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Abstract

In August 1993, two high resolution seismic experiments were performed in N-Tunnel and on the surface of Rainier Mesa above it. The first involved a surface-to-tunnel imaging experiment with sources on the surface and receivers in tunnel U12n.23 about 88 meters west of the NPE. The data obtained in this part of the experiment were of limited quality because of overwhelming 60 Hz noise in the tunnel. However, it was possible to estimate that the apparent average velocity between the tunnel and the surface was approximately 2.0 km/sec, which does provide a constraint on the mean velocity of P waves between the depth of the NPE and the surface. In a separate experiment, a high resolution reflection experiment was performed in order to image the lithology in Rainier Mesa down to the depth of the NPE and possibly greater. Good quality, broad band, reflections were obtained from depths extending into the Paleozoic basement, well below the NPE. A preliminary interpretation of these data yields several reflectors which correlate well with the lithology derived from drill hole logs. A high velocity layer near the surface is underlain by a thick section of low velocity material, providing a nonuniform but low average velocity between the depth of the NPE and the surface.

Introduction

In the interpretation of seismic data to infer properties of an explosion source, it is necessary to account for wave propagation effects. In order to understand and remove these propagation effects, it is necessary to have available a model of the material properties in the region between source and receiver which the elastic waves have sampled. An open question concerning this matter is the detail and accuracy which must be present in the velocity model in order to produce reliable estimates in the estimated source properties. While it would appear that the reliability of the results would be directly related to the accuracy of the velocity and density models used in the interpretation, it may be that certain deficiencies in these models can be compensated by the type and amount of seismic data which is used in the inversion. The NPE provided an opportunity to test questions of this sort, as the experiment was announced well in advance and the site was available for ancillary experiments. Taking advantage of this opportunity, two companion experiments were performed, the first involving controlled source surveys in the vicinity of the NPE which were designed to produce high resolution information on the velocity structure, and the second involving the recording of waveform data from the NPE which could use this velocity structure in its interpretation. The results of the first of these experiments are

described in the present paper, and the results of the second can be found in Johnson (1994).

In August two controlled source, high resolution, seismic surveys were carried out at Rainier Mesa in the vicinity of the NPE. Both involved a surface profile along a north-south line about 660 meters long and located about 600 meters west of the epicenter of the NPE. The relation of this profile to the NPE is shown in Figure 1. During the first part of the experiment, controlled sources were placed along this profile and receivers were placed in the tunnel U12n.23 near the NPE, which is also shown on Figure 1. This part of the experiment was designed to provide the data for a surface-to-tunnel imaging study. During the second part of the experiment, the surface profile was the site of both sources and receivers in order to collect data for a conventional multi-fold reflection study.

Surface-to-Tunnel Experiment

In the tunnel U12n.23 extending south toward Misty Echo, 96 30-Hz geophones were placed at 3 meter increments along the wall of the tunnel and connected to a 96-channel high resolution Bison model 90-96 seismograph. After the geophones were deployed, a Bison EW-4 impact source was used at the surface of the mesa to provide an energy source for the surface-to-tunnel tomographic imaging experiment. The source was used at 15 meter increments along a line on the surface approximately parallel to the tunnel but offset about 600 meters to the west, as shown in Figure 1.

Due to overwhelming 60 Hz noise in the tunnel, the data acquired for the tomography experiment were of limited quality and a full image was not possible. However, it was possible to identify first arrivals on the seismograms for some of the surface sources. On the basis of these arrival times an apparent average velocity between the surface and the tunnel, calculated as the ratio of the slant distance to the travel time, was estimated to be 2.0 km/sec. Because the tunnel was only 88 meters west of the NPE, this result provides a constrain on the mean velocity for similar paths between the NPE and the surface profile.

Surface Reflection Experiment

The surface reflection experiment was similar to the surface-to-tunnel experiment in most respects, the same equipment being used, but the receivers were now placed on the surface along the same profile as the sources. The receivers were the same 30 Hz vertical component geophones with a 3 meter spacing. The same impact source was used with a 6 meter spacing in source points. The recording system had 48 channels with a 0.5 msec sampling rate and a total recording interval of 1 sec. The passband of the recording was flat between 64 and 500 Hz.

Conventional reflection survey techniques were used in processing the data. The processing procedure was designed primarily to estimate the one dimensional P velocity as a function of depth in Rainier Mesa. After trace editing and trace scaling, the data were filtered to pass the 5 to 75 Hz band. After application of shot and receiver geometries, the data were sorted to common depth point (CDP) gathers, with maximum fold 24 traces. During the velocity analysis, several trial stacked profiles were generated using velocities from 500 m/sec to 6000 m/sec at 500 m/sec steps. A velocity semblance calculation was performed in order to estimate the mean velocities that yielded the most coherent normal-move-out stacks. A velocity function was then estimated and used to compute the final stack. Spiking and predictive deconvolution were also applied, but these did not significantly improve the data quality. The results were migrated after the stack. Automatic gain control with a characteristic time of 100 msec was then applied to the final section.

In Figure 2 the migrated section is shown as a function of travel time. This section shows numerous reflection events that extend throughout the recorded time interval of 1 sec. Some of these reflectors are quite strong, such as those arriving at two-way travel times of approximately 80, 200, and 600 msec. While there is definitely some lateral variations in the strength and continuity of these reflections over the length of the profile, the general picture is one of roughly horizontal layering. With the intention of obtaining a preliminary one-dimensional interpretation of the reflection data, the data were processed so as to enhance horizontal correlations in the reflectors. These results are shown in Figure 3. While this type of filtering has tended to smooth out any lateral variations in the reflectors, it has helped to identify the reflectors which have the most coherence over the length of the profile.

The reflection data of Figures 2 and 3 have been interpreted with the aid of the geological information contained in drill holes, as described in the paper by Baldwin et al. (1994). While the reflection data give accurate information on the two-way travel times of prominent reflectors, the information on interval velocities is much less accurate, and thus fixing the depth of the reflectors remains a problem. However, in most cases it was possible to identify the reflector with a change in the lithology noted in the drill hole logs, and the combination of these two types of information was sufficient to fix the likely depth of the reflector. The preliminary one-dimensional velocity model for P waves that has emerged from this type of interpretation is shown in Figure 4.

The sections in Figures 2 and 3 show a strong reflector at a two-way travel time of about 80 msec, and the semblance and normal-move-out stacks indicate that this reflection is caused by a decrease in velocity. This is interpreted in Figure 4 as a decrease in velocity within the Rainier Mesa Tuff (Tmr) at a depth of about 80 meters. At a time of about 180 msec in Figure 3 there is another reflector, but the velocity stacks are insufficient to indicate whether this represents an increase or decrease in velocity. In Figure 4 this is represented as a further decrease in velocity at a depth of about 130 meters, with the interpretation that this represents the transition from the ash flows of the Rainier Mesa Tuff (Tmr) to the ash falls of the Paintbrush Tuff (Tp). The velocity below this reflector appears to be quite slow, less than 1.5 km/sec. Although there is some evidence of reflectors at times of about 360 to 370 msec in Figure 3, the evidence in Figure 2 is somewhat uncertain. However, at a time of about 450 msec there is a better defined reflector which represents an increase in velocity to more moderate values of about 2.7 km/sec. This is interpreted as the boundary between the Paintbrush Tuff (Tp) and the Grouse Canyon Tuff (Tbg) at a depth of 315 meters. The next strong reflector is at a time of 610 msec and this is a further increase in velocity. It appears to be the boundary between the Tunnel Beds Tuff (Tt3) and the Belted Range Tuff (Tbt) at a depth of 530 meters. There appears to be another reflector at a time of 680 msec, but the interpretation of this event in terms of the geology is still not clear. At a time of 770 msec there is a reflector which appears to represent the transition to the Paleozoic basement, the boundary between the Older Tuffs Units (Tot) and the Wood Canyon Formation (CpCw). At a time of 920 msec there is still another strong reflector, which appears to be a reflector from within the basement at a depth of approximately 1100 meters.

The forgoing interpretation of the reflection data, as represented in Figure 4, is a preliminary attempt to reconcile the travel times of prominent reflectors, the velocities suggested by the semblance and normal-move-out stacks, and the geological information contained in the drill holes. It is worth noting that the model which has emerged is generally consistent with the low apparent average velocity that was obtained in the surface-to-tunnel experiment, primarily because of the low velocity in the thick section of the Paintbrush Tuff unit. The resulting velocity model is noteworthy because of the

relatively high velocity layer near the surface which is underlain by a thick section of quite low velocities. The model suggests, however, that at the depth of the NPE (389 meters) the velocity has increased to a more moderate value of about 2.6 km/sec.

Discussion and Summary

This study illustrates the type of information which can be obtained with simple, efficient, controlled source, velocity surveys. These experiments were performed in a single day, and the processing up to this point has been fairly standard. While it remains to be shown just how useful these data will be in the interpretation of the NPE data, it has been demonstrated that rapid acquisition and interpretation of velocity data of this type could be easily incorporated into a verification scenario if it was deemed useful.

The surface-to-tunnel survey suffered from the large amount of 60 Hz electrical noise that existed in the tunnel, but, anticipating this type of problem in future experiments, there might be methods of mitigating this problem. Nevertheless, this part of the experiment did provide some useful information on the mean velocity of the upper 400 meters of Rainier Mesa, which turns out to be quite low.

The surface reflection survey employing an impact source produced good quality, broad band, reflections with good penetration. High resolution data were obtained down to depths that are well below that of the NPE. The length of the profile was rather short for this survey, but it was still possible to distinguish between high and low velocity segments of the section by using standard velocity stacking procedures. Such information can be critical in removing propagation effects from waveforms registered from explosions.

References

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Figure Captions

Figure 1. Relation of the surface profile to the location of the NPE. Also shown is the location of the tunnel U12n.23 which was a shot level and west of the shot point.

Figure 2. Migrated stacked section as a function of two-way travel time. The velocities on the left are those which were used in the stacking and migration process. The north end of the profile is on the left and the south end on the right.

Figure 3. Similar to Figure 2 except that the data have been filtered to enhance lateral coherence.

Figure 4. The preliminary one-dimensional velocity model for P waves which was derived on the basis of the reflection data.

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 NPE
200 meters