Application of suspension P-S Logging System to high velocity ground

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Introduction

The Suspension P-S Logging System is a velocity logging system based on the principles of unlocking type receivers and indirect excitation type sources. In Japan, this system is mainly applied to site investigations where the ground is of low velocity, for large scale building projects on land or undersea. The development of the Suspension P-S Logging System and its effectiveness in low velocity ground have been previously reported (Ogura *et al.* 1980; Yoshimura *et al.* 1982: Tanaka *et al.* 1984). This paper concerns our attempt to deal with the problems involved in improving the system's probe for application to high velocity ground.

Problems of measurement in high velocity ground

The first problem presented by high velocity ground concerns the source. Because the source for the Suspension P-S Logging System is located inside the probe, it is not capable of high energy output. Intended mainly for use in low velocity ground and located only a short distance from the receiver, this type of source was sufficient for measurement. However, it is not able to adequately displace the borehole wall in high velocity ground.

The second problem concerns the frequency characteristics of the receiver. When the specific gravity of the suspension type receiver equals that of borehole fluid, flat frequency characteristics are obtainable. In practice, if the specific gravity is within ±20% of borehole fluid, there is no problem (Kitsunezaki 1975). The probe currently in use has a specific gravity more than 2, which includes the receiver—which has a specific gravity of 1—directly attached by means of a rubber tube. Because of the vertical constrained force exerted by this rubber tube, the higher the frequency range, the less sensitivity is obtained. The authors attempted to develop an improved probe that would surmount the above difficulties.

Improvement of source

The indirect excitation type source is designed to emit vibrations that pass through the borehole fluid and exert force on the borehole wall at right angles to the axis of the borehole. The diagrams labelled Type A and Type B in Fig. 1 are the types of source presently in use. In order to exert force on the borehole wall, the plate must attain a certain vibration velocity. Pressure on the front of the plate increases, while pressure on the back decreases. When vibration velocity of the plate is very slow, all that happens is that borehole fluid circulates from high to low pressure areas and energy is not transmitted to the borehole wall. However, as the vibration velocity of the plate increases, positive force is exerted on the front and negative on the back, and acoustic waves are emitted. Radiation impedance is the ratio between acoustic pressure and vibration velocity.

The shear wave source (Type A) corresponds to a double source type, and the P-S wave source (Type B) corresponds to a single source type.

It has been our experience in experimentation that in ground where the velocity of shear waves is 500 m/s or less, extremely good records are obtained with a shear wave source, but in ground where the velocity is more than 500 m/s, it is better to take records using a P-S wave source. This is not solely due to energy of the source. The increase of radiation impedance is proportional to the frequency of the double source raised to the fourth power and to the frequency of the single source squared. However, the structure of the shear wave source makes it difficult to obtain high frequencies from it. It is believed that as radiation power of the shear wave source declines, the P-S wave source attains greatest efficiency. However, with this wave source as well, as shear wave velocity

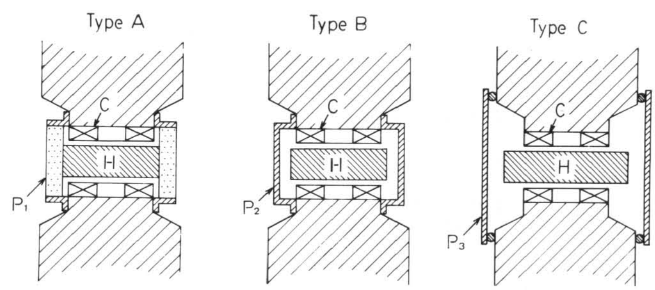

Fig 1 The three types of sources: H hammer; C solenoid coil, P_1 plate (rubber), P_2 plate (steel), P_3 plate (steel, cylinder type).

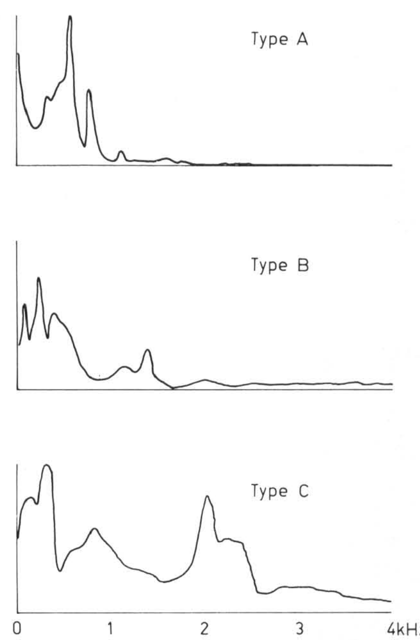

Fig 2 Spectra of the three vibration sources.

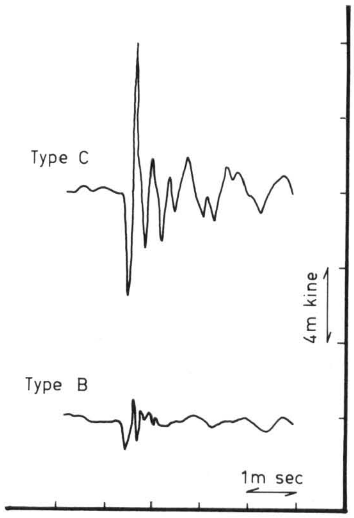

Fig 3 Waveforms measured in test borehole.

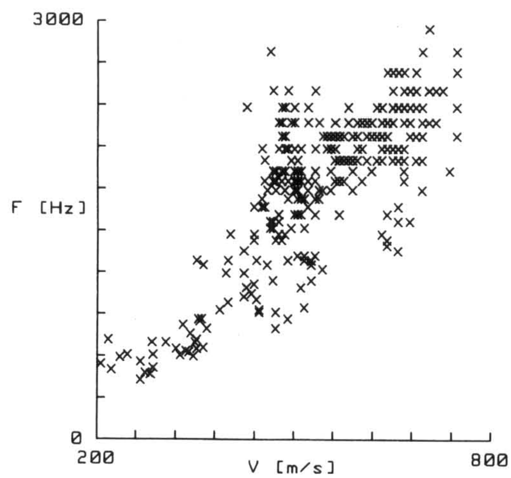

Fig 4 Relationship between shear wave velocity and frequency.

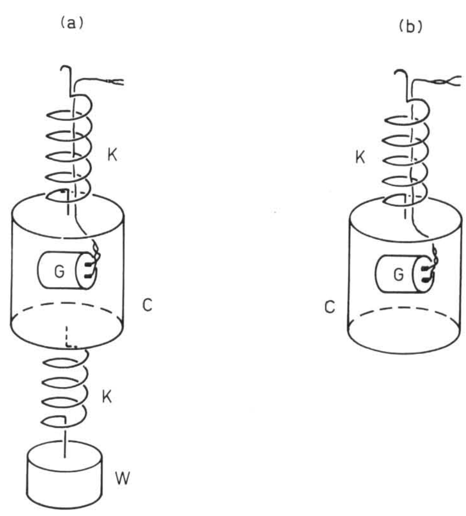

Fig 5 Unlocking type receiver: K spring, G geophone, C case (density = 1, including geophone), W weight.

exceeds 1 km/s, it becomes difficult to generate waves efficiently. In this regard, we attempted to improve the source to increase radiation power. The way to achieve this is to increase energy of the source, to use a double source and to apply as high as possible frequency impulses to the plate. Also, it is possible to increase radiation power by increasing the area of the plate. Type C in Fig. 1 is the pilot source we built in accordance with the above points. This is a double source type, cylindrically shaped to maximize surface area. An electrical current applied to a solenoid coil causes the hammer to strike the plate to produce high frequency vibrations. The distance of the stroke of the hammer is calculated for optimum velocity of the hammer when it strikes the plate. Figure 2 compares the spectra of source Types A, B and C. It can be seen that Type A produces only low frequency waves, while Type C produces waves through high frequencies.

Next, we tested these sources in a column shaped sample block of tuff. Vp value for this tuff was 2.4 km/s. Vs was 1.0 km/s and density was 1.7 (obtained from a core sample). Figure 3 shows the waveforms obtained with geophones on one side of the tuff and the source inside a borehole. With the Type A source, waves could be not measured. Type C showed approximately five times the radiation power of Type B.

Improvement of the receiver

Figure 4 shows the relationship between shear wave velocity and frequency. It clearly shows that as velocity increases, high frequency waves predominate. As Fig. 5 (a) shows, with the receiver presently in use, the receiver, which has a specific gravity of 1, is suspended at top and bottom by springs. This raises the possibility that sensitivity could deteriorate in the higher frequency range. For this reason, a comparison of sensitivity was made with the receiver shown in Fig. 5 (b). It was found that the sensitivity decreases by more than 6 dB when a constrained force acts on the receiver. Therefore, it is possible that by minimizing the constrained force on the receiver, the sensitivity can be increased.

Conclusion

The authors attempted to improve on the Suspension P-S Logging System for use in high velocity ground. Success was realized in increasing the radiation power of the vibration source fivefold and the sensitivity of the receiver twofold, thereby opening up the possibility of using the system in high velocity ground.

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Acquisition efficiency and flexibility of multichannel recording

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Introduction

The high cost of seismic surveys and drilling demands that modern seismic interpretation provides an accurate structural and stratigraphic analysis of an area the first time around. An interpreter cannot interpret subtle stratigraphic and small scale structural features he cannot see, thus it is necessary to acquire and to enhance in processing, high resolution, broad bandwidth seismic data.

This paper discusses basic geophysical theory relating to the design of a seismic survey specifically using a 1000 channel acquisition system to acquire high resolution data. Quantitative parameters such as signal to noise ratio (S/N), dynamic range, wavelength and bandwidth are discussed in relation to the qualitative parameters of resolution and interpretability.

High resolution requires the ability to sample and record as frequently as possible (both vertically and spatially) the returning broad bandwidth wavelet, while minimizing the recording of source-generated coherent and background random noise. High frequencies help identity stratigraphic and small scale structural features while lower frequencies contribute to signal character by reducing interference between reflections, and help identify depositional transitions. However, the production of a broad bandwidth source wavelet produces some inherent problems. High frequencies are subject to signal aliasing and wavelet degradation from insufficient sampling, system filters and excessive array lengths. Lower frequencies generally induce high amplitude coherent noise trains (groundroll and airwave) which swamp higher frequencies, reducing the effective bandwidth.

Vertical and spatial resolution

The signal to noise bandwidth as defined by Anstey (1983) is the maximum signal bandwidth recordable above random background noise, and is the critical parameter determining the bandwidth of frequencies expected on the final seismic sec-