Preliminary Geophysical Logging Report
Vertical Seismic Profile (VSP)

Overland Avenue Bridge, North Abutment
ITD Borehole DH-95-6, Burley Idaho

Paul Michaels
Claudine LaCasse

Center for Geophysical Investigation of the Shallow Subsurface
Boise State University
Boise, Idaho 83725

Technical Report BSU CGISS 95-10
15 June 1995

Contents

Figures

Preliminary* Geophysical Logging Report
Vertical Seismic Profile (VSP)

Dr. P. Michaels and C. LaCasse
Center for Geophysical Investigation of the Shallow Subsurface (CGISS)
Boise State University, 1910 University Drive, Boise, Idaho 83725
Phone: (208) 385-1929

Borehole: DH-95-6, Ground Elevation: 4136.7 ft (1260.8 m), Casing Elev 4138.6 ft
Location: West Side of North Abutment, Overland Ave. Bridge, Burley, Idaho
Distribution: Idaho Transportation Dept. (ITD) / U.S. Bureau of Reclamation (USBR)
Funding: Idaho State Board of Education Research Grant 95 056
Surveyed: 17 May 1995

Summary

Two Major Zones: The borehole was logged with both a vertical hammer (compressional, P-wave source) and a horizontal hammer (shear, SH-wave source). We found the 90 foot borehole to consist of two major zones. The shallow zone (less than 30 feet deep) exhibits slow velocities typical of partially saturated, noncohesive soils. The deep zone (greater than 30 feet) exhibits faster velocities than the shallow zone. The deeper velocities are typical of fully saturated soils, sands, or gravels. The shear velocities suggest that the lower zone is more rigid and better suited to support foundations. The following table shows the average velocities for the two zones as measured from Figure 1:

TABLE 1

Depth Range (feet)	Interpretation	SH-wave Velocity (f/s)	P-wave Velocity (f/s)
0 to 30	less rigid & partially saturated	520 (+/- 16)	2139 (+/- 64)
30 to 90	more rigid & saturated	901 (+/- 15)	5033 (+/- 263)

Average Velocities from slopes of vertical travel times (see Figure 1).

Details of the Shallow Zone: The USBR geologic report divides the upper zone into three layers (fill, sand, and clay). To better correlate with that report, we interpreted the upper zone for greater detail. The SH-waves suggest that the fill layer consists of an upper fast interval, and a lower slow layer. The slower layer is probably less compacted and potentially liquifiable. Note that shear velocities have been used to evaluate in-situ compaction treatment (Dise et al., 1994). Below the fill, the sand layer appears to be more rigid (faster SH-waves) than the underlying clay layer. We observed that the water level was 17 inches above ground level in the PVC case borehole. It may be that the clay layer forms an aquitard that confines the sands in the deep interval below. This might suggest that the sands below the clay form an artesian aquifer. Table 2 below summarizes the velocities measured from the Figure 2 travel times.

* The results presented here are preliminary and subject to revision by the authors in the course of further research. Neither the authors nor BSU accept any liability for decisions made by others based on the data in this report.

TABLE 2

Depth (feet)	Soil Type/Condition USBR/Geophysics	SH-wave Velocity (f/s)	P-wave Velocity (f/s)
0 to 9	fill / compacted	888 (+/- 189)	2213 (+/- 197)
9 to 15	fill / less compacted	303 (+/- 24)	3374 (+/- 435)
15 to 20	sand / compacted	977 (+/- 33)	1975 (+/- 718)
20 to 30	clay / soft	546 (+/- 28)	1824 (+/- 106)

Interval Velocities from slopes of vertical travel times (see Figure 2).

Figure 2 shows a strong correlation between the SH-wave arrivals and the USBR log. In contrast, the P-wave arrival times fall along a sublinear trend. Our interpretation is that the P-waves respond more to fluid saturations and porosity, while the SH-waves are most sensitive to the soil skeleton which depends largely on the soil type.

Reflection from Below Borehole: In addition to the travel times, a wavefield separation analysis was performed to determine if any significant reflections were evident in the data. It appears that there may be a deeper interface below the borehole at a depth of about 180 feet. This may be the transition from soils and fluvial sediments to bedrock. Mapping this interface might be possible from a surface geophysical experiment. Figure 3 shows the reflection in two-way time for the SH-wave data.

P-wave Reflections Masked by Tube Waves: We attempted to recover P-wave reflections, but were limited by what appears to be a tube wave. Further interference was produced by S-wave and converted wave energy, also present on the P-wave record. Figure 4 shows the P-wave enhanced records for both the vertical and horizontal hammer sources. The tube wave appears to be reflected at the bottom of the hole. Figure 5 shows the SH-wave direct arrivals. The vertical times (Figures 2 and 3) are offset corrected travel times for the direct waves shown in Figures 4 and 5.

RECOMMENDATIONS

It is not known how far the results of this survey can be extended from the borehole. We would expect that a surface P-wave experiment might produce mappable refractions or reflections. Such a survey might reveal unexpected geologic conditions, such as shallow bedrock. Surface surveys do not produce tube wave interference (since there is no borehole). Furthermore, it is likely that mappable formation boundaries exist (since SH-wave reflections were imaged). However, if the other boreholes produced similar USBR logs, there might not be enough risk to justify the cost of a surface survey.

In retrospect, we feel that the tube wave problem could probably have been reduced by moving the source further away from the borehole. A more distant source would be less likely to initiate a tube wave.

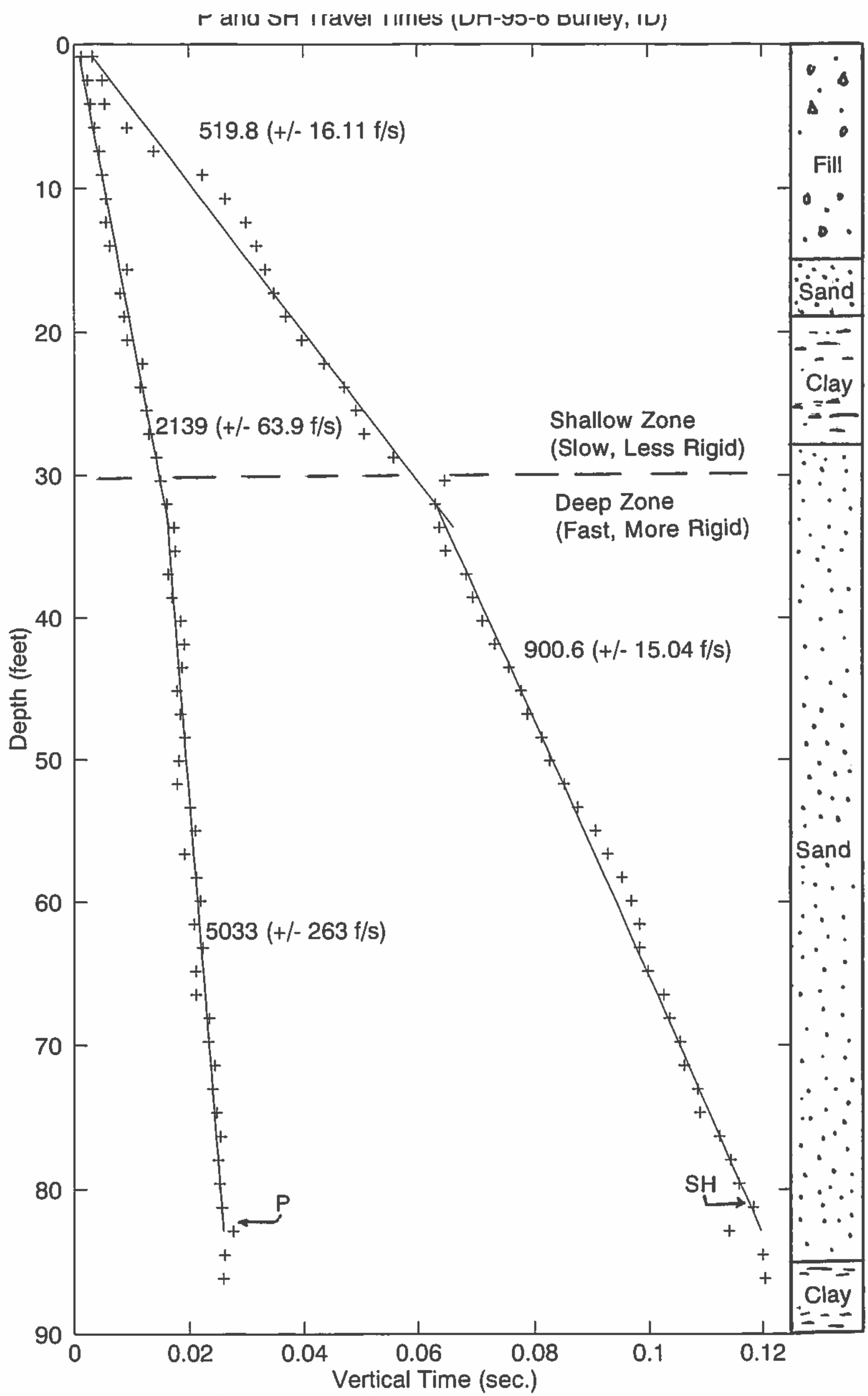

Figure 1: The vertical travel times of the SH and P waves suggest a transition to a more rigid soil at a depth of 30 feet. Velocities are found from the slopes of the linear fit (solid line) to the travel times. The observed data are shown by "+" symbols.

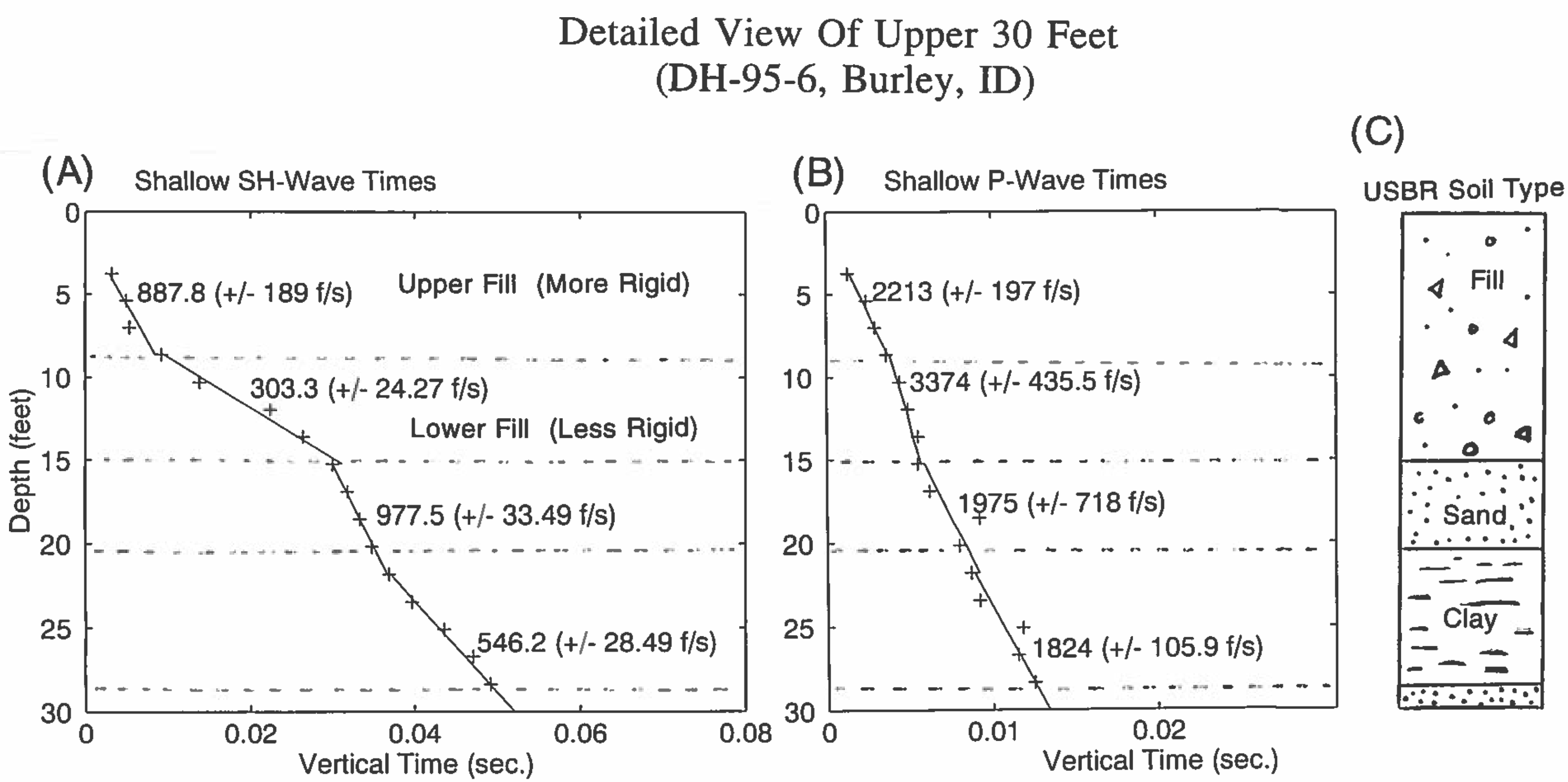

Figure 2: Detailed view of the first 30 feet. The shear (A) and compressional wave (B) travel time profiles are displayed next to the drillers report (C) supplied by USBR. The shear data reveals that the fill consists of a fast upper layer (probably compacted) over a slower, less rigid base layer. These are followed by the sand and clay layers, with the sand being more rigid than the clay. The compressional velocities are consistent with partial water saturation. It may be that the clay layer confines the deeper sand aquifer.

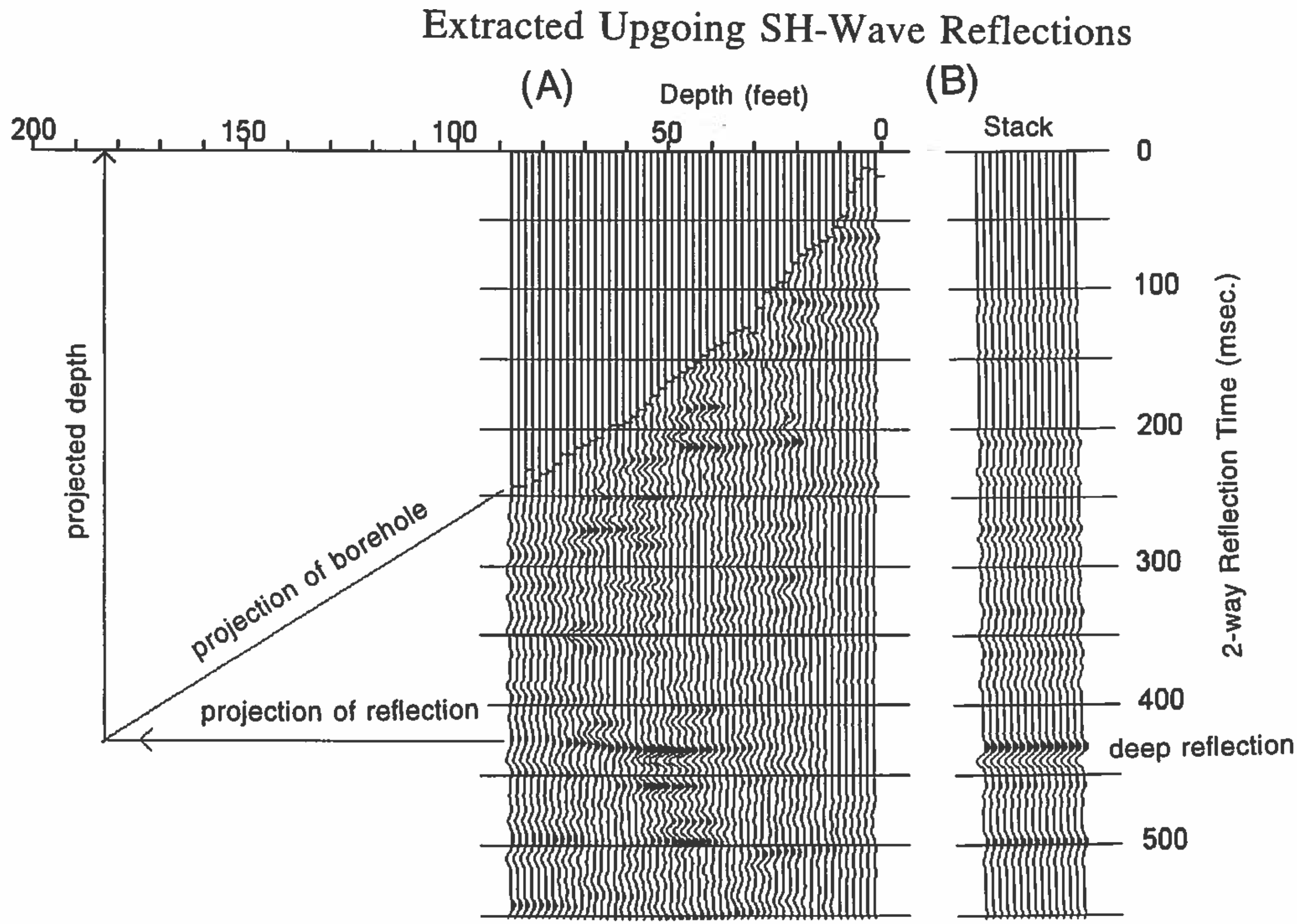

Figure 3: (A) The upgoing SH-wave reflections and (B) The stack of all up-going reflections in 2-way time. The most consistent reflection seems to be originating from below the borehole at a projected depth of about 180 feet. This may represent a boundary, such as bedrock, that could be mapped from the surface.

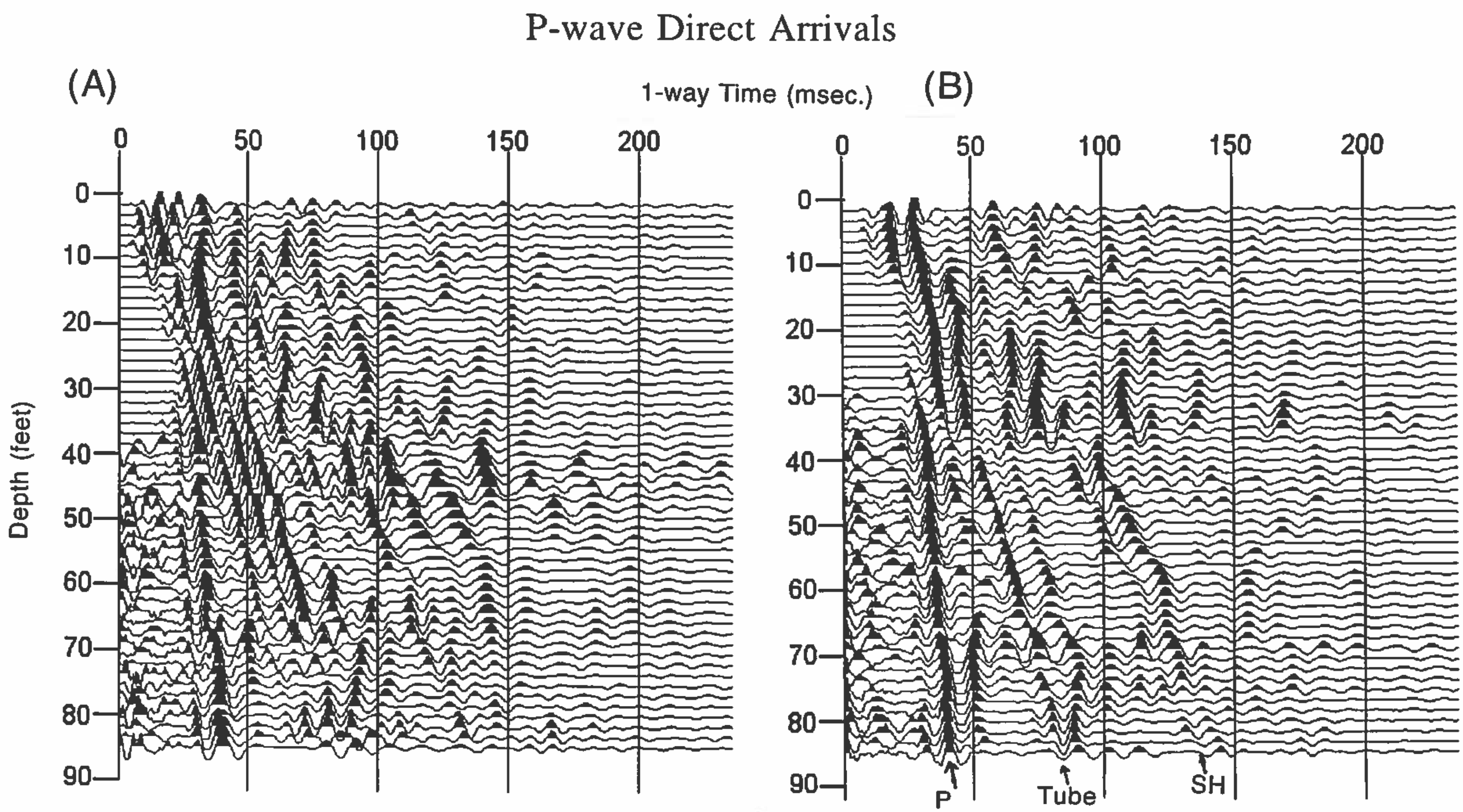

Figure 4: A) P-wave direct arrivals from the vertical hammer source. B) P-wave enhanced direct arrivals from the horizontal hammer source. Both recordings have been filtered (80Hz high pass) and balanced to reduce amplitude variations. The tube waves are in fact significantly larger in amplitude than the P-wave direct arrivals.

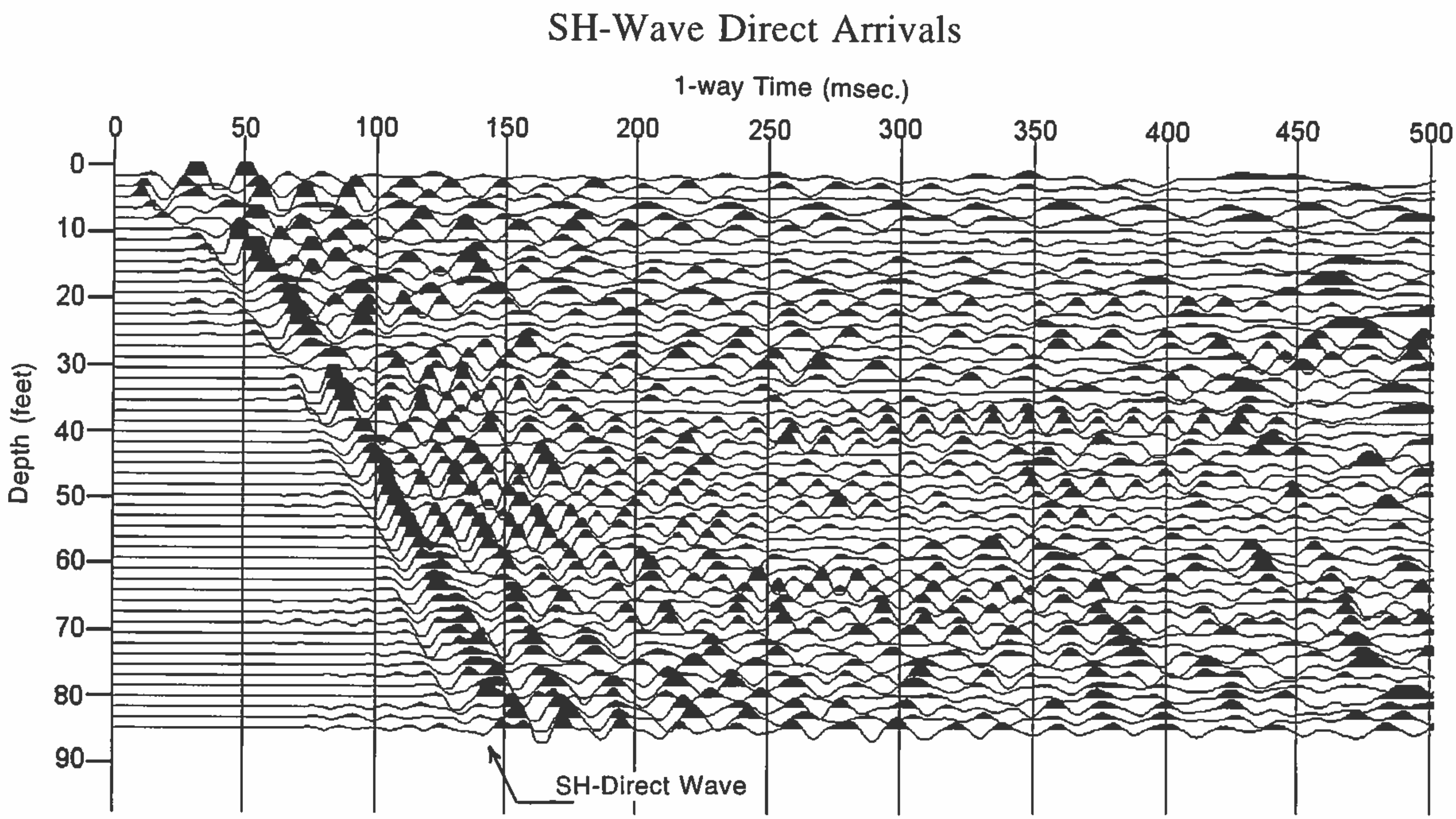

Figure 5: SH-wave direct arrivals. SH-wave motion was confirmed by reversing the source polarization. Subtraction of the polarized records produced the SH enhanced version shown above. Addition of the polarized records produced the P enhanced version of the horizontal hammer data shown in Figure 4. In all cases, a reference phone was used to correct for amplitude and triggering variations associated with the source.

Acknowledgements

The author's would like to thank the Idaho State Board of Education for providing funding for this work under research grant 95-056. Thanks also go to Keith Nottingham of ITD District 3 for suggesting this borehole location and to the U.S. Bureau of Reclamation for providing the geologic logs.

References

Dise, K., M.G. Stevens, and J.L. Von Thun, 1994, Dynamic Compaction to Remediate Liquefiable Embankment Foundation Soils, in In-Situ Deep Soil Improvement, Proceedings of sessions, ASCE National Convention, Atlanta, Georgia, ASCE Geotechnical Special Publication No. 45.

Recording Parameters

Bison 9600 Engineering Seismograph
Record Length: 2500 samples
Sample Interval: .00025 seconds
Low Cut Filter: 8 Hz
High Cut Filter: 1000 Hz

Source Location:
0.8 meters south of borehole at ground level
Source Parameters:

Horizontal Hammer

Polarization: Horizontal Blow, 90 and 270 Degrees Azimuth
Weight: 53.4 N
Drop Height: 0.5 meters, pivoted from 0.8 meter handle
Stricken Object: 1.0 x 0.23 x 0.17 meter railroad tie, weight=245 N
Hold Down Weight: (2) 300 N Sand Bags=600 N

Vertical Hammer

Polarization: Vertical Blow
Weight: 26.7 N
Drop Height: 0.5 meters, pivoted from 0.8 meter handle
Stricken Object: redwood base plate, 0.135 x 0.035 x 1.63 meters
Hold Down Weight: (2) 300 N Sand Bags=600 N

Geophone Stations:
Interval=0.5 meters
Shallow most Station, 0.3 meters below ground level
Deepest Station, 26.3 meters below ground level