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A seismic survey at the region near the mouth of Fuji River, Shizuoka Pref., Japan

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SUMMARY

It is very important to know the subsurface structure and depositional environment from the coastal to the shallow sea region, when studying groundwater flow. However, when we acquire geophysical survey data, since the data acquisition methods of both land and marine cannot successfully acquire the data at the domain from the coastal to the shallow sea regions, such regions are often left as blank of geophysical surveys. Furthermore, in our country, such domains are generally highly developed and even setting up geophysical survey lines are difficult. Therefore, we are investigating the geophysical survey methods appropriate for the surveys beneath the coastal to the shallow sea region. We are also developing the evaluation methods for such regions. Therefore, we conducted a seismic reflection survey to image the subsurface structure of coastal to the shallow sea region of the mouth of the Fuji River, Shizuoka, Japan where the Fujikawa-kako fault group exists, and checked applicability of the technique. As a result, we obtained subsurface structure down to the 5000 m.

Key words: seismic reflection method, coastal region, shallow sea region, the Fujikawa-kako fault group, blank area of geophysical surveys

INTRODUCTION

We are carrying out a research project for the purpose of understanding groundwater flows under the coastal plains. The project is classified roughly into two parts; groundwater flow simulation and subsurface survey and evaluation techniques. We are in charge of the latter of them and have carried out the research and development for the purpose of gaining the investigation and evaluation techniques of characteristic geological structure and environment at the subsurface of the areas along the shore and the shallow sea. We can point out the survey and evaluation techniques below the coastal seabed using the geophysical exploration as one of the most suitable technologies for the purpose of our research project.

When considering the groundwater flow below the plains which exist in the coastal area, it is very important to know the subsurface structure and depositional environment not only of onshore but also of from the coast to the shallow sea region. However, when acquiring geophysical-exploration data at the regions from the coast to a shallow sea, since the data acquisition from both land and the sea is difficult, the regions still remain as blank zones of geophysical-exploration data at many locations (Wakita, 2009). Furthermore, in our country, the coastal plains have highly been developed and it is difficult even setting up the geophysical survey lines in many cases, moreover, since shallow sea regions are prosperous in fishery activity, data acquisition requires some novel device.

Wakita (2009) pointed out that two major earthquakes in 2007 (Noto Hanto Earthquake in 2007 and Chuetsu-Oki Earthquake) were occurred by the active fault systems distributed at the coastal marine area as hypocentres, and the domains were blank regions of geophysical surveys. It also pointed out that the geological and geophysical surveys of the marine and land regions were carried out independently and interaction from both sides was insufficient. We should also be careful of the problem because our research project is targeting the same domain.

In order to attain the goal, in this research, the reflection method survey was carried out targeting the subsurface of the shallow sea region and the coastal land area around the river-mouth of the Fuji River, Shizuoka, Japan. The active fault so called "the Fujikawa-kako fault group" exists in this area (Headquarter of Earthquake Research Promotion, 2010). Since existence of faults has big influence on groundwater flow, it is important for groundwater flow understanding in a plain to know the strike and dip of the faults.

Therefore, we planned to image the subsurface structure and the strike and dip of the faults by a seismic reflection survey. Like other coastal areas of our country, though it is difficult also in this area to even set up a seismic reflection survey line because of dense population, many human activities, and prosperous fishery activity, we solve the problem by combined data acquisition from land and marine. In the combined data acquisition, seismic wave is generated both on land and in marine, and seismic wave is recorded by receivers on land.
In this paper, we carry out a seismic reflection survey at the vicinity of the river mouth of Fuji River, Shizuoka, Japan where

the Fujikawa-kako fault group exists, and discuss about the seismic reflection section obtained by the survey.

OUTLINE OF THE SURVEY AREA

The survey area is the coastal area of Shizuoka City and Fuji City, Shizuoka and is located at the river mouth of Fuji River. The bay where the Fuji River flows in is the Suruga Bay. The negative landform like trench so called "the Suruga Trough" is in the Suruga Bay, and it continues to the Nankai Trough. The regional scale tectonics of the river mouth region of the Fuji River is characterized by the collision to the Eurasian Plate of the Philippine Sea Plate (Fig. 1). The Philippine Sea Plate is a marine plate, and since it is heavy, it subducts beneath the Eurasian Plate at the Suruga Trough. The accretionary prism and the reverse faults are formed at the boundary of both plates. Active faults (the Fujikawa-kako fault group), such as the Iriyamase Fault, the Iriyama Fault, and the Zempukuji Fault, exist around a survey domain (Fig. 1, Fig. 2).

Since fishery activity was especially prosperous in this sea area, we acquire data only on land in the present paper. Seismic energy are generated from both on land and marine. Since data acquisition was carried out with such a configuration, we try to image shallower portion by land source with higher frequency content and deeper portion by marine source with strong energy and lower frequency content. As a result, we obtain high quality subsurface image from shallower portion to deeper.

A receiver line of about 12 km is arranged both on the paved top of the tide-embankment and sandy beach. Synchronized two vibroseis trucks on the same line generate seismic energy. Moreover, a tuned air-gun cluster generates wave energy along the marine survey line with 16.5-km long which is parallel to the land survey line (Fig. 2).

DATA ACQUISITION

We set up two receiver lines. The east side of the Fuji River is named LineL-1 (RP 1001-1226) and the west side is called LineL-2 (RP 2001-2223). In east side survey line, LineL-1, data were acquired by the stand-alone type receivers MS2000 and GSR. In west side survey line, LineL-2, data were acquired by the ordinary geophone system with seismic cable deployment. The Sercel type 428XL data recording system recorded seismic reflection data acquired by the receivers with seismic cable.

In survey-line LineL-2, the survey line was generally configured on the paved top of the tide-embankment. Exceptionally, in the section where constructions were carried out on the paved top of the tide-embankment, we set the survey line to neighbouring sandy beach. In the case of seismic energy generation on land, two synchronized vibroseis trucks generated seismic energy in the shot line. Moreover, they also carried out offset shots at the river mouth area (VP 5001-5047) for refraction tomography analysis. In the case of marine seismic energy generation, a tuned airgun array generated seismic energy along the marine shot line. Specifically, arrayed air-gun with the chamber size of 1520 cubic inches and two tri-guns of 600 and 900 cubic inches were used. Finally, total chamber size capacity was 3020 cubic inches. In addition, the air gun system called "tri-gun" closely arranges three sets of the same capacity air gun in the triangle shape, and suppresses the noise due to bubble vibration using the interference with each other.

Table 1. Specifications of data acquisition.

	Specifications	
Survey type	Land shots	Marine shots
Line length	12.0 Km	16.5 km
Shot parameters		
Seismic source (land)	Vibroseis HEMI50	–
#of soueces for each SP	2	–
Shot interval	25m	–
Sweep length	20 sec	–
#of staks for each SP	10 (reflection) 50-175 (refraction)	–
Sweep frequency	6-60Hz (reflection) 6-40Hz (refraction)	–
Shot array length	8m(B-B)	–
Seismic source (marine)	–	Bolt 1900LL Eight Guns-Array, 1520cu.in Bolt 1500LL Tri Gun-Array, 600cu.in + 900Cu.in
Source capacity	–	3020cu.in, 2000PSI
Source depth	–	8m
Source interval	–	25m
#of shot points	434 (reflection) 3 (refraction)	633
Reciver parameters		
Reciver interval	25m	
Geophone type	SM-24 (f_0=10Hz)	
#of geophones for each RP	3	
Geophne spread	Fixed spread	
Recever line length	12 km	
#of RP (conventional cable)	223	
Rec. line length (cable)	5.55 km	
#of RP (stand alone MS2000)	138	
#of RP (stand alone GSR)	88	
Rec. line length (stand alone)	5.62 km	
Total #of RP	449 or 454	
Recording parameters		
SERCEL 428XL (digital telemetry system)		
Sampling rate	2 msec	2msec
#of recording channels	223	223
Parameters of diversity edit	W=7.0sec(Ovl=3.5sec) α=2.0	–
Preamplifier gain	12dB	12dB
Cross-correlation	CAS	–
Record length (after corr.)	8 sec	8 sec
Stand alone type recording system (MS2000, GSR)		
Sampling rate	2 msec	2 msec
Preamplifier gain	31dB	31dB
Record length	Continuous recording (Shot record is constructed by editing.)	Continuous recording (Shot record is constructed by editing.)

In order to synchronize the land data recording system and the marine navigation system, we used the energy source control system manufactured by MACHA international Co. Setting navigation-system as the master and land data recording system as the slave, we connected them to the energy source control system via the radio system.

Data acquisition was carried out with the fixed receiver spread by simultaneous deployment of all receivers on the land survey line. Survey specification is summarized in Table 1.

DATA PROCESSING AND ANALYSIS

Acquired data were processed by the ordinary reflection method data processing sequence based on NMO correction and the CMP (common mid point) stacking.

(1) Minimum phase conversion

Land and marine shot records were converted into minimum phase by using zero phase vibroseis sweep waveform and observed airgun record, respectively.

(2) Refraction wave first break analysis

We analysed refraction wave first-break by the modified time term method, and estimated the surface structure. Firstly, we picked the first arrival time of all the shot records. Then, we performed the refraction tomography inversion with picked values as inputs. During the inversion procedure, the time term values and velocity of the refracting interface at shot and receiver locations were set as unknowns, whereas, surface velocity was kept 0.8 km/s. The velocity of refracting surface was about 1.4 km/s at the west end of the survey line, and was about 1.8 km/s at the east end. The inversion results were used for travel time correction when surface layer thickness and altitude change.

(3) Velocity analysis

Velocity analysis by constant velocity stack was performed at every 1250 m. The stacking-velocity-to-time relationship obtained by velocity analysis were interpolated in both temporal and spatial directions, as a result the stacking velocity table was created. A hyperbolic correction (NMO correction) with the velocity table align the reflection event.

(4) CMP stacking and post stack migration

The data after NMO correction were stacked within each CMP gather, then finite difference method migration was applied to the post stack data. Laterally smoothed stacking velocity was used as migration velocity. Fig. 3 shows the migration section.

Furthermore, the time axis of the migration time section shown in Fig. 3 was converted into depth axis. The migration depth section obtained by depth conversion is shown in Fig. 4.

RESULTS

The subsurface structure down to 5000 m was imaged by the seismic reflection method data processing. Two remarkable reflection events were observed in the migration depth section. The first one is a reflection event observed at the shallow portion (shallower than 1000 m), and another is a west-dipping reflection surface which exists in 1500 m deep at the east end of the survey line and in 3500 m deep at the west end. Watching the reflection section more in detail, we can find following features.

1. The reflection event of the shallow portion (shallower than 1000 m) shows the different features in the east and the west sides of the Fuji River (CMP 430-480). In the east side, the reflection surfaces tend to continue horizontally, whereas, in the west side, some syncline and anticline pairs can be observed. The difference by the east and west of this shallow portion suggests existence of a fault.

2. In the west side at the depth between 1000 to 3000 m, reflection events show poor continuity. The lack of continuous reflection surface at the portion suggests that the accretionary prism has developed around the portion.

3. The reflection event group with high amplitude continues over the whole survey line at the depth of between 1500 to 4000 m. The dipping reflection event group has a clear gap at the section of 2000 to 3000 m (CMP600-700). Reflection patterns differ on the east side and the west.

4. On the east side of the section, above-mentioned strong reflection-event group seems to form a reflection-surface group at the depth from 1500 to 3000 m(more than 1000 m of layer thickness), whereas on the west side, it forms an isolated reflection surface at the depth from 3500 to 4000 m.

CONCLUSIONS

In this paper, a seismic reflection section around the river-mouth of the Fuji River, Shizuoka, Japan was obtained. Like other coastal areas of our country, though it is difficult also in this area to even set up a seismic reflection survey line because of dense population, many human activities, and prosperous fishery activity, we solved the problem by combined data acquisition of seismic wave generation and reception on land and marine acoustic wave generation.

As a result, we could interpret the subsurface structure down to 5000 m under deep. In the seismic section, the remarkable reflection events were observed at the shallow portion (shallower than 1000 m) and the deep portion (1500-4000m). Concerning the reflection event of the shallower portion, flat reflection surfaces are dominant on the east side of the on mouth of the Fuji River. On the other hand on the west side of the survey line, there are several syncline and anticline structures. The difference of the east and west sides of the shallow portion suggests existence of the fault. However, the exact position of the fault is still left behind as a future work. The deeper reflection events incline to the west with a gap at about 2000 to 3000 m west to the mouth of Fuji River. On the east side of the survey line of a gap, the reflection event seems as a reflection-surface group of more than 1000 m of layer thickness. Meanwhile on the west, it seems to be a sheet of reflection surface. This can be interpreted as the sedimentary layers in the east side have been stripped off and they have been added as parts of accretionary prism in the west side.

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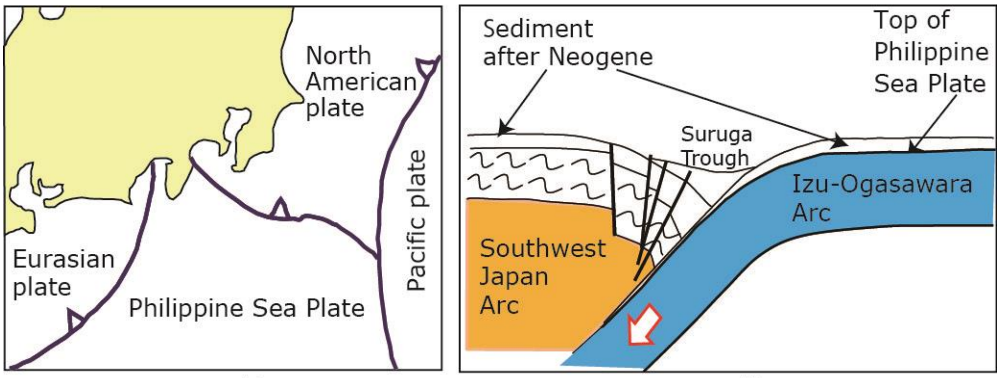

(a) (b)

Figure 1. Schematic diagram of survey domain. (a) Plate distribution around Japan. (b) The schematic cross section around the survey area.

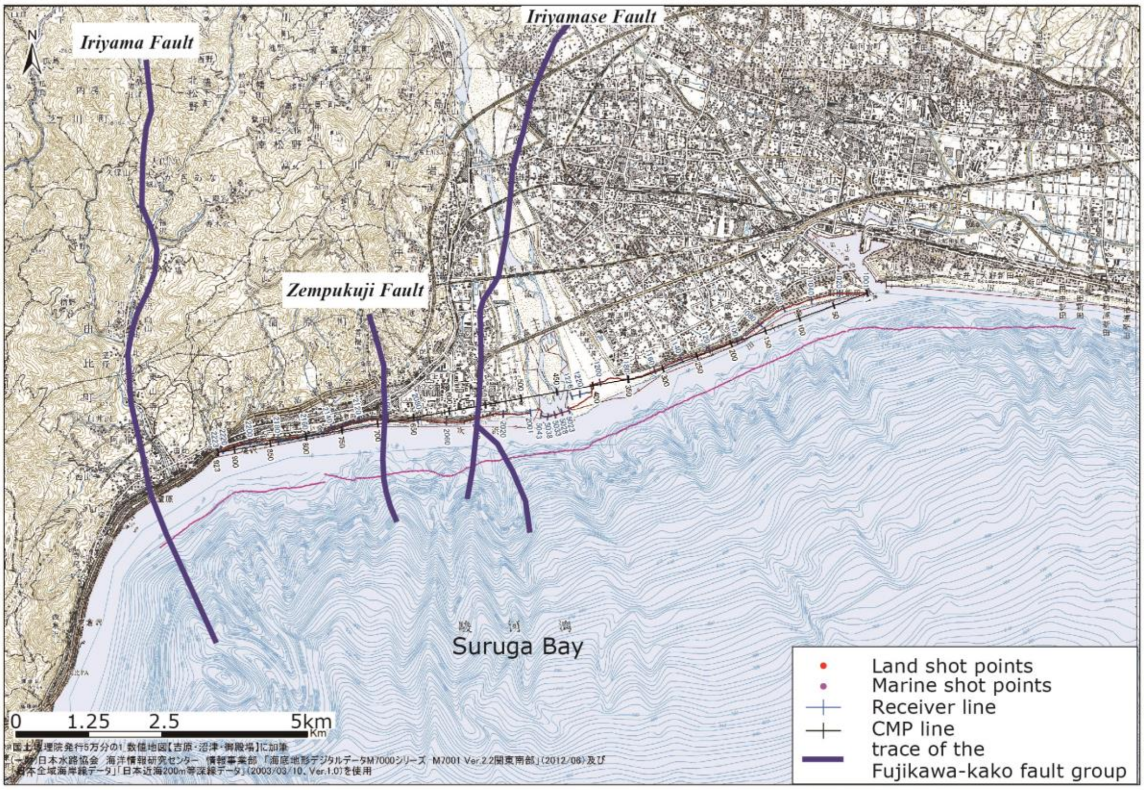

Figure 2. Map of survey-line [receiver points, shot points, and CMP line]. Modified after 1:50,000 Geographical Survey Institute publication digital map [Yoshiwara, Numazu, and Gotemba] and Japan Hydrographic Association (2012). The fault strike locations are referred from Headquarter of Earthquake Research Promotion (2010).

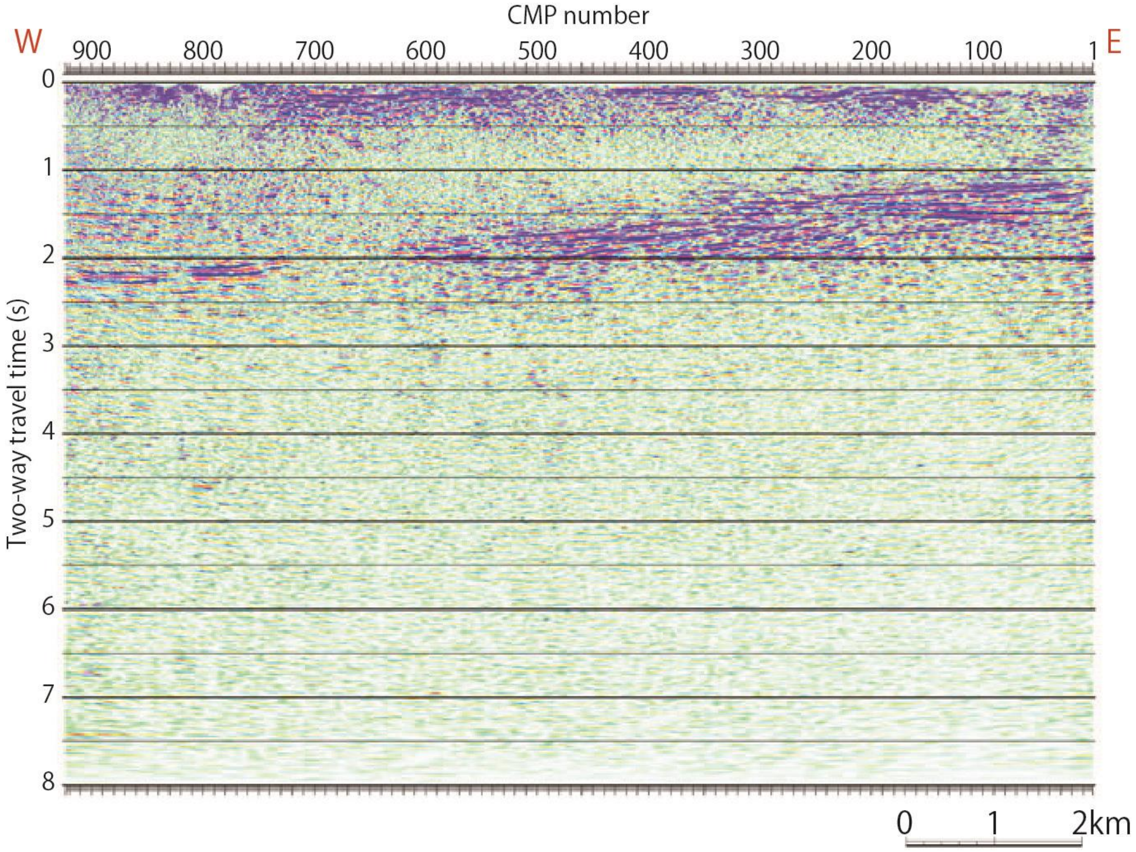

Figure 3. Migration time section.

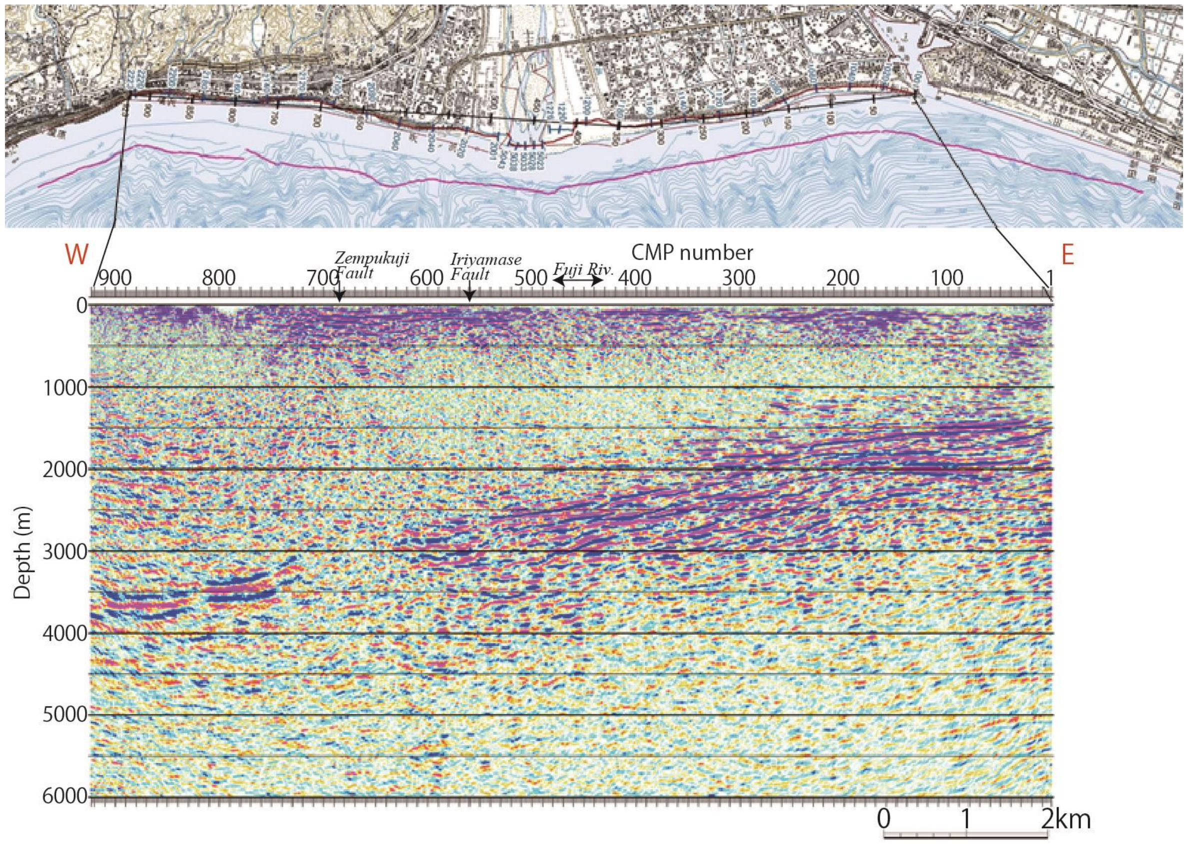

Figure 4. Migration depth section.