Off-Line Deep-Towed Seismic Profiler

K. Kisimoto, K. Nishimura, T. Miyazaki*, M. Joshima, F. Murakami & T. Ishihara

Geological Survey of Japan
Marine Geology Department
*(*Geophysics Department)*
1-1-3 Higashi, Tsukuba
Ibaraki, 305
Japan

Summary

A deep-towed seismic profiling system is being developed to obtain detailed subbottom structures in deep seas around island arcs like Japan. Features of the system are as follows:

(1) *Off-line towing:* both a hydrophone streamer and a recording unit with power supply are equipped onto a deep-towed frame, whereas the sound source is towed at the surface. This means that the underwater system can be towed by wire without using any special cable.

(2) *No depth limitation:* all electrical units except the streamer are kept in the pressure vessels (depth limit 10 000 m), and unlimited depth hydrophone elements are used for the streamer. Thus the system can be used in the deepest seas such as the Japan Trench, the Izu-Ogasawara Trench, etc.

(3) *Digital recording:* an A/D converter with a floating point amplifier and magnetic bubble memory are used to obtain high quality and high volume data. This provides 120 db in dynamic range with 12 bit significance and 16 megabytes data space.

The prototype of the system hardware is complete, and the control software for the system is under examination. Field tests have proved the operability and functional ability of the system.

Introduction

It has been shown that the modification of the conventional vertical reflection seismic profiling method from 'surface source/surface receiver' configuration to 'surface source/near bottom receiver (deep-towed system)' configuration and the post processing of the digitized data could significantly improve the resolution of sea bottom and sub-bottom reflectors (Purdy *et al.*, 1980; Robb *et al.*, 1981, Purdy and Gove, 1982; Cochrane and Lewis, 1984; Lewis and Cochrane, 1984; Bowen, 1984; Bowen and White, 1986). In the works cited above, deep-towed systems are connected to the onboard equipment through the conducting cable. Such a system allows real time monitoring using the cable, but restrictions arise as a result of the cable.

We have been developing another type of deep-towed seismic profiling system. Two main features of the system show our attitude to the initiation of this development program. Firstly, the deep-towed system is towed by a wire rope, not by an armored coaxial cable, so that the system is free from trouble with electrical cable (Collins *et al.*, 1984). Secondly, digital data recording with IFP (Instantaneous Floating Point) amplifier enables full wave usage in post processing; 120 db dynamic range data with 12 bit significant samples will provide enough quality for various data enhancement techniques, such as filtering, stacking, source deconvolution, etc. (Purdy and Gove, 1982; Bowen, 1986; Bowen and White, 1986).

System

The deep-towed system has been designed as a single channel seismic profiler (Ishihara; ed., 1986). Features are as follows:

(1) *Off-line type:* both a hydrophone streamer and a recording unit with power supply are equipped onto a deep-towed frame, whereas the sound source is towed at the surface. This means that the underwater system can be towed by a wire without using any special cable.

(2) *No depth limitation:* All electrical units except the streamer are kept in pressure vessels with a depth limit of 10 000 m. Unlimited depth hydrophone elements are used for the streamer to operate the system in deep trenches such as the Japan Trench and the Izu-Ogasawara (Bonin) Trench.

(3) *Digital recording:* A/D converter with a floating amplifier and magnetic bubble memory are used to obtain high quality and high volume data. This provides 120 db in dynamic range and 16 megabytes data space.

Figures 1 and 2 show block diagrams of the digital-unit and the underwater system, respectively. The underwater system consists of a seismic unit, a bubble unit, an analog recorder unit, a relay transponder, a hydrophone streamer and depth and temperature sensors. The seismic unit is equipped with a signal conditioner, an A/D converter with IFP amplifier, buffer memory and the unit system controller. The bubble unit is the mass storage unit composed of 32 magnetic bubble 4-megabit memory modules controlled by a CPU. Because magnetic bubble memory is a non-volatile storage device, each module is activated only when data are transferred to it.

The underwater system is operated by three CPUs (two in the towing package, one in the portable console terminal) which communicate with each other through RS-232C ports. As the system works in off-line mode, all operational parameters are digitally programmable through the portable console terminal. Parameters to be set before the deployment of the system are as follows: internal clock calibration, start time of data logging,

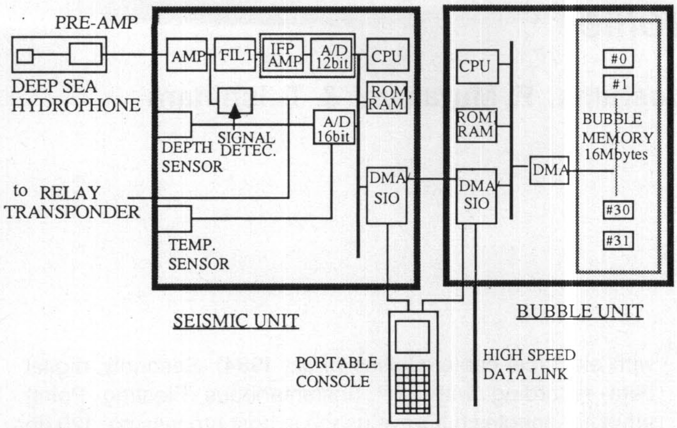

FIGURE 1
Block diagram of seismic unit and bubble unit. Each unit is installed in the pressure vessel and equipped on the deep-towed frame. Both units and the portable console are linked through the RS232C ports.

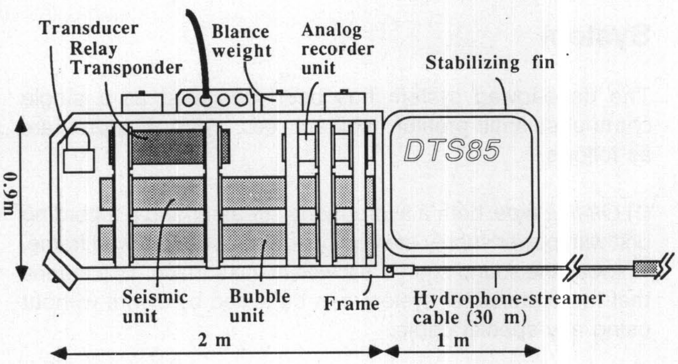

FIGURE 2
Schematic view of the underwater system equipped on the aluminium frame. The frame is towed by a wire rope. Each unit on the frame is connected with cables (not drawn in the figure).

pre-amp. gain (0–60 db), logging mode parameters, sampling rate (0.5–5 ms), record length (max. 8 s), anti-aliasing filter (60–500 Hz, att. 100 db/oct), low cut filter (off or 10–50 Hz, att. 12 db/oct). There are three data logging modes: signal detector mode, relay transponder mode and time mode. Signal detector mode initiates data logging when the signal detector circuit picks up the first arrival wavelet. In the relay transponder mode, data logging is activated from the onboard transponder system. In time mode, logging is repeated at the rate of prefixed time interval and duration. Every shot record is stored in the buffer memory and sent to the bubble memory with time code, depth and water temperature data and logging parameters stated above.

After the recovery of the deep-towed package, data are transferred to the post processing system onboard through high speed data link (see Fig. 3). Maximum data transfer rate is 76.8 kbaud through RS232C.

Field test

A field test was carried out in the area off Kii-peninsula, mainland Japan in March, 1987. Water depth was about 2 000 m. An airgun (Bolt model 1900C, 120 ci.) was used as a surface source. Towing speed was less than 2 knots on EM-log reading. Logging conditions: Sampling rate, 1 ms; record length, 4 s; low cut filter, 20 Hz; anti-aliasing filter, 200 Hz; relay transponder mode.

Figure 4 shows the deployment of the seismic package from stern of the ship.

An acoustic transponder system was used for navigation and determination of the hydrophone position change during the survey. Three transponders were deployed on the sea floor and a relay transponder was mounted on the deep-towed frame. Ship position and hydrophone position were calculated based on the long-baseline acoustic transponder measurement.

Although our system was not fully operational at the field test, about 5 megabytes of data were recovered. Several successive shot records are shown in Fig. 5. Hydrophone height above the seafloor was about 700 m. Direct arrival wavelet and following wave train are recorded in good quality.

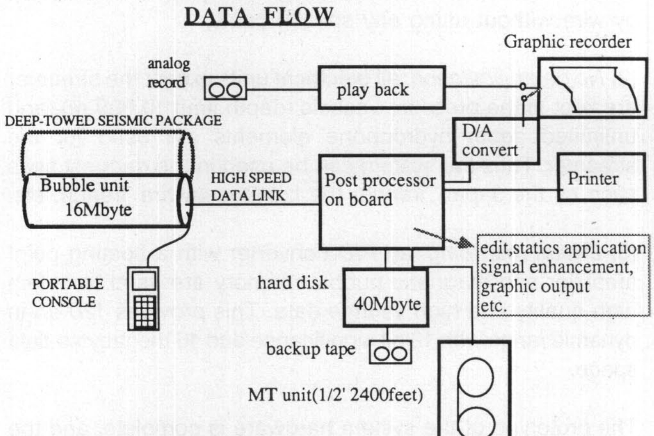

FIGURE 3
On the recovery of the towed system, digital data are transferred to the post processing system on board through RS232C port at a rate of 76.8 kilobaud.

FIGURE 4
Photograph of the deep-towed system at the sea surface.

Conclusions

Preliminary field testing shows the potential of *in situ* data acquisition using IFP amplifier and solid state mass storage

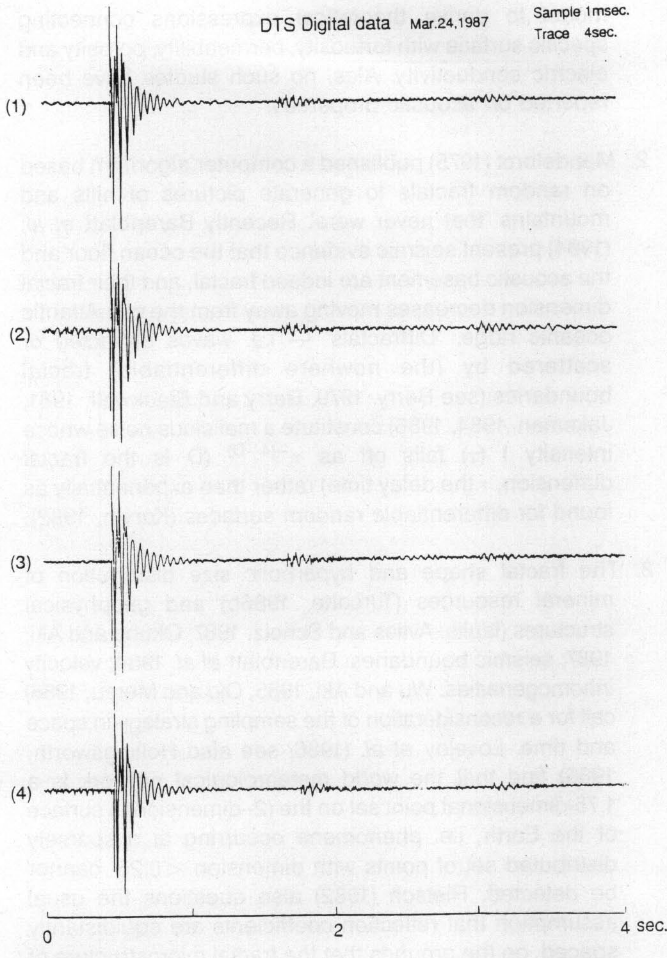

FIGURE 5
Digital data retrieved at the field test on May 23, 1987. First arrival wavelet (direct wave) and following wave train are recorded in good quality.

system. The present configuration of the system allows 5 hours of recording a 1ms sampling rate, 4 s record length and 10 s shot interval. Data quality obtained suggests that post processing could improve seismic profiles.

Acknowledgements

We wish to express our thanks to Captain Okumura of R/V Hakurei-maru and his crew for their expert assistance at the field experiments. This work was supported by a special fund for promotion of science and technology, Agency of Science and Technology of Japan.

References

Bowen, A. N. (1984)—'A high-resolution seismic profiling system using a deep-towed horizontal hydrophone streamer', *Marine Geophys. Res.* **6**, 275–293.

Bowen, A. N. (1986)—'A comparison of statistical and deterministic Wiener deconvolution of deep-tow seismic data', *Geophysical Prospecting* **34**, 366–382.

Bowen, A. N. & White, R. S. (1986)—'Deep-tow seismic profiles from the Vema Transform and ridge-transform intersection; Oceanic fracture zones', *J. Geol. Soc. London* **143**, 807–817.

Cochrane, G. R. & Lewis, B. T. R. (1984)—'Preliminary deep-tow seismic reflection profiles from cruise 180 of University of Washington Research Vessel Thomas G. Thompson', *University of Washington School of Oceanography*, Special Report No. 99.

Collins, J. A., Koelsch, D. E. and Purdy, G. M. (1984)—'Seismic reflection profiling with a deep-towed vertical hydrophone array', *Marine Geophys. Res.* **6**, 415–431.

Ishihara, T. (ed.) (1986)—'Preliminary report on the development of deep-towed seismic profiling system', *Geol. Surv. Japan*, pp. 82 (in Japanese).

Lewis, B. T. R. & Cochrane, G. R. (1984)—'Comparison of seismic reflection methods used to study the Washington-Oregon margin', *EOS* **65**, 1089.

Purdy, G. M., Ewing, J. I., & Bryan, G. M. (1980)—'A deep-towed hydrophone seismic reflection survey around IPOD site 417 and 418', *Marine Geology* **35**, 1–19.

Purdy, G. M. & Gove, L. A. (1982)—'Reflection profiling in the deep ocean using a near bottom hydrophone', *Marine Geol. Res.* **5**, 301–314.

Robb, J. M., Sylwester, R. E. & Penton, R. (1981)—'Simplified method of deep-tow seismic profiling', *Geo-Marine Let.* **1**, 65–67.

Fractals in Applied Geophysics — A Guided Tour

G. Korvin
University of Adelaide
North Terrace
Adelaide SA 5000

Summary

The geometrical patterns encountered in geophysics are irregular and fragmented at all scales. This expository talk reviews the possible applications of ther novel ideas of fractal geometries (Mandelbrot, 1982) to diverse fields of applied geophysics and rock physics. Examples include the internal surfaces of porous rocks, the irregular shape of earth materials and the fine structure of sedimentary sections.

Discussion

'A fractal is a mathematical set or object whose form is extremely irregular and/or fragmented at all scales'. So runs Mandelbrot's definition of the term he coined and widely popularised in his monograph (1982). One well-known example is the coast line of Britain (Mandelbrot 1967) whose length increases when the resolution of measurement l tends to zero as l^{1-D}, where D is called the *fractal dimension* of the curve (for the west coast of Great Britain it is 1.25). The fractal dimension measures the density with which the curve fills the space into which it is embedded. For higher dimensions, if spherical balls of Euclidean dimension E and of radius r are centred on every point of an object with fractal dimension D then the total volume covered by the balls scales as r^{E-D}.

The size-distribution of fractal objects is usually hyperbolical: out of a total number N of such objects there are Nr^{-D}