

Reflections from Geologic Interfaces Shallower than 30 m at the Pittman Lateral, Henderson, Nevada

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Richard D. Miller*, Don W. Steeples, Kansas Geological Survey; and Aldo Mazzella, U. S. Environmental Protection Agency

SUMMARY

The shallow seismic-reflection technique was effective in imaging reflectors within the upper 20 m at the Pittman Lateral in Henderson, Nevada. The single 12-fold, 260 m long reflection profile was acquired with a 0.6 m station spacing. Appropriate recording equipment and parameters were critical to the success of the study. Parameter selection during data processing enhanced reflection energy difficult to identify on unprocessed shot gathers. Three reflection events are interpreted on the CDP stacked section with vertically incident two-way travel times of less than 60 ms. The seismic profile enabled detection of a second intra-alluvial feature capable of channeling contaminated ground water previously undetected by a linear series of test borings spaced 60 m apart, parallel to, and 20 m offset from the seismic survey.

INTRODUCTION

The Pittman transect in Henderson, Nevada, is a site where polluted waters from an unknown source are moving laterally toward intake facilities for the Las Vegas water supply. Detailed knowledge of the bedrock surface is crucial in planning well locations for ground-water-quality monitoring. Changes in ground-water quality often first appear in monitor wells located in topographic lows in the bedrock surface. Data possessing necessary detail for conclusive mapping of bedrock surfaces have generally come from extensive drilling programs which are time consuming, expensive, and environmentally undesirable. The seismic-reflection technique has the potential in suitable geologic conditions to image a shallow (4-20-m deep) bedrock surface with sufficient detail to assist in the locations for monitor wells (Miller et al., 1989).

GEOLOGIC SETTING AND FIELD PROCEDURES

A 12-fold CDP line, 260 m long, was acquired parallel to a series of wells approximately 60 m apart (Figure 1). Conductivity and gamma logs and geologist's stratigraphic logs, previously acquired at each well, were used to assist in planning the seismic field work and interpreting the resulting data.

The water table at this site is at a depth of roughly 5 m and is overlain by alluvial material composed predominantly of poorly sorted sands and clays. Drill data suggest these sands and clays terminate against a semi-consolidated clay bedrock at a depth of 12 to 30 m. The borehole data suggest the acoustical impedance contrast across this stratigraphic bedrock

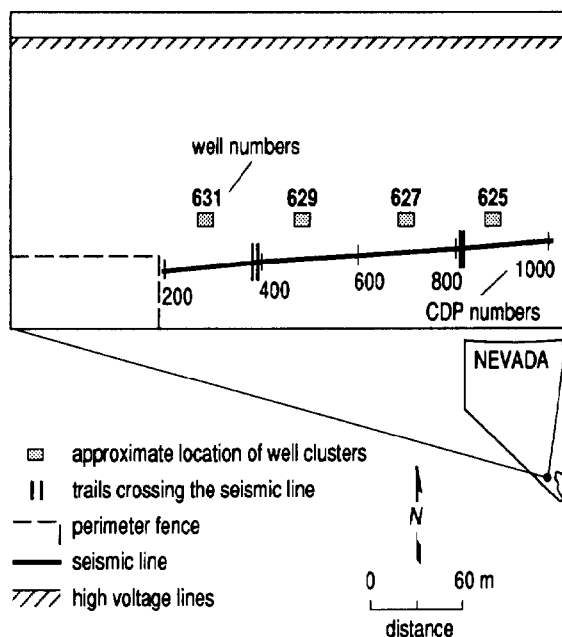


FIG. 1. Base map showing the 260 m of CDP seismic line.

boundary is marginal for production of seismic reflections. The seismic survey was intended to determine the feasibility of mapping the boundary between the alluvial materials and the underlying clay bedrock.

The data were collected using a silenced .30-06 hunting rifle as the seismic source and single 100-Hz Mark Products geophones with 14 cm spikes as receivers. The recording equipment as a unit possesses characteristics conducive to the generation and recording of high-quality seismic signal in dry, unconsolidated near-surface environments (Birkelo et al., 1987; Treadway et al., 1988; Miller et al., 1989).

An end-on source/receiver configuration with a source-to-closest-receiver distance of 3.7 m was used to collect the data. The 0.6 m shot and receiver station interval resulted in an effective spread length of 14.5 m. This spread geometry allowed the optimum recording window (Hunter et al., 1984) to be maintained while minimizing the horizontal subsurface sampling interval and therefore maximizing horizontal resolution across the entire line.

A 24-channel Input/Output DHR 2400 seismograph recorded the data on half-inch magnetic tape in modified SEG-Y format. The record length was

125 ms with a sampling interval of 0.25 ms. Analog-to-digital (A/D) conversion was 11 bits plus sign. Pre-A/D low-cut filters with a -3 dB point of 220 Hz and a 24 dB/octave roll-off were used to maximize potential resolution and reduce ground roll effects.

DATA PROCESSING

Data processing was done on an Intel 80386-based microcomputer using a proprietary set of algorithms (Eavesdropper) developed by the Kansas Geological Survey (Somanas et al., 1988). The processing flow was similar to that used in petroleum exploration. The main distinctions relate to conservative use of correlation statics, precision of the near-surface velocity analysis, extra care during muting operations, and lack of deconvolution.

Determination of an initial velocity function required analysis of a series of test sections, each simultaneously adjusted for a variety of possible velocity and static values. A group of constant velocity gathers were individually corrected for apparent static variability (no single trace was time-shifted more than 1 ms), using a correlation routine, and then CDP stacked. The series of constant velocity stacks resulting from this iterative velocity/statics technique were analyzed and preliminary time/velocity pairs determined for use in the primary processing flow. We emphasize that this procedure was only used to establish a velocity model and was not used on final processed sections.

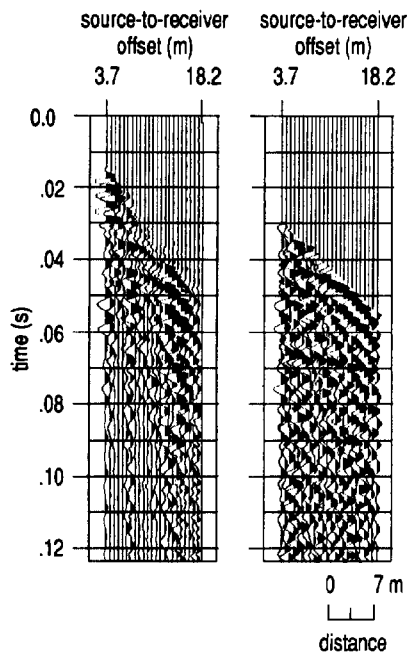


FIG. 2a) Unprocessed shot gather, b) same gather filtered, muted, and scaled.

RESULTS

Unequivocal identification of reflection information on field files is crucial for discriminating reflection energy from noise on a CDP stacked seismic section. A strong reflection event can be identified on some of the raw field files at about 40 ms (Figure 2a). The average calculated normal moveout (NMO) velocity of the event at 40 ms is around 525 m/s. This velocity and two-way time suggests a reflector depth of approximately 10 m. Deeper reflection energy present around 60 ms on the unprocessed file possesses an average NMO velocity of approximately 615 m/s representing a reflector depth of about 20 m. The reflection energy, as identified on field files, possesses a dominant frequency of around 180 Hz. Vertical bed resolution on the order of 1 m can be expected, assuming the 1/4 wavelength criterion (Widess, 1973). The coherency and consistency of the two events on unprocessed field files, in conjunction with high correlation of the calculated moveout velocities to appropriate hyperbolae, allows high confidence in classifying them as reflections.

Several reflection events can be interpreted on the final stacked section in Figure 3a & 3b. Two of the three reflection events interpreted on the CDP stacked sections can be identified on the filtered field files (Figure 2b). The shallowest reflection (30 ms)

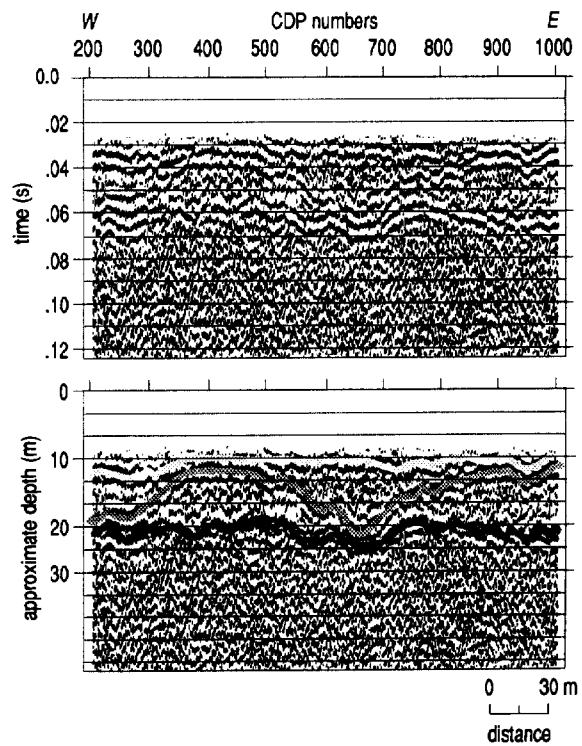


FIG. 3a) 12 fold CDP stacked section, b) interpreted stacked section.

equates to a reflector depth of approximately 10-12 m across most of the line. The deepest interpretable reflection event varies across the line from 50 ms (15 m) to 70 ms (21 m) and is interpreted as an unknown layer below the clay bedrock noted in drill cuttings. A subtle intermediate reflecting event is identified at times ranging from 40 to 60 ms (12 to 18 m) and is interpreted as the top of the clay bedrock. The 20 ms of variation in two-way traveltime of the intermediate reflection represents approximately 6 m of vertical change in the reflector along the line. Stratigraphic interpretations of the reflection data are speculative at this time without detailed drill information from at least two additional holes.

INTERPRETATION

The reflectors imaged by this seismic survey range in depth from approximately 10 to 25 m. No attempt was made to record reflections from times greater than 70 ms. The intermediate reflection interpreted on the seismic section is probably the unit defined by drilling and geophysical logs as the bedrock surface. The interpreted surface of this reflector agrees quite well with the drill and log information. Some subtle interference phenomena along the edges of the buried valleys near CDPs 600 and 200 suggest that the unit may be very thin (i.e., less than 2 m) or absent in the valleys. Seismic data suggest a deeper, relatively flat reflector is present at a depth of 20 to 25 m.

The horizontal resolution of drilling at this site was not sufficient to detect one of the buried valleys interpretable on the seismic-reflection data. The low between CDPs 500 and 700 is on the order of 50 m wide. The relative low in the intermediate layer was invisible to previous drilling. The horizontal sample spacing of the seismic data is on the order of 1/3 m, while the horizontal spacing of the drilling was 60 m. The same number of drill holes could have detected all the relative highs and lows in the intermediate reflector across the expanse of the seismic line if the seismic survey had preceded the drilling.

The seismic data do suggest the presence of acoustical interfaces as interpreted (Figure 3b). These acoustical interfaces can represent either velocity or density contrasts that can sometimes be caused by age discontinuities that are difficult or impossible to interpret from drill cuttings. For that reason, any verification holes should be core-drilled.

Positive correlation of the interpreted reflection events to borehole information is not possible without an uphole seismic-velocity survey. One-way traveltime measured from an uphole velocity survey would allow an accurate time-to-depth conversion. NMO velocities used here are estimated from a curve fitting routine and then multiplied by 1/2 the reflection time to calculate approximate reflector depths (Figure 3b).

CONCLUSIONS

The seismic-reflections technique can be used to map at least three reflectors shallower than 25 m at the Pittman Lateral in Henderson, Nevada. Correlation of reflection times to geologic unit depths will require a seismic uphole survey. Reflection energy was recorded from as deep as 70 ms two-way travel time. The deepest recorded reflection is relatively flat but fluctuates between about 60 and 70 ms in two-way traveltime which is probably about 20 m deep. Higher-frequency seismic energy would eliminate, or at least greatly reduce, the interference observed between the refractions and the 30-40 ms reflector.

The "bedrock" / alluvium interface does not possess a strong enough acoustic impedance contrast to generate high-quality reflections on unprocessed data. However, substantial effort during velocity analysis and careful application of minimal static corrections resulted in the enhancement of an intermediate reflection. This reflection is probably what has been called "bedrock" on the basis of drill cuttings and geophysical logs. A previously unknown 20-25 m deep valley is interpreted on the stacked section between CDPs 500 and 700.

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NOTICE

Although the research described in this article has been supported by the United States Environmental Protection Agency through contract 68-03-3245 to the Kansas Geological Survey, it has not been subject to Agency review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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