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V. DEEP-TOWED MULTU-SENSOR VEHICLE SURVEY REVEALS A HIGH RESOLUTION ACTIVE FAULT SYSTEM IN THE OFF TOKAI AREA

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Introduction

The development of a deep-towed single-channel seismic survey system has been conducted from 1984 in Geological Survey of Japan (here after GSJ) (e.g., Nishimura *et al.*, 1988). The main objective to develop this system was to obtain high resolution sub-bottom geological and geophysical information by a reflection seismic method. In the early stage of development, the following was achieved.

1) establishment of an off-line towing system
2) 10 km maximum towing depth
3) 12 bits digital recording with a 120 dB dynamic range
4) mass storage using a bubble memory

Several sea trials have been carried out and the results have been reported (e.g.. Kisimoto *et al.*, 1988). The deep-towed reflection seismic system has been an important tool to obtain high resolution data so far. The towing speed, however, was usually low (approx. 2 knots), that was a critical disadvantage. GSJ is currently developing a new type of deep-towed system that will overcome the disadvantage. One of our solutions is to develop a multi-sensor vehicle for the deep sea. We put many electronics and acoustic sensors on the vehicle. We will introduce our recent achievements in the development of deep-towed multi-sensor vehicle and it's results in the Tokai area.

Outline of the deep-towed multi-sensor vehicle

On the basis of the previously developed deep-towed vehicle, we started to develop a new type multi-sensor vehicle in GSJ from 1994. The main concept of development is to overcome the disadvantages of the deep-towed system. High speed towing is one of the best solutions, but it may very difficult to achieve in the near future. Then we focus to get many significant data in same time by the system. A hybrid acquisition system is extremely interesting from geological and geophysical point of view. Integration of geological and geophysical data is of the utmost important to understand the sub-bottom phenomena.

The outline of our system is shown in Fig. V-1. A deep sea side-scan sonar is installed at the bottom of vehicle. The side-scan sonar (EG&G SMS960/990) was used

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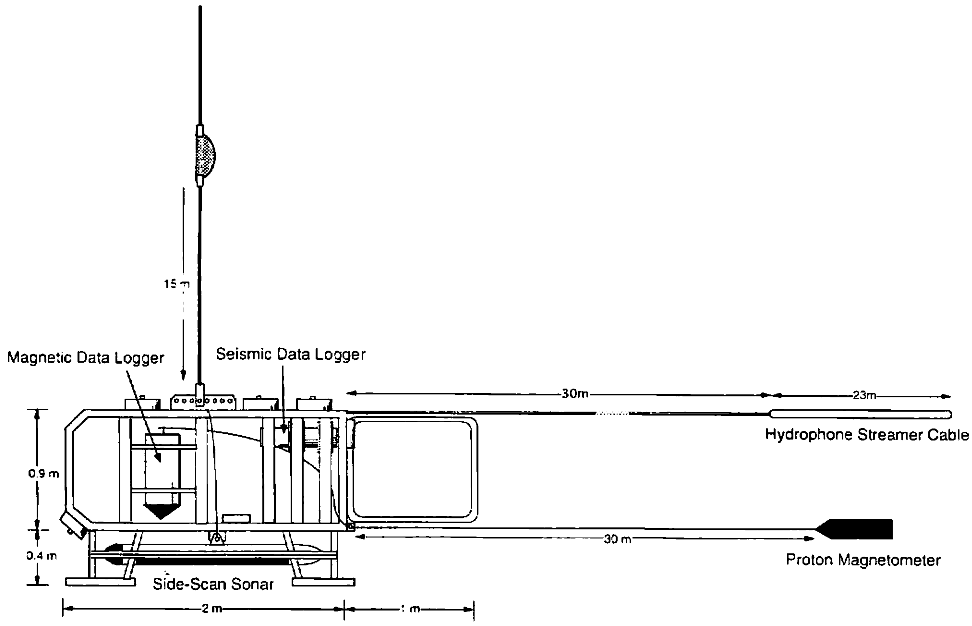

Fig. V-1 General outline of the deep-towed multi-sensor vehicle, that was originally developed in GSJ from 1984. Side-scan sonar is installed at the bottom of the vehicle. Seismic equipment is installed in the back of the vehicle.

alone so far. It is installed and connected to the co-axial cable that makes it possible to see the profile on-line. The side-scan sonar is equipped with an altitude meter, that is very useful, while operating the vehicle, to keep the height from seafloor. A single-channel reflection seismic system is installed in the back of the vehicle. Only one pressure vessel is used for the seismic system. A data logging system, an A/D board, an amplifier board and batteries are set in the vessel. The lead-in cable is 30 meters long, whereas the hydrophone streamer cable is 23 meters long. A 40 litters sea anchor is attached at the tail of the cable. The sea anchor takes a vital effect in tension to improve the S/N (signal/noise) ratio of the data. A deep sea proton magnetometer attached in the middle of the vehicle. The original data logging system of the magnetometer, that is installed in the pressure vessel with batteries, is the G856AX of EG&G Geometrics, Inc. The proton magnetometer is towed 30 meters behind the vehicle. During GH97 experiments the magnetometer system was not installed. Depth and temperature sensors are attached in the middle of frame. Two GI-GUNs are used as high resolution sound source. All data logging systems and shots of the GI-GUNs are synchronized by a GPS clock.

Results of sea trials

We had opportunities to deploy our system in 1997 during the GH97 cruise with the R/V Hakurei-Maru. Fig. V-2 shows our survey area and track lines in 1997. The study area is a part of the Nankai accretionary prism where the Philippine Sea plate is subducting beneath the Southwestern Honshu arc. NE-SW trending thrust faults are

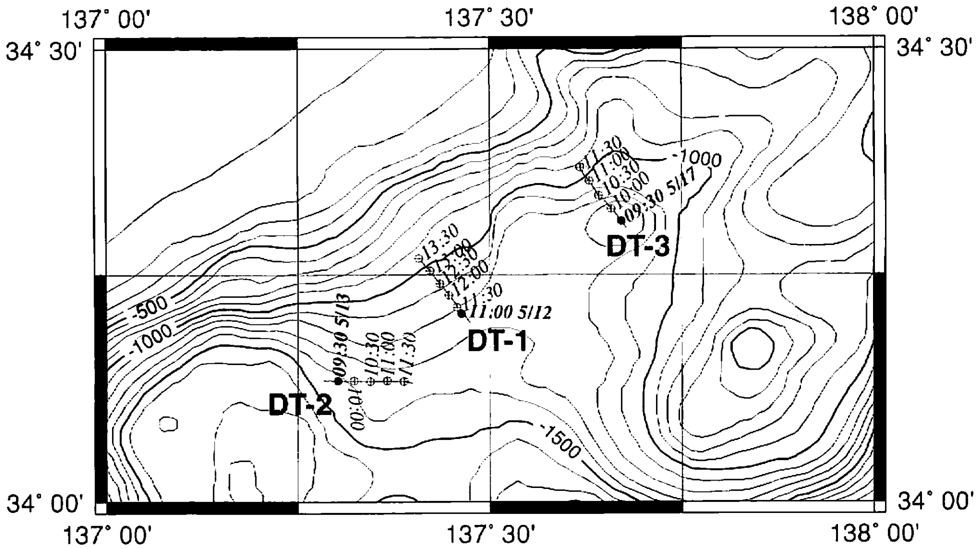

Fig. V-2 Topography map with the track lines of the deep-towed surveys during the GH97 cruise. The surveys are focused on an active fault that strikes SW-NE.

clearly visible on the acoustic imagery map of this area (Kuramoto *et al.*, 1998). Deep-towed multi-sensor surveys were carried out on the three lines, DT-1 to DT-3, in this area (Fig. V-2). The target of these investigations is to detect submarine active faults and to reveal the nature of those active faults precisely.

Fig. V-3 to V-5 show simply processed profiles of each line. Unfortunately, DT-1 and DT-2 do not show as good S/N ratio as DT-3. There are several reasons why the DT-3 data are of a much better quality than other data. A significant difference is that during the DT-3 experiment a sea anchor was added at the end of hydrophone streamer cable, making it more balanced. The deep-towed vehicle was towed about 100 m above the seafloor. Then, the direct wave from the sound source comes very close to the reflector from seafloor. The towing altitude, however, appropriates to the side-scan sonar survey. The seismic data are sampled by 1 msec. interval, and recorded during 4 seconds. The data quality is extremely high compared to surface towed single-channel data. The profile obtained by deep-towing shows good penetration and high resolution. Some major faults are seen in the profile. The offsets of faults although very small, are clearly visible in the profile. The data are just corrected for the geometry and a band-pass filter and auto gain control were applied. Further processing may much improve the data.

Geological Interpretation on DT-3

In this section we will discuss the geological significance of the processed data of the DT-3 line.

DT-3 runs from the deepest part of the Tenryu canyon to the northern wall of the canyon. It is assumed that there is an active fault at the base of the north wall of Tenryu canyon on the basis of the acoustic imagery map (Kuramoto *et al.*, 1998). More than 1 second (two-way travel time) thick sediments are deposited in the Tenryu canyon. Deformed strata are seen in the edge of the wall. Although an active fault is not clearly visible the deformation suggests the existence of an active fault there. Fig. V-6 implies that it is a reverse fault. Further processing, e.g. migration processing etc., may improve the quality of the profile.

There are minor deformation structures like a flower structure on the knoll northwest of the Tenryu canyon. In general such structures suggest strike slip faults. The deep-towed seismic profile shows such vertical faults that have no significant vertical offset. This is a great advantage of deep-towed seismic data. These structures are also traced on the basis of side-scan sonar data (see Joshima *et al.*, this volume). A blanking phenomenon on the profile, that suggests the existence of gas hydrate, is also visible. This might imply the presence of a bottom simulating reflector (BSR) beneath the blanking zone. However, it needs much more processing of the data in order to elucidate it.

Summary and future development

During the GH97 cruise, we deployed our deep-towed multi-sensor vehicle 3 times in the off Tokai area. Single-channel seismic profiles are successfully taken and the data are processed. The DT-3 profile has the highest quality data. It shows very precisely deformation and fault structures that are not shown by surface-towed profiling.

According to our experience and many investigations in the world, deep-towed survey is an important method to obtain highly detailed and precise geological and geophysical information of subbottom. We will continue to develop and improve our system. Our next target is the sound source. Our current system. using surface-towing air guns, has a limited resolution. We will use deep-towed sound sources that will produce a frequency of around 2-16 kHz (charp wave). The second target is to modify the shape of the towing body to reduce water resistance. Currently we use a co-axial cable, that sometimes is the bottleneck in our system. We may develop the system in such a way that it will correspond to the both, on-line and off-line operations.

References

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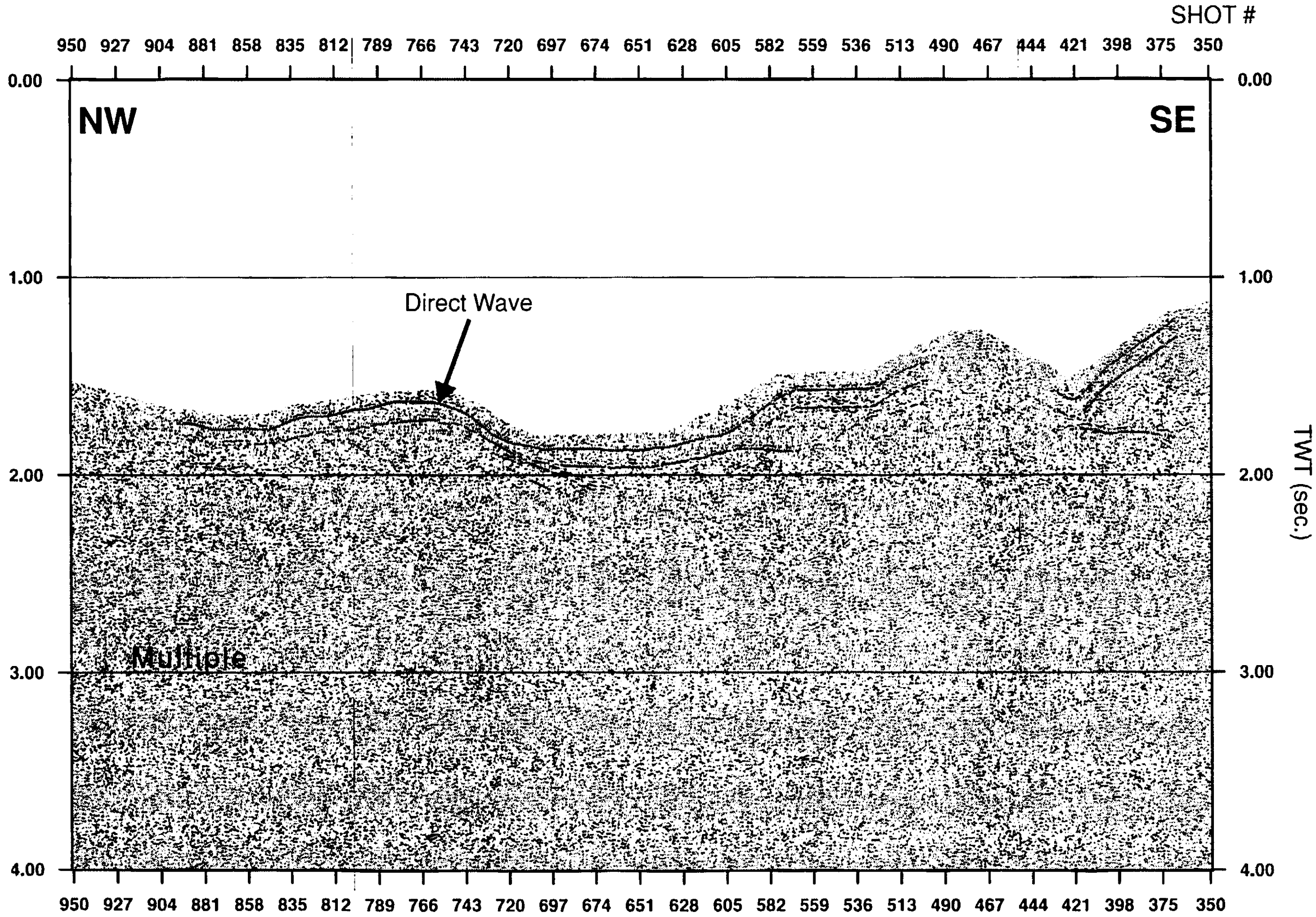

Fig. V-3 Processed single-channel seismic profile DT-1. This line runs across an active fault, but does not show it well.

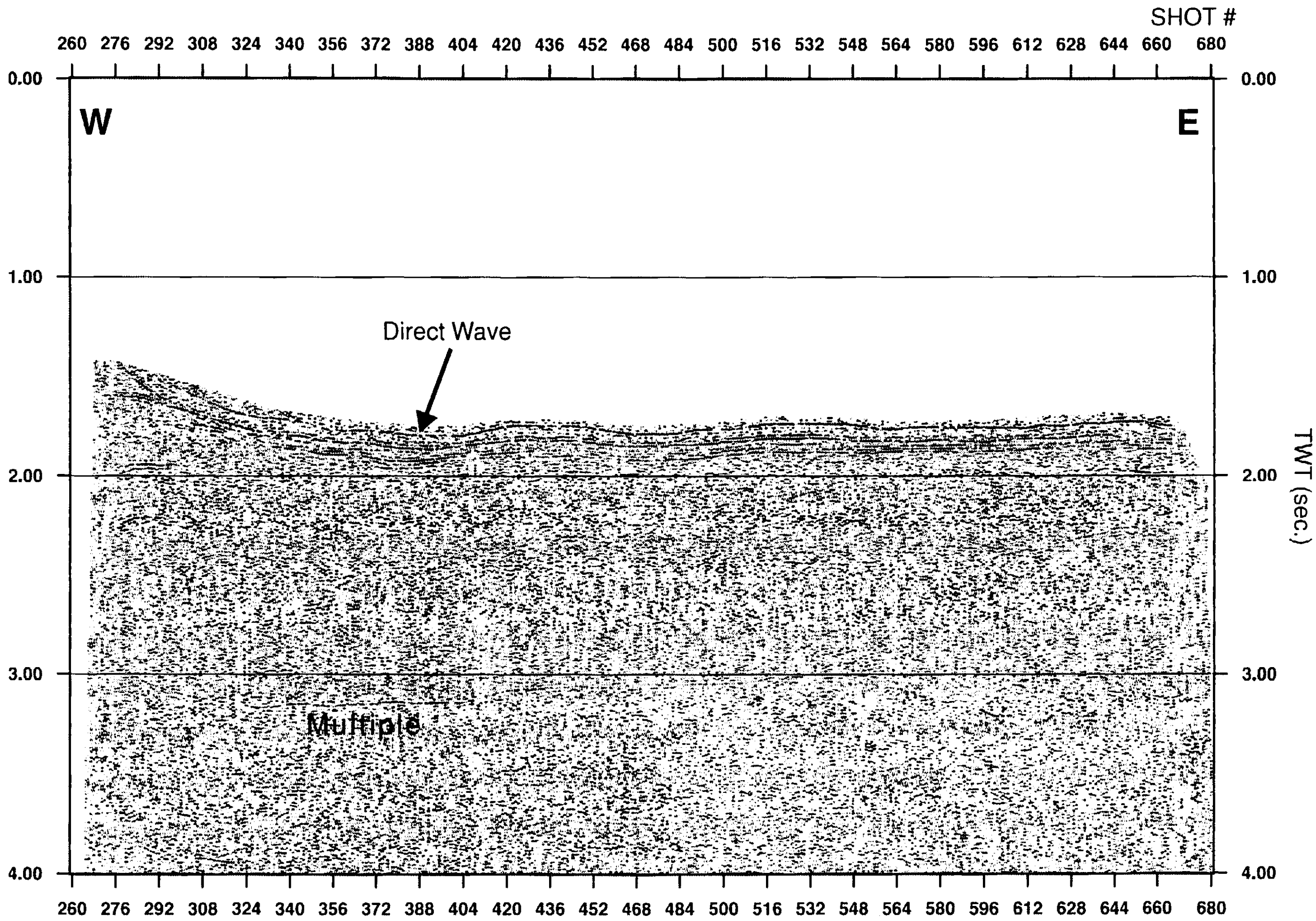

Fig. V-4 Processed single-channel seismic profile DT-2. The S/N ratio is not enough to see any sub-bottom structure.

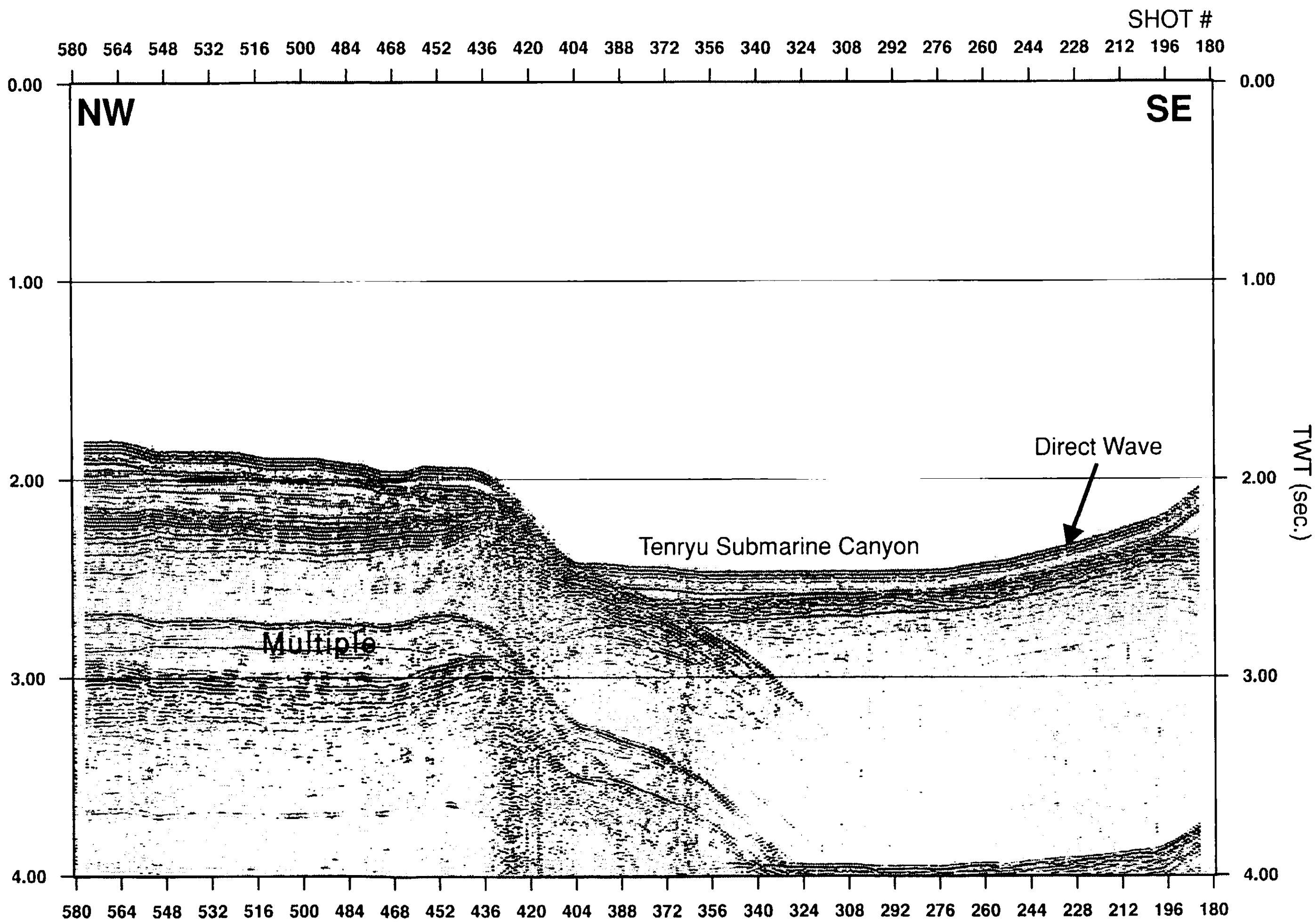

Fig. V-5 Processed single-channel seismic profile DT-3. Data quality is much higher compared with the previous two profiles (Fig. V-3 and V-4).

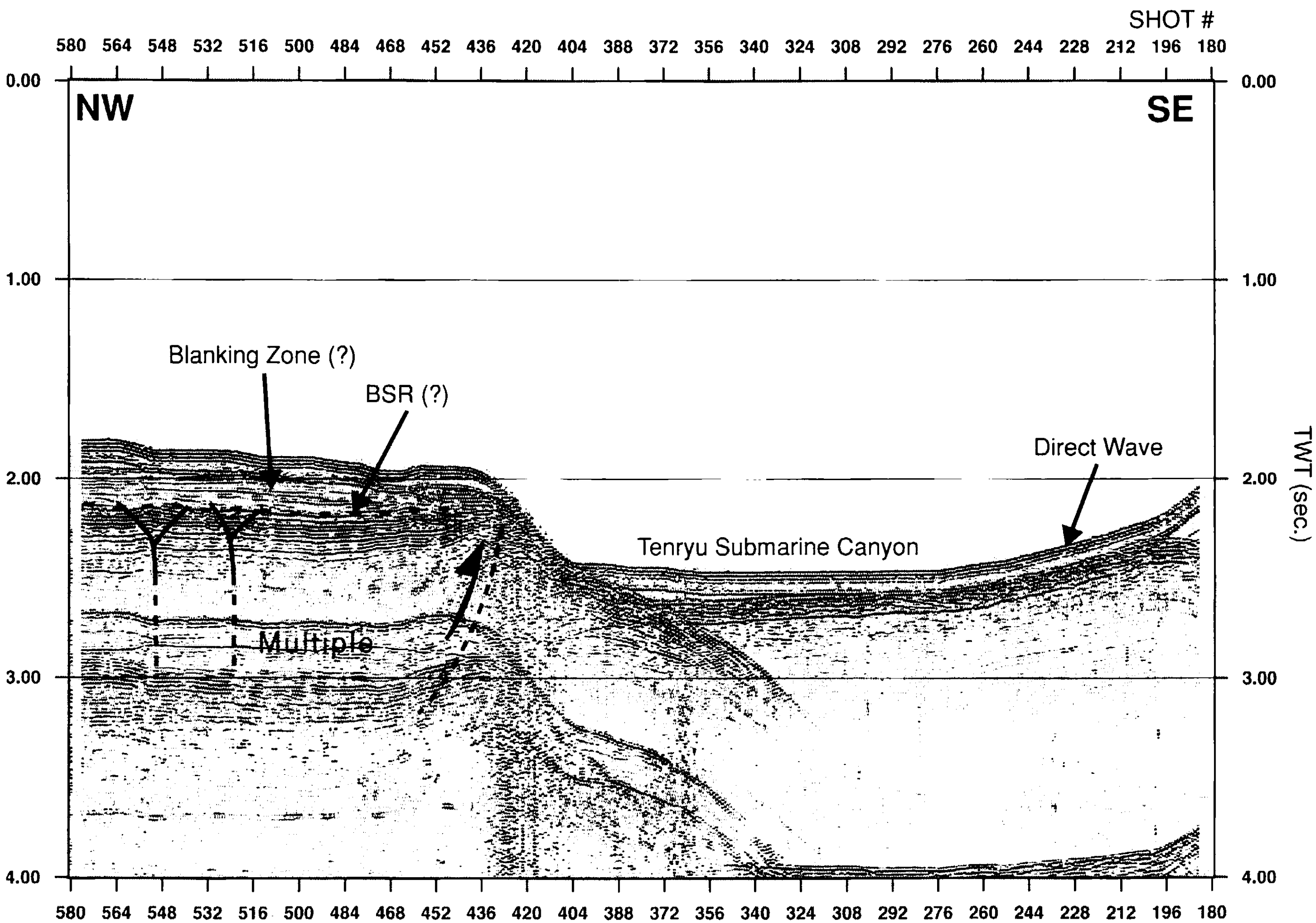

Fig. V-6 Geological interpretation of the DT-3 profile. High resolution interpretation is available and further data processing is required.