Combined use of common depth point and common offset techniques in shallow reflection seismics

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Introduction

The application of high-resolution shallow reflection seismics is dependent on the ability of the near-surface material to propagate high-frequency seismic energy in the 100-500 Hz range. In overburden, this is normally encountered in areas with a high water-table and fine-grained surface materials (Hunter et al. 1984). Under these conditions, reflectors at depths of ten to several hundred metres can be mapped. Over the last ten years equipment has been developed to transmit and record high-frequency seismic energy using in-hole shotguns, high-frequency geophones and digital seismographs with a high dynamic range. The method has become more cost-effective through the introduction of the microcomputer for data acquisition and processing. High-resolution shallow reflection seismics can now be successfully applied to geological, engineering and environmental problems (e.g. Meekes et al. 1990, Pullan & Hunter 1990, Miller & Steeples 1994). The most commonly applied shallow reflection seismic techniques are common offset (CO) (or optimum offset) (Hunter et al. 1984) and common depth point (CDP). In this contribution we discuss the pros and cons of both methods. We also show how CO-data can be derived from data recorded with the CDP technique and how CO- and CDP-data both can be used in the interpretation of reflection seismic time sections.

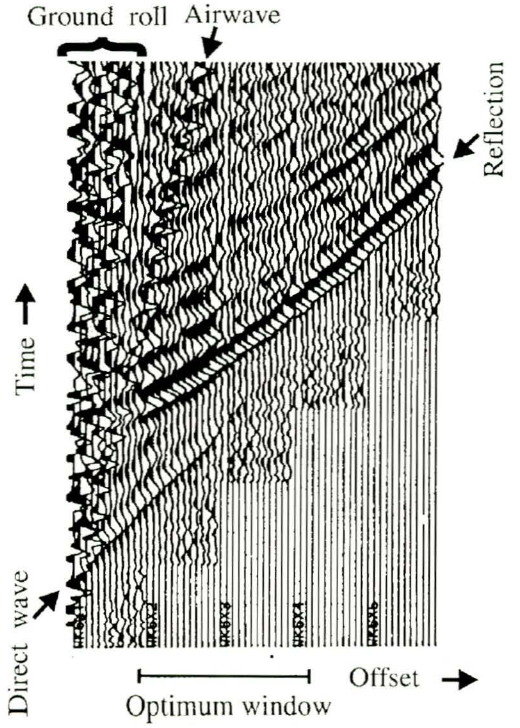

Fig. 1. Common events on a walkaway noise test record.

The common depth point and common offset techniques

Choosing the optimum window

A seismic time section is shown in Fig. 1 (from Hunter et al. 1988). The section was recorded as a walkaway noise test (Knapp & Steeples 1986). The optimum window (Hunter et al. 1984) is the horizontal range in which reflectors of interest can be viewed with a minimum of noise interference. To reduce the amount of surgical muting, the left (near-offset) side of the window is chosen so that noise events from surface waves (ground roll and ground-coupled airwaves) arrive after the reflections from the deepest target of interest. There are several factors governing the choice of the right (far-offset) side of the window; (1) reflections from shallow targets will interfere with the direct wave or refractions at great offsets; (2) reflections from shallow targets will be wide-angle and suffer from phase- and amplitude changes according to the Zoeppritz equations (Pullan & Hunter 1985); (3) apparent low frequency pulses and loss of resolution will be the result after time stretching from NMO corrections (see below) of wide-angle reflections.

From the points listed above, it is obvious that the choice of the position of the right side of the optimum window will affect the definition of shallow reflectors.

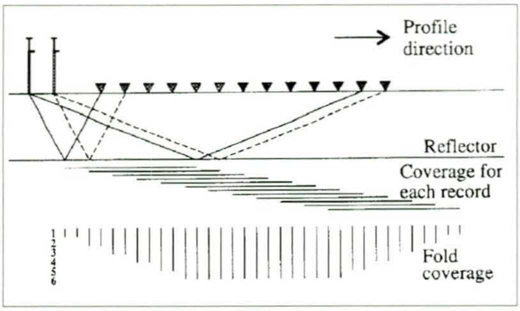

Fig. 2. Common depth point profiling.

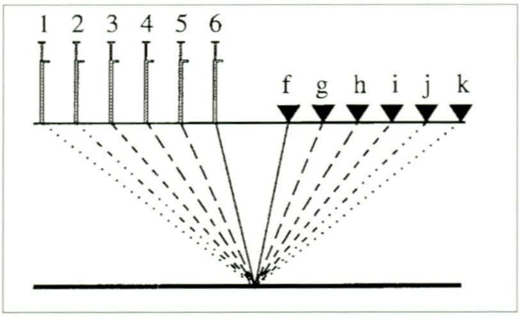

Fig. 3. Example of source-receiver configurations in a CDP gather.

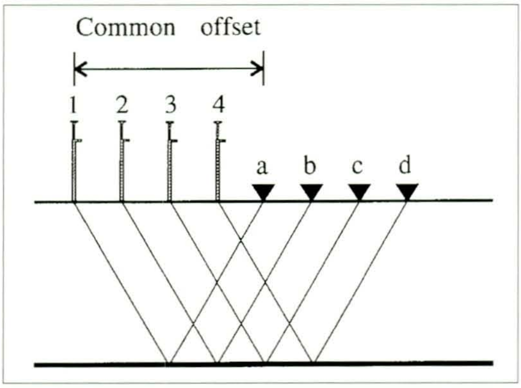

Fig. 4. Common offset profiling.

Short outline of the CDP and CO techniques

When conducting a CDP seismic reflection survey, it is ideal to place all receivers equal spaced in-line inside the optimum window. Once having found the appropriate source-and-receiver spacing and the offset from source to the near-offset receiver, a CDP survey can be conducted according to Fig. 2. The recorded traces are sorted into CDP gathers (Fig. 3). Prior to stacking the traces in the CDP gathers, one has to perform normal move-out (NMO) correction. This correction has the effect of moving the source and receiver to the location directly above the reflection 'point'. The correction is dynamic, and its magnitude is dependent on source-receiver offset, two-way traveltime to a reflector and the seismic velocity of the medium above a reflector. Velocities can be found by performing velocity analysis on CDP gathers. The NMO correction involves time stretching that becomes severe at large offsets and for shallow reflectors. Thus, shallow reflectors won't stack or they become ill-defined and blurred. To be able to record both shallow and deep reflectors with a minimum of surgical muting, the optimum window can be quite narrow, and the production rate becomes small.

The extraction of common offset (CO) data from multichannel records allows us to broaden the optimum window. By doing so, there will be noise from surface waves on the near-offset traces late on the CDP record that can be removed by surgical muting. CO-data can be assembled by picking the same channel from subsequent CDP records. CO can also be carried out as a stand-alone acquisition technique as shown in Fig. 4. Depth conversion of CO records is non-linear.

Pros and cons of the CDP and CO techniques

While the CDP technique requires cost- and time-consuming processing, very little processing is needed with the CO technique, allowing the user to quickly obtain a picture of the subsurface without having to first determine its velocity structure. Data acquisition efficiency is quite similar for the two techniques. Due to multifold coverage of subsurface reflectors, the signal-to-noise ratio is better with the CDP technique. Shallow reflectors are often ill-defined with the CDP technique due to large offsets and wide-angle reflections. The definition of shallow reflectors can in some cases be improved by performing amplitude versus offset (AVO) analysis to reduce move-out errors (Ursin & Ekren in press).

Examples of CDP and CO records

The first example is from Vigra, western Norway. The objective of the survey was to map bedrock topography. Fig. 5 shows the CDP record (left) and the CO record. The records are derived from the same multichannel records. Recording time is 100 ms, distance from source to the near-offset receiver is 20 m and the receiver spacing is 4

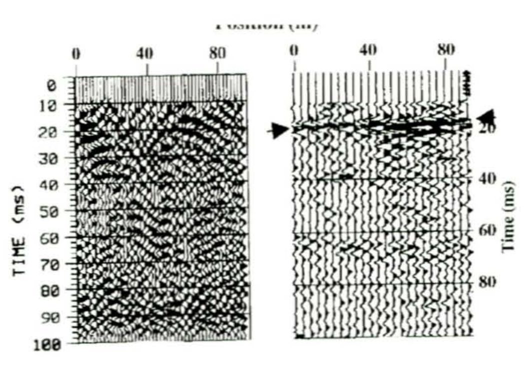

Fig. 5. CDP (left) and CO records derived from the same multichannel records. Arrows denote bedrock reflector.

m. The CO record was assembled by picking the first trace from each multichannel record. The example illustrates the problem with shallow reflectors on CDP records. The shallow bedrock reflector on the CO record (indicated by arrows) cannot be recognised on the CDP record due to NMO time stretching and far-offset interference with direct/refracted waves.

The second example is from Haslemoen, southeastern Norway. The objective of the survey was to delineate intra-alluvial structures. Fig. 6 shows the CDP record (left) and the corresponding CO record, illustrating the better signal-to-noise ratio that can be achieved with the CDP technique. Recording time is 300 ms (only a part of the record is shown). Distance from source to the near-offset receiver is 10 m and the receiver

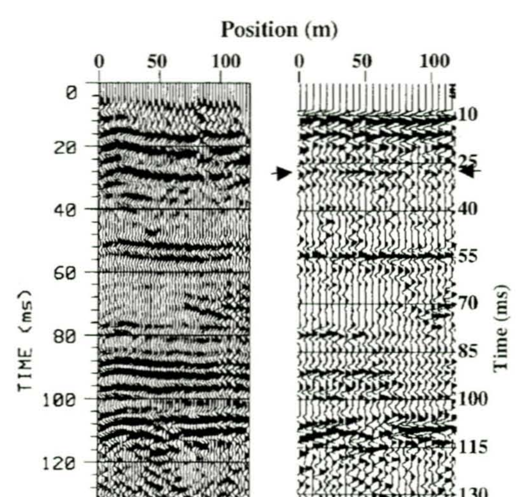

Fig. 6. CDP (left) and CO records derived from the same multichannel records. Arrows denote shallow, overburden reflector.

spacing is 5 m. The records are dominated by horizontal reflectors, probably representing layered sand/silt (according to Riis, 1992). The event at 105-110 ms is the bedrock reflector. Events between 20 and 30 ms on the CDP record appear low-frequent and incoherent due to NMO time stretching. Shallow reflectors can more reliably be detected on the CO record. In the example, a weak overburden reflector can be observed at about 30 ms (indicated by arrows).

Conclusions

CDP- and CO-data can both be derived from multichannel records. While CDP-data offer a higher signal-to-noise ratio than CO, it is shown that using only CDP-data can give poor resolution of very shallow reflectors. In the interpretation of seismic reflection data the combined use of CDP- and CO-data has proven to give more information than by using either CDP- or CO-data.

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