GEOPHYSICS, VOL. 63, NO. 4 (JULY-AUGUST 1998); P. 1348–1356, 6 FIGS., 3 TABLES.

Large near-surface velocity gradients on shallow seismic reflection data

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ABSTRACT

Extreme velocity gradients occasionally present within near-surface materials can inhibit optimal common midpoint (CMP) stacking of near-surface reflection arrivals. For example, abrupt increases in velocity are observed routinely at the bedrock surface and at the boundary between the vadose and the saturated zone. When a rapid increase in near-surface velocity is found, NMO correction artifacts manifested on CMP gathers as sample reversion, sample compression, or duplication of reflection wavelets can reduce S/N ratio on stacked data or can stack coherently. Elimination of these nonstretch-related artifacts using conventional NMO-stretch muting requires near-vertically incident reflection arrivals and allowable stretch ratios as small as 5% in some shallow environments. Radical allowable stretch mutes are not a feasible means to subdue these artifacts if high-amplitude coherent noise on near-offset traces inhibits identification and digital enhancement of shallow reflections. On most shallow seismic reflection data, long-offset reflection arrivals (but less than wide angle) are critical to the generation of an interpretable stacked section. The difference in offset between the optimum window for shallow reflections within unsaturated sediments and reflections from the underlying saturated or consolidated-material portion of the section inherently limits the effectiveness of conventional NMO corrections. Near-surface average velocity increases of 200% in less than two wavelengths and at two-way traveltimes less than 60 ms are not uncommon on shallow reflection data. Near-surface reflections separated by large velocity gradients can rarely be accurately or optimally CMP processed using conventional approaches to NMO corrections. Large velocity-gradient shallow reflection data require segregation of shallow lower velocity reflections from higher velocity reflections during processing to maximize the accuracy and resolution potential of the stacked section, as shown by examples herein.

INTRODUCTION

Contrasts and comparisons between conventional seismic reflection (predominantly used for petroleum exploration) and shallow seismic reflection (which focuses on environmental, engineering, mining, and groundwater problems) consistently suggests reciprocity of methodologies and techniques is not automatic and is more than a simple relationship of scale (Steeples and Miller, 1990; Miller, 1992; Steeples et al., 1995). This lack of linearity is not surprising when considering the diverse propagation characteristics of source-generated noise in the early time portion of a seismogram. Shallow seismic reflection studies routinely have been plagued by overwhelming near-source noise arriving within the optimum time and offset window for most shallow reflecting events.

One of the more troublesome and potentially detrimental near-surface problems relates to the occasional extreme contrast in interval velocity between the unconsolidated portion of the vadose zone and the bedrock surface or water table (Birkelo et al., 1987; Miller and Xia, 1997). Degradation in frequency content of shallow reflection wavelets during the transformation from shot gathers to common midpoint (CMP) stacked sections has been correlated to insufficient compensation for statics, incomplete correction for nonvertical incidence, changes in reflection wavelet with source-to-geophone offset, and source or receiver variability (Pullan et al., 1991).

Adjusting reflection wavelets on seismic data to compensate for nonvertically incident raypaths is necessary prior to CMP stacking (Mayne, 1962). Because average velocity normally increases with depth, the normal moveout (NMO) curves for a series of reflection events will possess decreasing curvature with increasing depth for a given offset window (Yilmaz, 1987). Correcting or flattening these curves to allow enhancement stacking of all reflection wavelets from a particular reflector,

Manuscript received by the Editor April 25, 1997; revised manuscript received November 25, 1997.
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