THREE DIMENSIONAL GEORADAR ACQUISITION WITH A REAL TIME POSITIONING SYSTEM

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SUMMARY

For efficient acquisition of three-dimensional (3-D) subsurface information, quasi-continuous georadar and coordinate data are recorded simultaneously as the georadar antennas are continuously transported across survey areas. A self-tracking laser theodolite with automatic target recognition capabilities has been adapted to serve as a real-time positioning system for the acquisition of the 3-D data. This surveying system provides complete coordinate information with high accuracy. To take advantage of advanced processing procedures the georadar data must be transferred on to a regular grid. A fast two-dimensional Fourier transform technique has been designed for this task. The system has been tested successfully across a number of geological targets in Switzerland. For example, 3-D georadar data were recently collected and processed across a glaciofluvial environment of 25 m x 25 m within a single day. Using the full 3-D information of the data set, channel sediments as well as surface reflections could be clearly identified with the help of time slices.

INTRODUCTION

Several investigations have shown the potential of three dimensional georadar measurements in different applications of near-surface geophysics (Beres et al., 1995; Grasmück and Green, 1996; Grasmück, 1996). Unfortunately, acquiring 3-D georadar data is usually time-consuming and therefore cost intensive. A particularly lengthy operation is the determination of the true coordinates of the georadar antennas. To ensure complete coverage of the investigation area, coordinate information is needed in real-time.

A vital component of a newly developed automated acquisition system, which increases significantly the speed of georadar data collection, is a commercially available self-tracking laser theodolite with an automated target recognition capability. The laser theodolite serves as a precise positioning system for the georadar surveys. To take advantage of standard multi-trace processing routines, the 3-D georadar data sets are passed through a modified processing scheme.

THE 3-D ACQUISITION SYSTEM

High quality subsurface georadar images require the application of trace-dependent topographic corrections. For example, to guarantee optimum processing of 100 MHz georadar data, location and elevation changes should be known with an accuracy of better than 2.5 cm. We obtain this level of accuracy with a newly developed commercial theodolite, which is capable of tracking a reflecting prism mounted on a moving georadar antenna. To match the coordinates to each georadar record, the personal computer (PC) triggers the georadar system using a signal transmitted via a long fiber optic cable (Fig. 1) or optional through a radio link.

Figure 1: The acquisition system uses a commercial georadar system, a self-tracking laser theodolite and a personal computer.

THE PROCESSING

Georadar data are usually collected along approximately parallel straight lines oriented in an arbitrary direction (Fig. 2). After acquisition, the data have to be gridded before they can be processed. We have to account for the much denser sampling along the recording lines than between them; initially, we choose to have smaller grid point intervals along the "inline" direction than along the "crossline" direction. To estimate the optimum orientation of the grid, we employ a two-dimensional Fourier transform technique. It is well known that coordinates of a series of nearly parallel lines in the X-Y recording plane will map to a single linear feature in the two-dimensional Fourier plane (Fig. 3). By fitting a straight line to the coordinates in the Fourier plane, an estimate of the optimum orientation of the grid may be determined. Once the grid has been defined, all georadar signals recorded within a small area are summed together to yield a single record for each grid point. The maximum size of the summed area depends on the radiation pattern and the area of the first Fresnel zone of the chosen antennas.

Figure 2: Coordinates of a 3-D survey.

Figure 3: 2-D Fourier spectrum of the coordinates.

THE 3-D DATA SET

One of our 3-D data sets was acquired from a glaciofluvial environment characterized by braided river deposits (Beres et al., 1995). By combining information derived from time slices and cross sections it is possible to quickly interpret structural variations with travel time (depth). Important features such as the ground water table may be determined from simple cross sections (Fig. 4a). More complex features associated with sediments that were deposited in an east-west oriented braided river system are best identified by using a combination of cross sections and time slices (channel sediments in Fig. 5a). Because we used unshielded antennas, noticeable reflections from the surrounding quarry walls are a feature of the images (Fig. 4b). Time slices allow these surface reflections to be readily identified (Fig. 5b). Appropriate processing strategies to eliminate them may be designed and implemented on the basis of information provided by the 3-D data set (Grasmück, 1996).

Figure 4: Example cross sections extracted from the processed data set: gridding, trace stacking and scaling (agc 30 ns) have been applied. Structural variations with travel time (depth) may be interpreted from the two cross sections; one in an east-west (a) and one in a north-south (b) direction. Linear features oriented in a roughly east-west direction correspond to sedimentary units deposited in braided river channels. Note the reflection from the ground water table as well as the strong unwanted reflections from the quarry walls.

Figure 5: Time slices from (a) 130 ns and (b) 240 ns: Linear features oriented in a roughly east-west direction correspond to sedimentary units deposited in braided river channels in time slice (a). Surface reflections can be correctly determined from time slice (b) in combination with the corresponding cross sections.

CONCLUSIONS

With the new 3-D acquisition system, one person is able to survey a relatively large area within a single day with a positioning accuracy of ± 2.5 cm in all three directions. Recording intervals along and between the lines have to be chosen small enough to avoid spatial aliasing. The data may be processed and visualized automatically within a short period of time. To apply standard processing techniques, the data must be transferred on to a regular grid. An optimum fit between the grid points and the original recording locations can be achieved using a two-dimensional Fourier transform method. Reflections from channel sediments and from surface features may be quickly identified and interpreted on the basis of the resultant 3-D georadar data set by using time slices together with cross sections.

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