensor, a transmissometer, an ADCP and a gamma ray

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sensor. Electric potential difference between the underwater cable ends (between the observatory and the land station in Hatsushima Island which are about 8 km apart) was also observed.

Two video cameras attached to the present observatory are 3CCD camera and Super HARP (High-gain Avalanche Rushing Photoconductor) camera. The latter is far more sensitive than a CCD camera [4].

Usually the shore station on Hatsushima Island is uninhabited and daily visual monitoring of seafloor is performed automatically twice a day - at midnight and at noon - for 13 minutes at each time i.e. totally 26 minutes a day. The video images are recorded on DVCAM videotapes and they are replaced once a week when manual observation is performed. Although the mudflow on April 21st did not occurred within the automatic recording time, fortunately, besides automatic recording on DVCAM videotape, the video images are also recorded on S-VHS videotape continuously until 03:15 JST. Unfortunately, however, since the videotape had run out at 03:15 JST, the motion video image after that time does not exist. Instead, a certain amount of manually captured still images, which were remotely controlled through the terminal at Yokohama Institute of JAMSTEC, were obtained after the videotape had run out.

Fig. 2. Video image from the observatory at 02:53 JST on April 21st 2006, after the earthquake had occurred and just before the mudflow came in.

Fig. 3. Video image from the observatory at 02:55 JST, about one minute after the mudflow had come in

Fig. 4. Video image from the observatory at 02:57 JST, about 3 minutes after the mudflow had come in. The sight was covered with mud and became dark.

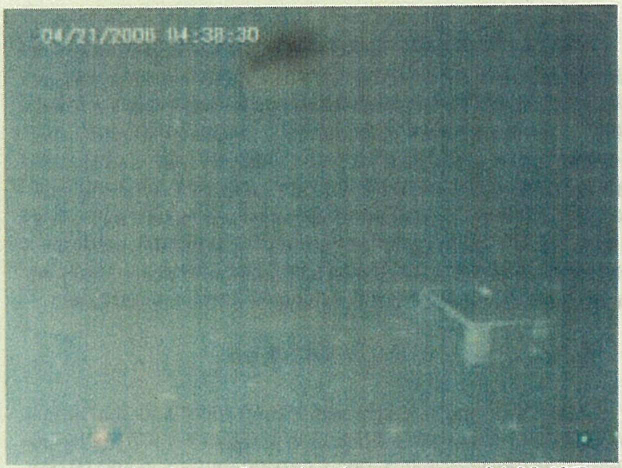

Fig. 5. Video image from the observatory at 04:38 JST, about one and half hours after the mudflow had come in. Hydrophone was moved from right-hand side.

Fig. 6. 3CCD video image of the bottom frame of the observatory at 00:34 JST, before the earthquake and the mudflow occurred.

Video images showed that the mudflow arrived at 02:54 JST, about 4 minutes later than the occurrence of the earthquake (Fig. 2, Fig. 3). A few minutes after mudflow came in, the sight was covered with mud and became dark (Fig. 4). The mudflow continued more than one hour and it was about one and half hours after the mud flow had came in that the seafloor could be seen again(Fig. 5). It turned out that a hydrophone, which was deployed on the seafloor, was moved a few meters by the mudflow.

Fig. 7. 3CCD video image of the bottom frame of the observatory at 04:49 JST, after the mudflow passed by. The frame was covered with sediment.

After the mudflow passed by, several millimeter sedimentation was recognized by video images. Both Fig. 6 and Fig. 7 show the images of the bottom frame of the observatory which were viewed by the 3CCD video camera of the observatory which had tilt control. Fig. 6 and Fig. 7 are the images before and after the mudflow occurred respectively. It turned out that the frame was covered with sediment after the mudflow passed by.

In addition, acoustic signal observed by a hydrophone was recorded on the sound track of the videotape and possibly the sound of falling pebbles on slope associated with the mudflow could be heard, though a lot of electric noises were mixed regrettably.

B. Environmental Fluctuations Associated with Mudflow

Besides video images, environmental fluctuations associated with the mudflow were observed by other sensors of the observatory.

Fig. 8 shows the ADCP profile from 02:00 to 05:00 JST on April 21st 2006. It shows that moderate bottom current associated with the mudflow occurred, though it was limited near the seafloor, i.e. up to 30 m high from the seafloor.

Fig. 9 shows the profiles from 02:40 to 04:40 JST on April 21st 2006 of bottom water current (horizontal current velocity and current direction, 12 m in altitude above the seafloor) observed by the ADCP, seismograms (two horizontal components and a vertical component) observed by a seismometer (servo-velocimeter), an electric potential difference between the underwater cable ends i.e. between the observatory and the shore station in Hatsushima Island which are about 8 km apart, light transmission (black curve) observed by a transmissometer, water temperature (red curve), salinity (green curve) observed by the CTD sensor and gamma ray intensity.

Significant change in light transmission observed by the transmissometer occurred at 02:57 JST and horizontal water current velocity reached 27 cm/s at maximum at 03:23 JST. Those data indicate that the mudflow passed from the slope, which is located west of the observatory, to the northeastern direction.

The mudflow continued more than one hour and associated fluctuations were also observed at horizontal components of the seismometer and the water temperature.

The significant increase of about 20 mV in the cable ends electric potential difference occurred at 03:09 JST. It was about 14 minutes earlier than the time of water current velocity peak observed by the ADCP. This increase probably indicates the motional induction caused by the mudflow on the slope west of the observatory.

As for the gamma ray intensity, a step increase was detected. Considering that several millimeter sedimentation was recognized by video images after the mudflow passed by, it corresponds to the inflow of sediments from the slope west of the observatory.

Looking over these profiles, it seems that the accumulation quantity of sediments associated with the mudflow this time was less than those in 1997 and 1998 [5],[6]. It possibly related with the accumulation quantity associated with the spring bloom of plankton on sea surface.

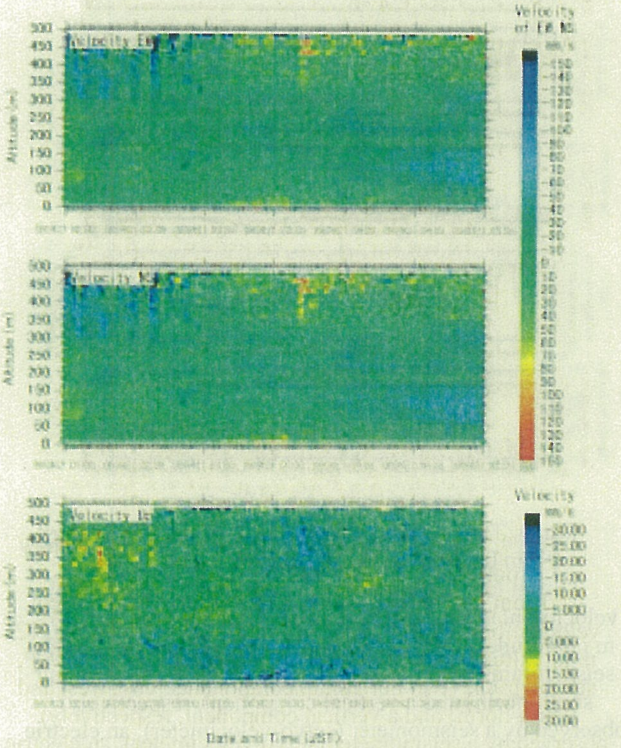

Fig. 8. ADCP profile from 02:00 to 05:00 JST on April 21st 2006.
From top: horizontal water current velocity of east-west component, north-south component and vertical water current. Warmer colors mean east, north and upward faster water currents respectively.

III. CONCLUSIONS

Mudflow triggered by an earthquake was observed by a cabled multi-disciplinary observatory on deep seafloor in Sagami Bay on April 21st 2006. Current velocity observed by ADCP reached 27 cm/s at maximum. The significant increase of about 20 mV in electric potential difference between submarine cable ends probably indicates the motional induction caused by the mudflow on the slope west of the observatory. Step increase of the gamma ray intensity was observed corresponding to several millimeter accumulation of sediments observed by the video camera. The accumulation of sediment associated with the mudflow this time seems to be less than those in 1997 and 1998, possibly related with the accumulation quantity associated with the spring bloom of plankton on sea surface.

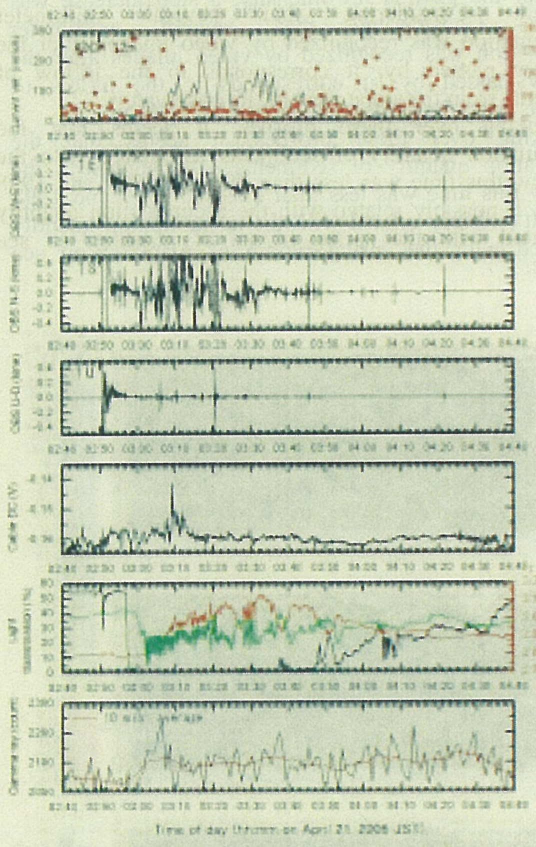

Fig. 9. The profiles of each sensor of the observatory (from 02:40 to 04:40 JST on April 21st 2006). From top: bottom water current (horizontal current velocity [black curve] and current direction [red dots], 12 m in altitude above the seafloor) observed by the ADCP, seismograms (two horizontal components [east-west and south-north] and a vertical component, respectively) observed by a seismometer (servo-velocimeter), an electric potential difference between the underwater cable ends i.e. between the observatory and the shore station in Hatsushima Island which are about 8 km apart, light transmission (black curve) observed by a transmissometer, water temperature (red curve), salinity (green curve) observed by the CTD sensor and gamma ray intensity (black curve shows 1 minute count and red curve shows 10 minute running average).

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