NOTE AND CORRESPONDENCE

TAO, Vol.5, No.1, 109-119, March 1994

Ocean Bottom Seismograph: Instrumentation and Experimental Technique

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(Manuscript received 5 January 1994, in final form 22 March 1994)

ABSTRACT

A set of Ocean Bottom Seismographs (OBS) has been constructed recently at the National Taiwan Ocean University (NTOU) for offshore seismic surveys and earthquake observations. The instrument is identical in design to the recently upgraded Texas OBS. It is controlled by an 80C88 microprocessor. Signals from up to four channels of sensors are recorded digitally on either a cartridge tape or a disk. It was successfully field tested during *R/V Ocean Researcher I* cruise No. 277 in 1991, and has been in use in subsequent cruises.

(Key words: Instrumentation, Offshore measurement, Refraction)

1. INTRODUCTION

Recently, we built a set of three ocean bottom seismographs (OBSs) at the National Taiwan Ocean University. They were successfully tested off southwestern Taiwan during *R/V Ocean Researcher I* cruise No. 277 in 1991, and have been used in subsequent cruises Nos. 282 in 1991, 312 in 1992, and 347 in 1993. The instrument can be deployed at depths of up to 6000 meters. Although this was not the first time an OBS was used near Taiwan (e.g., Hagan *et al.*, 1988), cruise No. 277 marked the first occasion in which an OBS built and operated by a Chinese institution was used.

The instrument was built according to the specifications of the recently-upgraded Texas OBS developed by the Institute for Geophysics of the University of Texas at Austin (Nakamura and Garmany, 1991). It is the latest version of a long series of low-cost, small, easy-to-deploy-and-recover Texas OBS's, starting from the earliest single-channel analog instrument (Latham *et al.*, 1978) and developed through the earlier digital units (Nakamura *et al.*, 1987). For comparison of various OBS's, the reader may refer to a report by Sutton *et*

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al. (1980) and a recent compilation by Trehu (1992). According to this latter report, which was based on a survey conducted through the international marine seismological community, there were a total of 232 OBS's in the world, including three units from NTOU-R.O.C. The Texas OBS's have been extensively used in studies of deep crustal structures in the Middle America Trench (Ibrahim *et al.*,1979) and in the Gulf of Mexico (e.g., Ebeniro *et al.*, 1986, 1988), and in studies of micro-earthquakes in the Southwest Pacific (Pontoise *et al.*, 1979; Ibrahim *et al.*, 1980; Chen *et al.*, 1981; Coudert *et al.*, 1981; Frohlich *et al.*, 1990) and in the Aleutian Trench (Frohlich *et al.*, 1982). In this paper, we briefly describe the instrument and the operational procedures for seismic refraction surveys. The use of these instruments in an array for offshore earthquake observations is planned for the near future.

2. SYSTEM DESCRIPTION

The system consists of several interacting units, or modules, as shown in Figure 1 and described below.

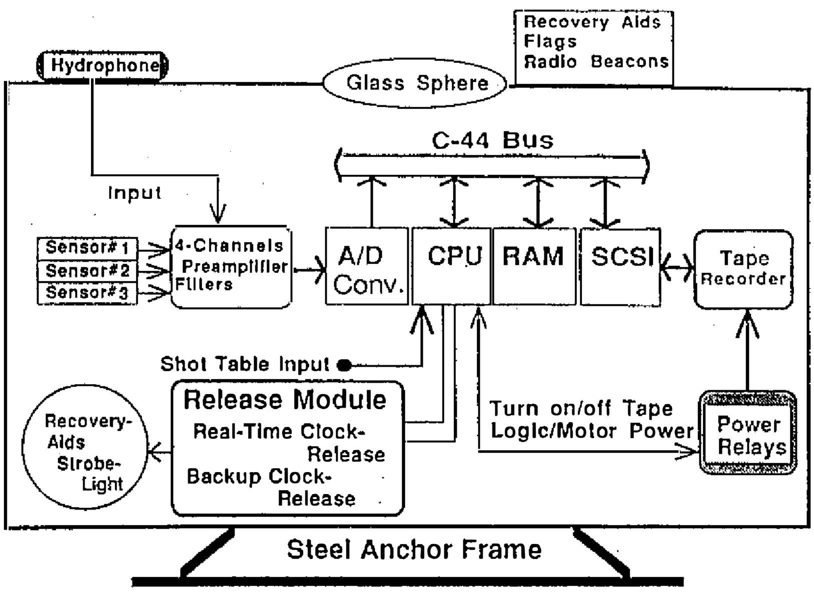


Fig. 1. The OBS system block diagram.

2.1 Sensor Unit

The instrument accepts up to four channels of sensor inputs, which normally consist of three orthogonal geophones and an optional hydrophone. Three Mark Products L-15B 4.5-Hz geophones, two horizontals and a vertical, are mounted on gimbals to maintain a level position even when the instrument housing is tilted by up to 25 degrees on the ocean floor. The gimbal mechanism is damped with high-viscosity silicon oil to maintain its level position.

2.2 Signal Conditioning and Temporary Storage Units

Signals from the sensors are amplified and low-pass filtered to avoid aliasing. A three-stage gain-ranging amplifier and a 14-bit analog-to-digital converter (QADC-3 made by QSI) convert the filtered analog signal to a digital signal, achieving a total dynamic range of 126 dB. The maximum sample rate is 1000 samples per second per channel. The digitized data are temporarily stored in a random-access memory (RAM) of 512K byte capacity on a memory board (RAM-2M made by Onset).

2.3 Recording Unit

The acquired data are transferred from the temporary memory to a more permanent digital-recording device through a SCSI interface at a given interval or when the temporary memory is filled. Although practically any SCSI storage device will serve for the permanent storage of data, we used a Tandberg TDC-3600 cartridge tape drive on each of our first units, which gave a maximum of 155 M bytes of storage capacity on a 600-ft cartridge tape. This capacity has since been upgraded to 525 M bytes using a 1000-ft cartridge tape on a Tandberg TDC-3820 tape drive. The system is also capable of recording the data on a hard disk, e.g., Conner 3200 or Toshiba MK2224FB disk drive, each of which has 203 M byte capacity. The power to the recording device is controlled by the CPU through a pair of relays.

2.4 Control Unit

The system is controlled by an 80C88 microprocessor on a CPU-8088 board manufactured by Onset. This board also contains a small RAM, a programmable memory (EPROM), in which the control software is stored, serial and parallel ports, and a crystal-controlled real-time clock. The processor controls the entire data-acquisition sequence as well as the release of the instrument from the ocean floor following a pre-set schedule. Optionally, the processing software may contain an event-detection algorithm that allows detection of earthquake events based on a long-term-short-term signal-level comparison.

2.5 Release Unit

Two independent release functions are employed to assure release of the instrument from the anchor frame (see below) even when one fails to function properly. The main CPU controls one of them and issues a release command when the time for release as given in the pre-set schedule is reached. A backup clock, a preset timer, also issues a release command independently when the preset time is up. Each release command turns on a separate relay to apply a current through a stainless steel wire (release wire), which then dissolves itself at some water-exposed sections to release the instrument housing (see below) from the anchor frame.

2.6 Instrument Housing (pressure vessel)

The whole electronic package is housed in a glass sphere of 43 cm (17 inch) diameter, which acts as a pressure vessel, with the gimbaled geophone package firmly set at the inside bottom of the sphere. The sphere is put into a hemispherical plastic protective 'hat' and then is fastened to a steel anchor frame with three pieces of elastic (bungee) cord tied to the

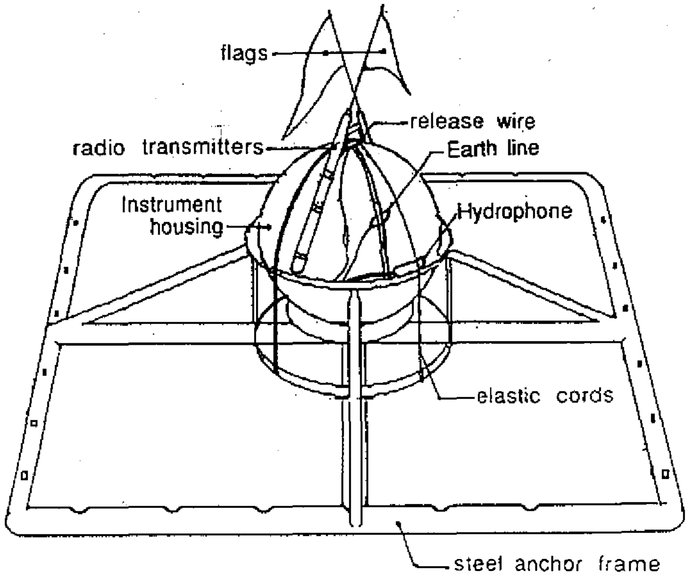


Fig. 2. The OBS sphere is fastened to the steel anchor frame with elastic cords. The recovery aids, including two radio transmitters and flags, are on top of the OBS while a strobe light is installed inside the sphere (not shown). When the release wire is dissolved, the OBS is released from the anchor frame and ascends to the surface of the water.

triangular release wire mentioned above (Figure 2) for deployment. If a hydrophone is used, it is attached to the outside of the sphere with a water-tight cable connection through one of the penetrators through the sphere.

2.7 Communication Connections

A specially designed electronic-switching circuitry, the 'switch box' (Figure 3), serves to establish three-way communication among the OBS, a standard clock, and a personal computer (PC). We use an Omega navigation-signal receiver as the standard clock. A position on the switch allows a two-way communication between the OBS and the PC. This switch position is used to start up the OBS, to set the internal real-time clock of the OBS, to perform various test functions, to download a data-acquisition schedule, and to monitor the OBS while it goes through the preset schedule. Another position allows two-way communication between the PC and the standard clock to set the latter for proper output format. Still another position allows OBS-clock-PC three-way communication, providing a means for accurate calibration of the internal clock of the OBS against the standard clock.

2.8 Recovery Aids

One or two submersible radio transmitters (beacons) are attached to the sphere to transmit radio signals. A pressure-sensitive switch turns on each transmitter as soon as the released instrument reaches the surface. A direction finder is used to locate the instrument if it is out

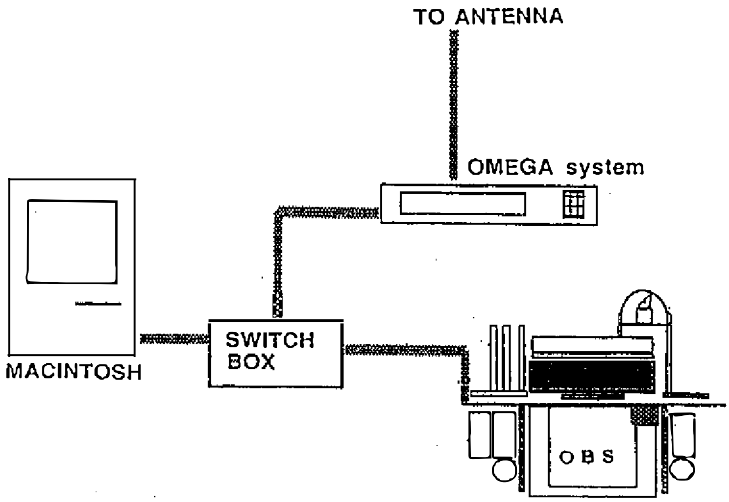


Fig. 3. The switch box serves as a linkage among OBS, PC and standard clock.

of sight. A strobe light, mounted inside the sphere, flashes to reveal the instrument at night. A fluorescent orange flag, attached to the transmitter antenna, serves as an additional aid for daylight recovery.

2.9 Power Supply

Independent sets of lithium batteries provide power for the CPU/pre-amplifier-filter/ADC/RAM, the tape drive, the main release, the strobe light, and the power-switching relays. The required total number of size-D battery cells, in addition to two smaller cells used for the relays, depends primarily on the duration of data acquisition, and generally ranges from 19 to 37. When fully loaded, the system can record data continuously for about a week, although it can stay dormant for several months. The submersible transmitters are each powered by four size-C alkaline batteries.

3. EXPERIMENTAL PROCEDURES

We describe below the basic steps in conducting a refraction survey using these instruments. Details of these procedures are given in a separate instruction write-up we prepared for the operators.

3.1 Pre-deployment Operations

Before each OBS deployment, a thorough check out of the instrument is performed to make certain that all connections are properly made. We also fill out a check list, the purpose of which is to maintain proper records (e.g., component serial numbers) and to ascertain correct voltage levels at various key test points. We also record low-frequency square waves, which provide calibration of the instrument. The shape and size of square waves recorded and played back in time domain are diagnostic of any malfunction of the signal channel.

Fourier transform of the step-function response multiplied by frequency will give the overall frequency response of the signal channel.

A schedule table for activating, deactivating and releasing the OBS is prepared on a PC. This table also includes all necessary parameters for data acquisition, such as number of channels and sampling interval.

When everything is ready, we turn on the power to the CPU, set and start the internal real-time clock in synchronization with the standard clock, download the schedule table, and put the CPU into the sleep mode to conserve power while it is idle. The system consumes about 3 mW of power in this mode. It wakes up momentarily every minute to output a time character string through a serial port, which may be used to calibrate the internal real-time clock against the standard clock.

After the backup timer is set, the entire electronic package is installed inside the glass sphere and sealed. Communication from here on, including clock calibration, is through a set of electrical feed-throughs (penetrators) through the sphere wall.

3.2 Deployment and Data Acquisition

As the ship approaches the deployment site, the sphere, with its yellow plastic protective 'hat' and submersible transmitters attached, is put onto a steel anchor frame and tied firmly with elastic cords. When the ship reaches the location, the instrument is lowered to the water surface from appropriate gear, such as an A frame, and released. It then free falls to the ocean bottom.

The sequence we normally follow in a refraction survey is as follows: We first drop a series of OBS's at pre-selected locations along a line. Then, we trace back the line while shooting an air gun at a constant interval (Figure 4). Finally, we retrace the line for the third time and pick up the OBS's as they float to the surface. Although such a sequence gives a linear seismic line geometry, other source-receiver geometries are equally permissible depending on the objectives to be accomplished.

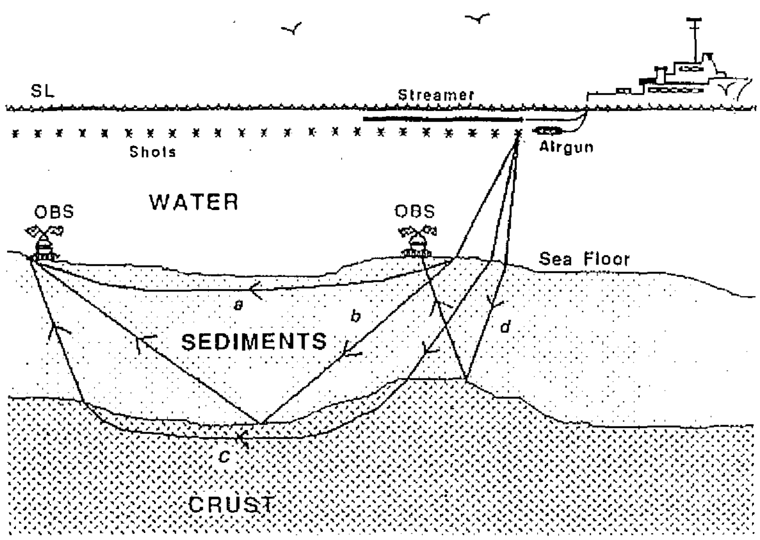


Fig. 4. The refraction seismic survey using OBS.

It is important that each shot time be accurately recorded and referenced to the same standard clock against which each OBS's internal clock is calibrated. We use specially built circuitry to generate a pulse from the shot-break signal supplied by the shot sequencer. The pulse is then sent to the standard clock to request the current time, which is received by a PC and recorded.

3.3 Post-recovery Operation

Immediately following the recovery of each OBS, its internal clock is re-calibrated against the standard clock, and the content of the error log, which is kept in the instrument's memory, is displayed to reveal if there has been any problem. We also play back selected portions of the recorded data to ascertain that expected data are properly recorded. If any problem is found, it must be corrected before the unit is re-deployed.

Before we re-deploy the instrument, we replace battery packs, if necessary, and go through a thorough check-out as before. After restarting the instrument, we download a new schedule and follow the normal procedures as described above. The turn-around time is usually less than two hours for each OBS.

4. TEST RESULTS

We conducted the first OBS field test off southwestern Taiwan during the *R/V Ocean Researcher I* cruise No. 277 in 1991. We recorded three components of seismic data at 4-ms sampling intervals while shooting a small air-gun array of total available volume of 10.2 *l*. (620 in^3) at 30 sec intervals while maintaining a constant cruising speed of 5.1 knots. The record sections in Figure 5 have been generated by stacking traces into uniformly spaced offset bins, band-pass filtering the traces, and adjusting the gain. The acquired data clearly show seismic arrivals of excellent quality; we can easily pick up some first arrivals even though the source energy was small and multiples are also present. The most impressive features include the big offset of arrivals near 15 km, which may imply a structural discontinuity, and the arrivals between distances of 25 and 30 km, which represent signals from deep refraction.

The OBS program at the National Taiwan Ocean University was started about three years ago. Our initial objective was to build up a capability to conduct research using this new tool in studies of deep crustal structures and seismic activities in the offshore region of Taiwan. To date, we have acquired data of reasonably good quality every year since using these OBS's we built and operated. These data sets mark an important step towards a new research territory in our studies of velocity structure and earthquake activities in offshore regions.

Acknowledgments This work was supported by National Taiwan Ocean University, National Science Council grants NSC80-0202-M019-01 and NSC80-0204-M019-01, and Ministry of Education Tai(80) Wen17717.

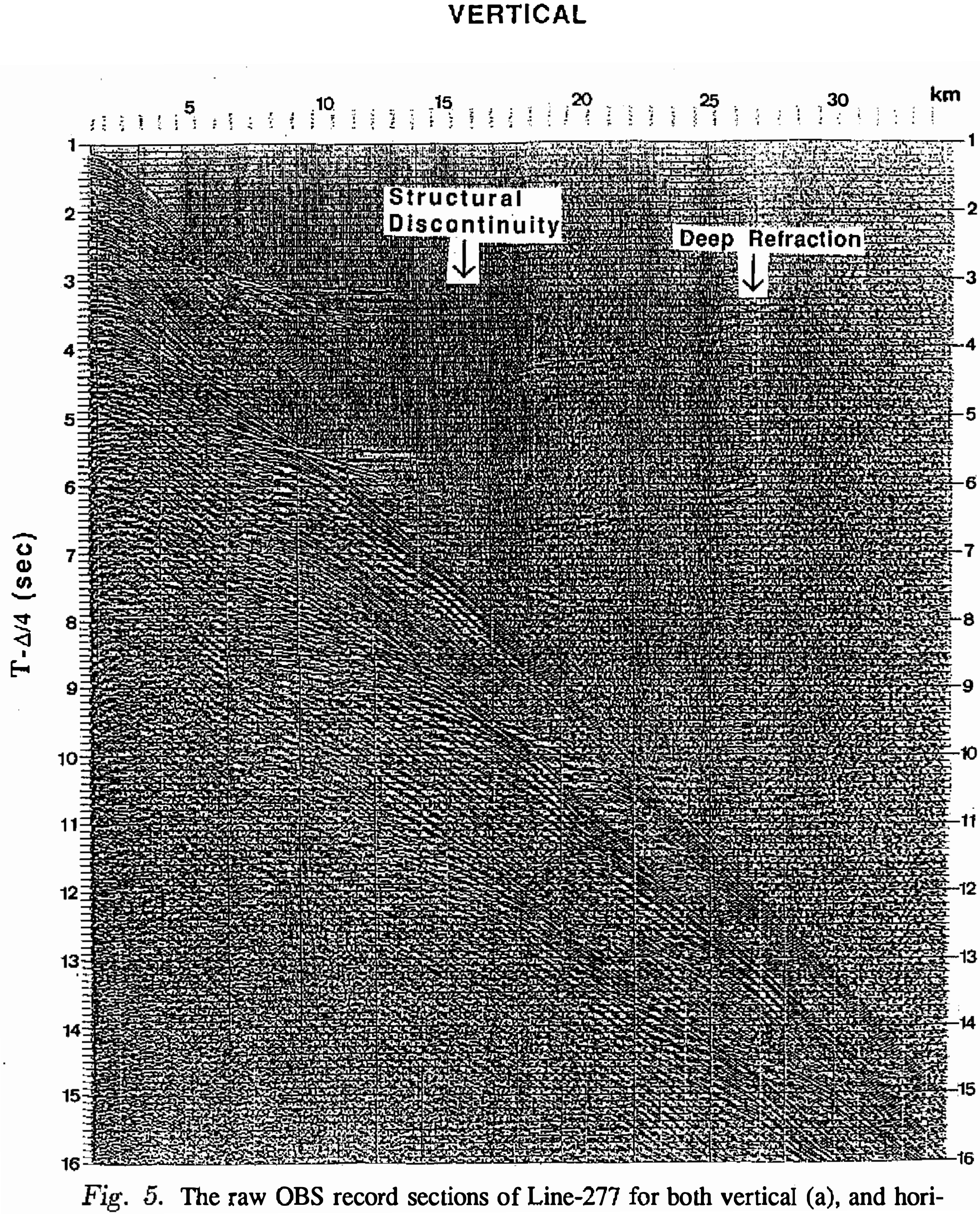
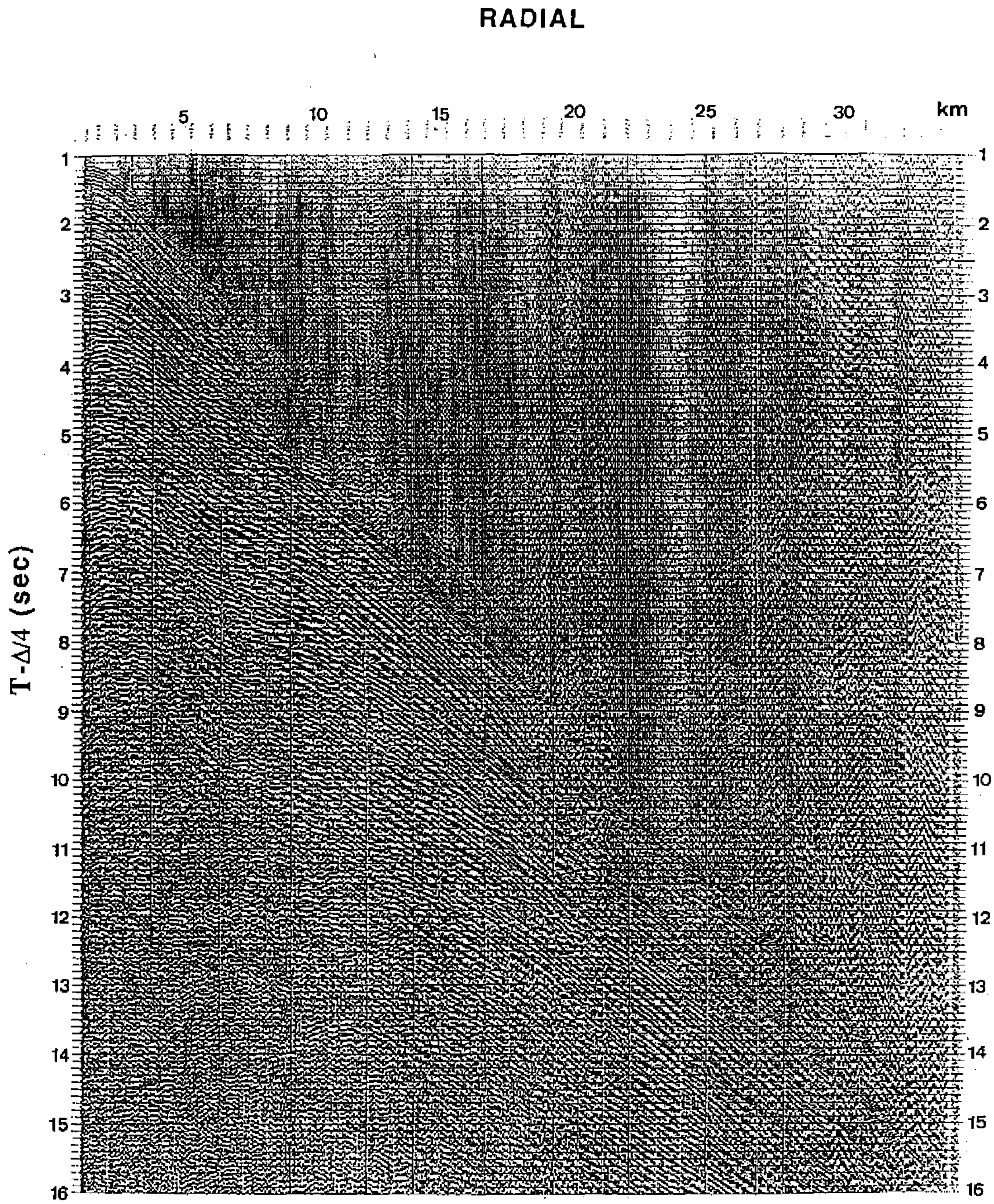
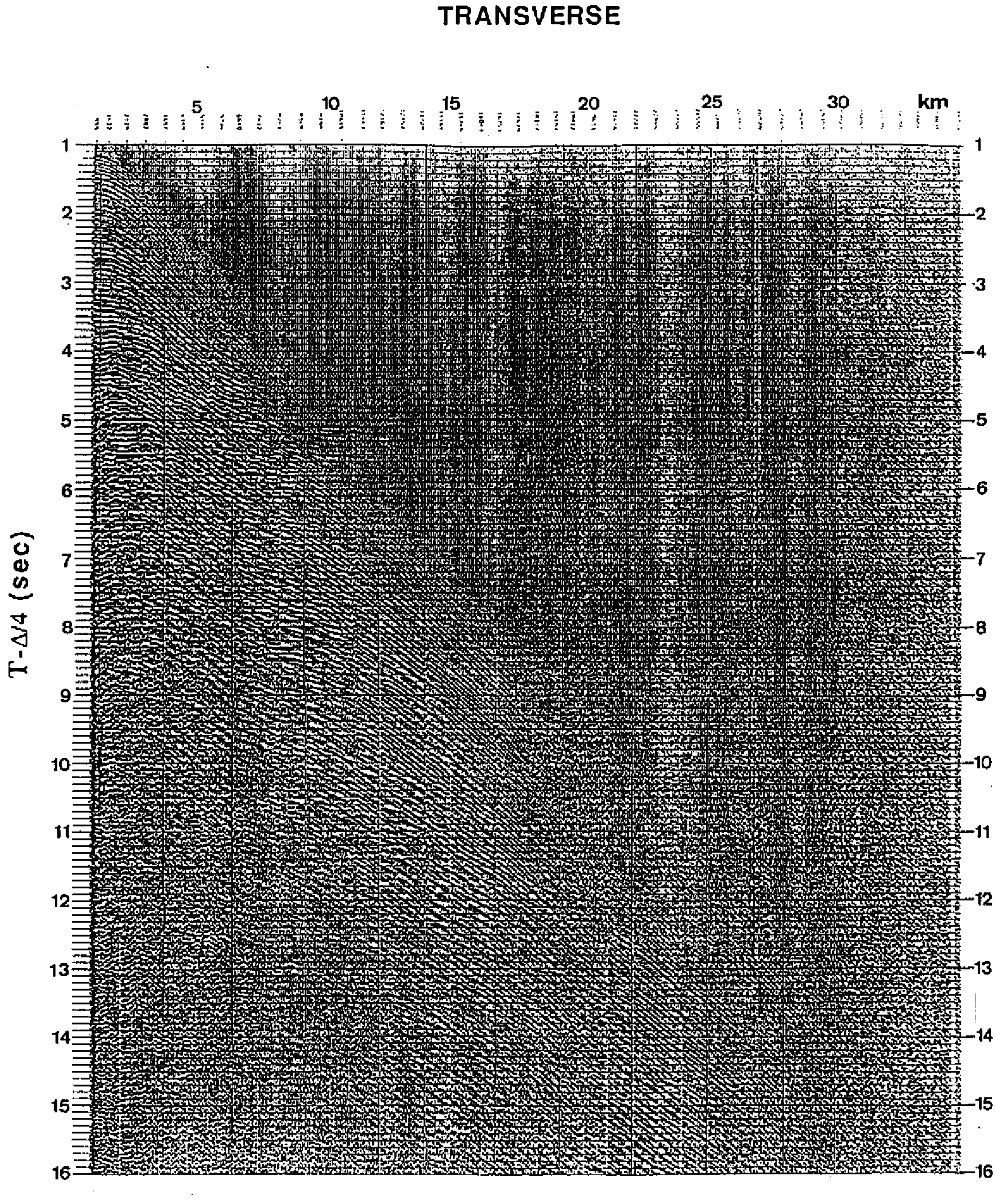


Fig. 5. The raw OBS record sections of Line-277 for both vertical (a), and horizontal (b, c) components. The OBS is located at the far left of the profile. Water wave and first refracted arrivals can be easily picked. Noted the large offset of arrivals near 15 km and arrivals from deep refraction after 25 km in vertical component (a).



(Fig. 5. Continued.)



(Fig. 5. Continued.)

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