Ground-penetrating radar (GPR) and shallow seismic surveys at Calgary International Airport, Alberta

Robert R. Stewart, Han-xing Lu, and Don C. Lawton

ABSTRACT

A ground-penetrating radar survey was conducted alongside a 2.4 km seismic line at the Calgary international airport, Alberta. The GPR survey used a 250 MHz Noggin® system. Shallow structure, to about 1 m depth, is evident on the GPR sections. Preliminary analysis of the GPR data gives velocities from 0.09 m/ns to 0.146 m/ns. We also acquired a shallow 3-C seismic profile. In this case, the hammer seismic line had 20 3-C receivers. We used vertical and SH-horizontal hammer blows on a specially constructed base plate to generate both P and SH waves. Shallow P-wave velocity is measured to be 464 m/s (from interpreted direct arrivals) while the SH velocity is 285 m/s. Stacking velocities were 400 m/s and 200 m/s for P and SH-waves, respectively. A brute stack section indicates reflectors to depths of about 20 m.

INTRODUCTION AND SURVEY OBJECTIVES

The goal of the ground-penetrating radar (GPR) surveys is to provide a very high-resolution image of the near surface. We are interested in testing the imaging capabilities of the GPR technique in areas of glacial till. Specifically, we would like to know if GPR data can assist with seismic operations and data processing. For example, is there some aspect of the GPR section that correlates with the quality of the seismic data recorded? Does the GPR structure give an indications of seismic statics? Analysis is ongoing, but this paper will show some of the data gathered and considered to date.

We also acquired a short 6-C seismic profile. By 6-C data, we mean that there were 3-C geophones that recorded a vertical hammer blow on a base plate as well as transverse hammer strikes on the base plate. Had we struck the plate with an in-line or radial blow, we could have recorded 9-C data. The purpose of the shallow seismic line was to, again, investigate methods to provide information about the near-surface.

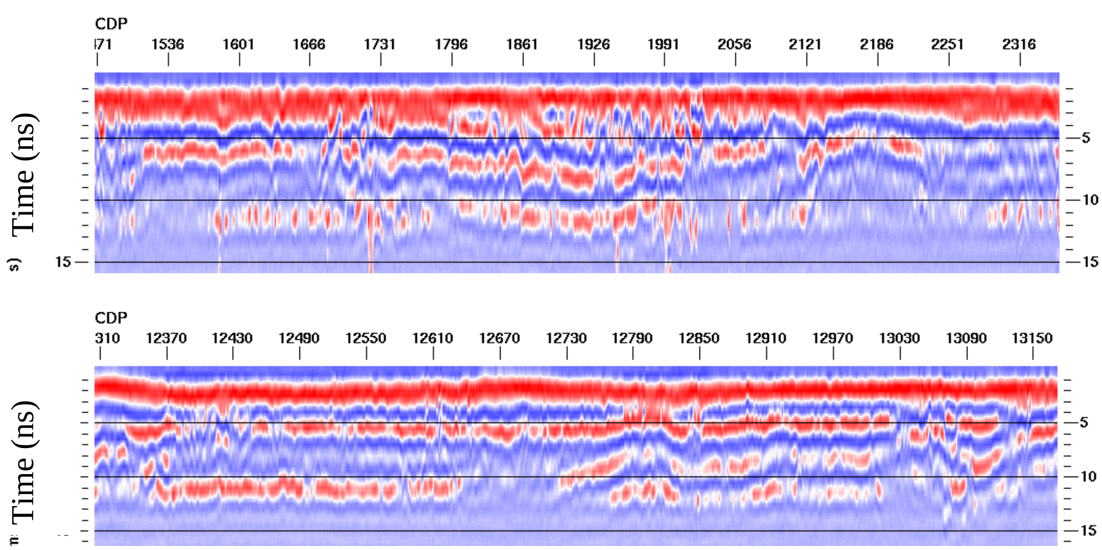
GPR EQUIPMENT AND SURVEY

We used Sensors & Software Inc.'s Noggin®^{plus} 250 and Smart Cart® system (Figure 1). This unit had a 250 MHz antenna (with bandwidth 125-375 MHz). The radar source is triggered every 10 cm (by a roller turned by one of the wheels). The measurements were conducted on August 28, 2001 under dry and hot (30°C) conditions. The total length of both the 3-C exploration seismic line and GPR survey was 2.4 km (Figure 2). We surveyed the line in both directions (for a total of 4.8 km). We made several velocity measurements from the data while surveying the line. The velocities were calculated by fitting a hyperbola to a diffraction event. Two velocities calculated near station 272 were 0.122 m/ns and 0.146 m/ns. Some sixty metres away (station 268), the velocity was 0.090 m/ns. Sensors and Software (1999) give values of 0.100 m/ns for soil, 0.130 m/ns for dry soil, and 0.170 m/ns for very dry soil.

Surveying the 2.4 km line with the Smart Cart® system took about one hour. These data are bulk shifted by 13 ns (to subtract out the direct arriving air wave) and gained with an AGC operator. We have also migrated these data with a velocity of 0.13 m/ns. Selected sections from along the 2.4 km line are shown in Figure 3.

FIG. 1. Noggin®^{plus} 250 MHz and Smart Cart® near station 101 at the Calgary International Airport site. The two vertical vibrators used to shoot the seismic line are in the background.

FIG. 2. North end of the 2.4 km seismic and GPR lines. Students deploy and plant 3-C geophones.



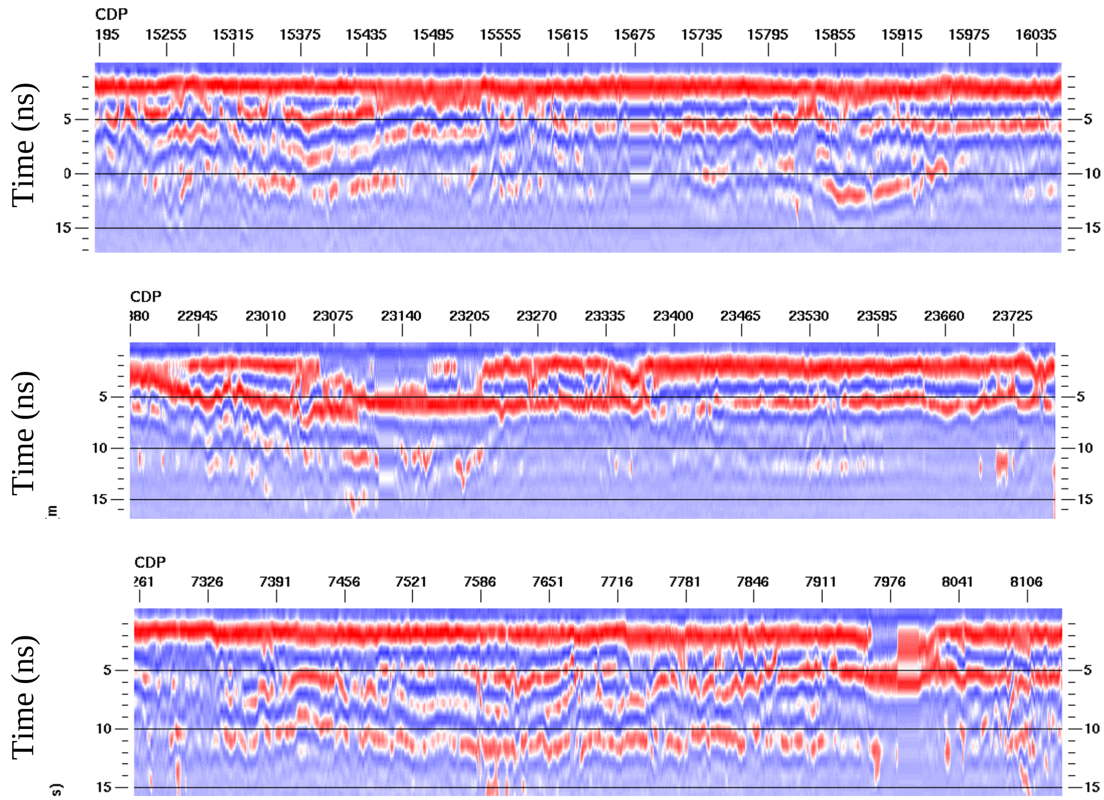


FIG.3. Selected portions of the 2.4 km GPR line. Traces are acquired every 10 cm. The zero-offset GPR data are migrated with a velocity of 0.13m/ns.

HAMMER SEISMIC SURVEY

We conducted a 6-C, hammer seismic survey near the central portion of the 2.4 km seismic line. In this case, we used a 60 channel EG&G seismic recorder and twenty 3-C geophones. The geophones were planted 1.0m apart. The source was a small sledge hammer that struck a special cleated base plate. The plate was first hit from the top to excite primarily P-wave energy. The plate was then struck on the side from east to west to generate an SH-wave, then west to east to generate an oppositely polarized SH-wave. The source was used at each half-station. There were 21 source location used. The data from the vertical hammer hit and vertical receivers are shown in Figure 4.

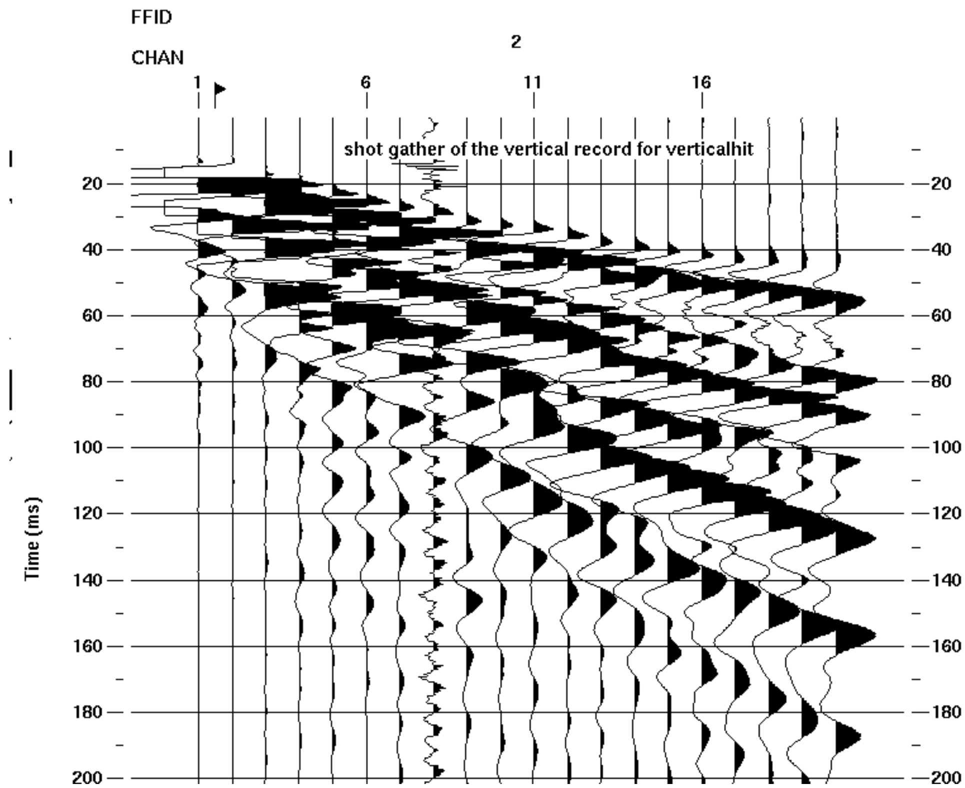


FIG. 4. Shot gather for the short-spread hammer seismic line. Vertical hammer blow as recorded by vertical geophones. Receivers are separated by 1.0 m.

The data recorded by the radial (or in-line) element of the geophone are shown in Figure 5. We intend to process these data for shallow converted waves. The east-west and west-east hammer blows on the base plate as recorded by the transverse geophone are shown in Figure 6. We can subtract these E-W and W-E traces to amplify the SH data and suppress the P-wave events or add them to enhance P-wave data. The results of both operations are shown in Figures 7 and 8.

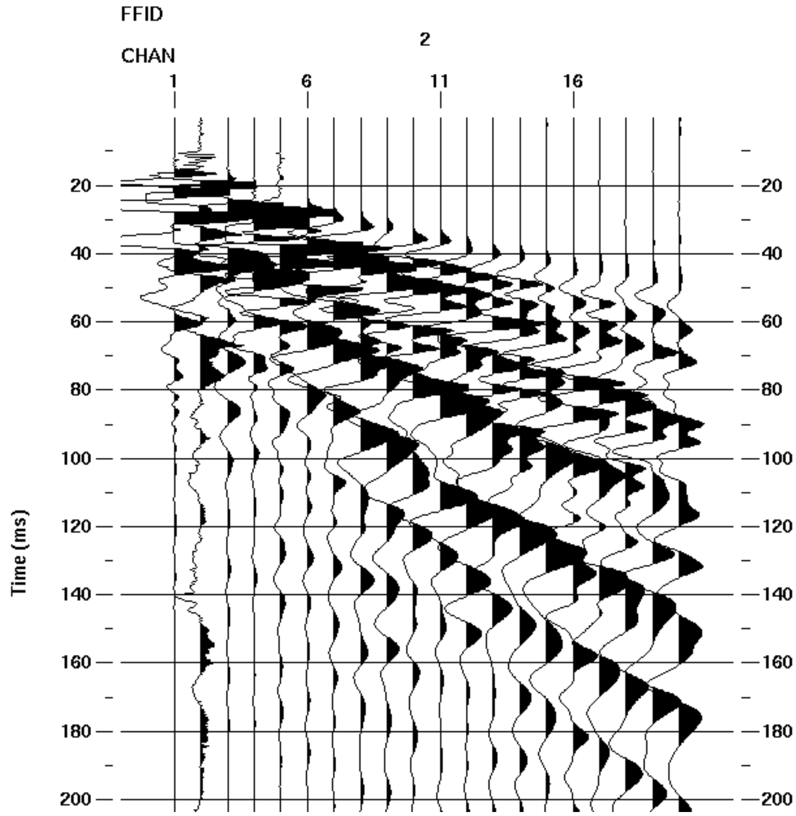


FIG. 5. Shot gather for the short-spread hammer seismic line. Vertical hammer blow as recorded by the radial geophones.

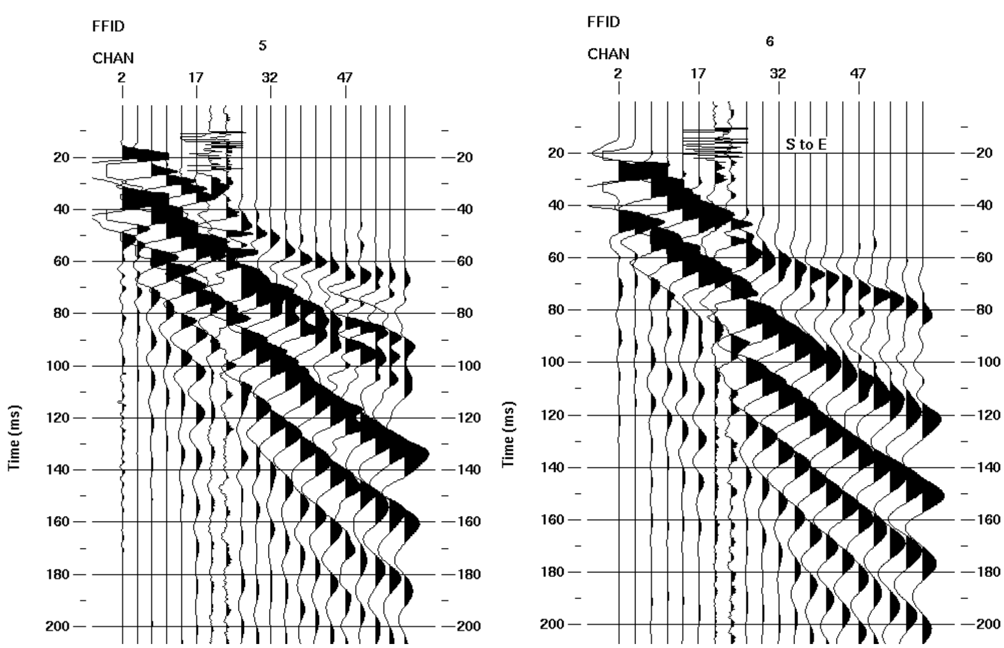


FIG. 6. Horizontal hammer strikes as recorded on the transverse geophones. a) the west-east blow, b) the east west strike.

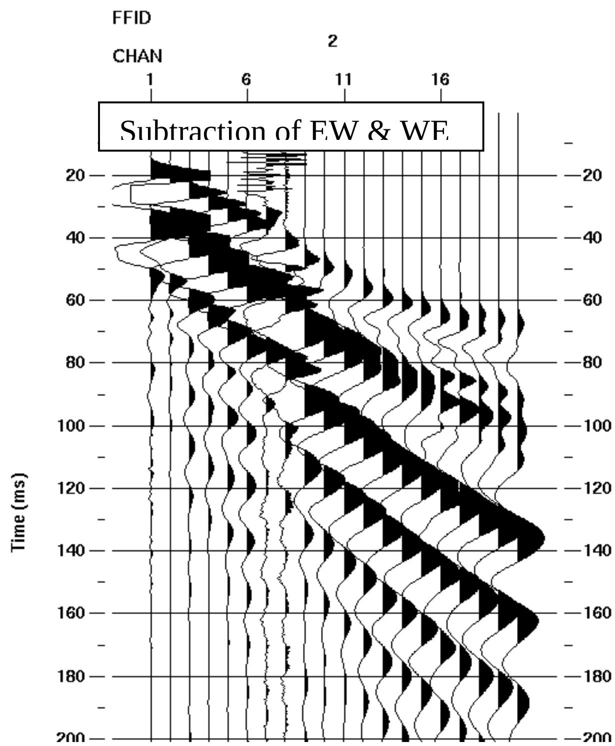


FIG. 7. Subtraction of the two polarized hammer blows, as recorded on the transverse channel, to provide an enhanced SH-wave.

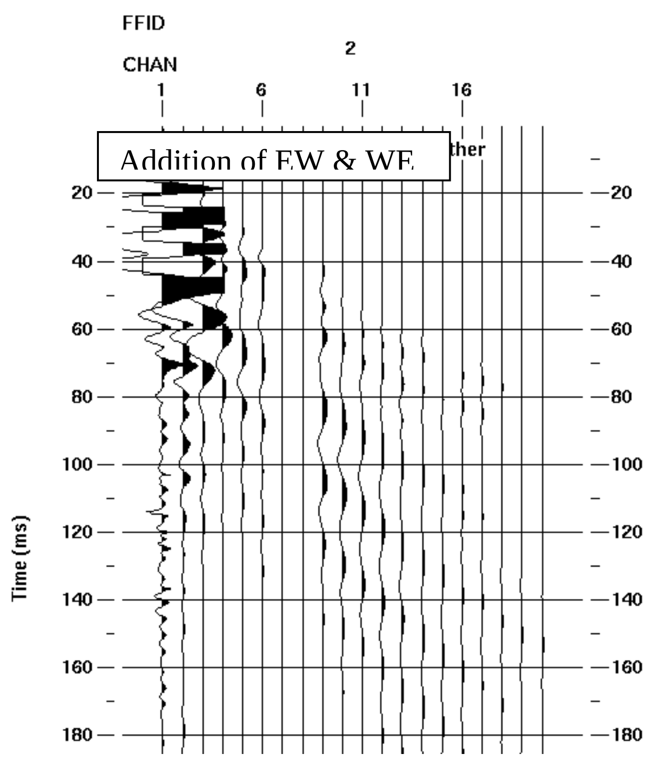


FIG. 8. Addition of the two polarized hammer blows, as recorded on the transverse channel, to provide an indication of the P-wave contamination.

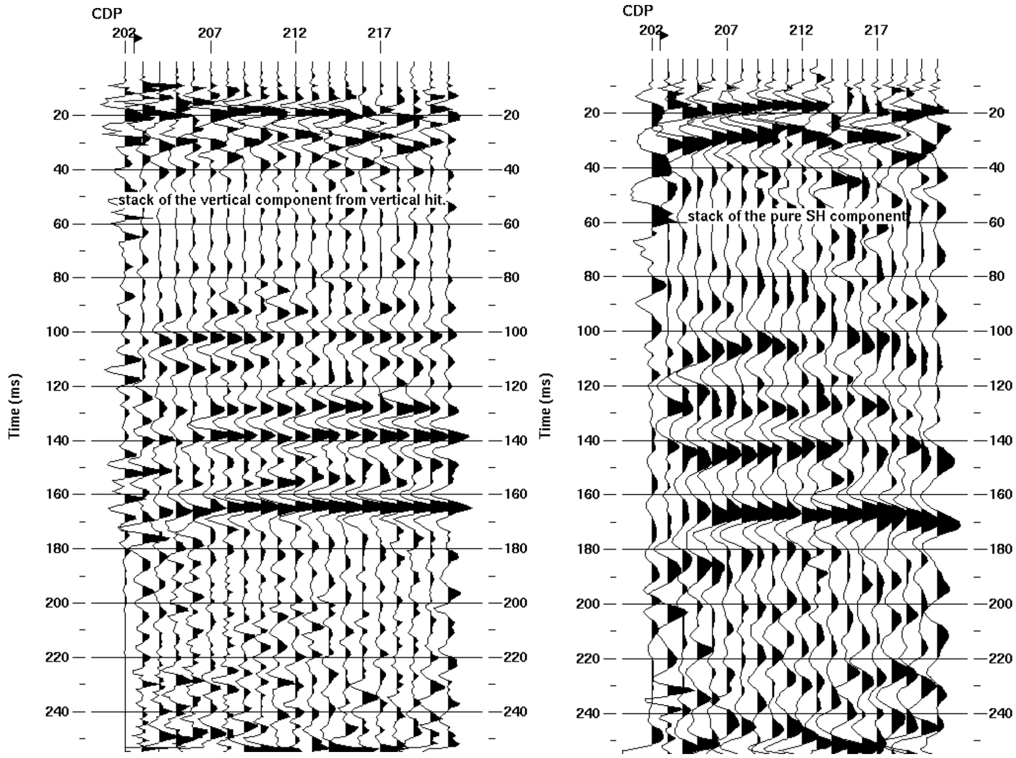


FIG. 9. The stacked section of the vertical component from vertical hit is on the left. The stacked section of the pure SH section from the subtraction of the two polarized blows is on the right.

The hammer seismic survey generated usable signal from about 100-250 Hz. From the direct arriving energy on the vertical channel, we calculate a P-wave velocity of 464 m/s. Similarly, on the enhanced transverse channel, we calculate an SH-wave velocity of 285 m/s. Stacking velocities for P and SH-waves were 400 m/s and 200 m/s, respectively. The processed section shows good reflectors to depths of around 20 m. We are puzzled by the similarity of the sections in Figure 9. The structure for the SH-waves should be at a time about twice that of the P-wave. Further research is required to solve this mystery and develop confidence in the final sections.

CONCLUSIONS

We acquired both shallow GPR and multicomponent seismic data. A preliminary assessment of these data sets indicates that that the two techniques are providing reflectivity sections of the shallow surface. The GPR appear to give a highly detailed view of the top 1 m or so. Velocities determined are in the range given by other authors. The shallow seismic data also have provided a brute stack image. We look forward to correlating all of these images, including the statics solutions given by the exploration seismic line.

ACKNOWLEDGEMENTS

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