Detection of Coals 30 cm Thick at Depths of 50 and 60 m by Seismic Reflection Profiling

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SUMMARY

A 70-m long 12-fold high-resolution seismic profile delineates quite clearly two coal beds of about 30-cm thickness each. The two beds are lower and upper Sibley coals which occur in the Tonganoxie Sandstone Member of the Stranger Formation, Upper Pennsylvanian. A cored drill-hole approximately 150 m from the profile shows the coals to be separated by about 10 m and to be about 8 and 18 m, respectively, beneath the Haskell Limestone which is the 2-m thick basal member of the Lawrence Formation. Synthetic seismograms derived from the cored information and modeling the synthetic seismogram with the coal removed confirm the interpretation of the section.

The seismic profile was shot using 2-m centers, single 100 Hz geophones, and 220 Hz low-cut field (laydown) filters. An important factor in the high data quality was the use of a .50-caliber rifle source with the gun fired down a shallow auger hole with about half the barrel beneath the surface. Dominant frequency of the coal reflections is about 400 Hz.

INTRODUCTION

Field data for approximately a 70-m 12-fold seismic profile were acquired using a .50-caliber rifle source (see Steeples et al., 1987), single 100 Hz geophones, 2-m surface-point interval, and 220 Hz low-cut field (laydown) filters. The profile is from west campus, University of Kansas, near the Kansas Geological Survey (KGS) building. The .50-caliber source has been commonly used by KGS as a surface source, firing through a device to dampen the sound waves; however, for this profile auger holes were drilled to depths of .8 m, and approximately half of the rifle barrel was submerged below the ground. This configuration served several purposes: (1) It was a more efficient muffler of sound energy; (2) it reduced ground-roll noise by removing bullet impact from the free surface; and (3) it improved seismic P-wave energy because, (a) all energy from the shot, including muzzle-blast gasses, coupled with the ground; (b) the energy coupled with firm subsurface soil rather than impacting against the aerated zone; and (c) all energy is directed downward rather than omnidirectionally as an explosion would be.

As a consequence of the reduction in ground-roll noise, we were able to dial back the low-cut filters to 220 Hz. This, along with the increased source efficiency, resulted in broader band data than we had previously recorded at the site. Because the source signature was higher frequency and higher energy than previous attempts, we were able to rely less on low-cut filtering than we had in the past.

DISCUSSION

Although the seismic profile was produced as a means of testing the seismic source, we became interested in the profile's ability to show stratigraphic detail. One aspect of the detail was delineation of two coals (Upper and Lower Sibley beds) occurring in the Tonganoxie Sandstone Member of the Stranger Formation (Douglas Group, Upper Pennsylvanian). The two coal beds are each about .3-m thick and occur, respectively, at about 8 and 18 m below the Haskell Limestone which is the basal member of the Lawrence Formation. The Upper Sibley coal was probably the first coal mined in Kansas and was used by the blacksmith at Fort Leavenworth shortly after the establishment of the post in 1836. The coal is its thickest in Leavenworth County (about .6 m) and thins in all directions from there. The Upper Sibley coal is more extensive than the Lower Sibley coal, but both are restricted to roughly the area of Douglas and Leavenworth counties, Kansas (Bowsher and Jewett, 1943).

The Tonganoxie Sandstone is a local non-marine channel sandstone which, in some areas such as beneath this section, has scoured down to the Stanton Formation limestones of the Lansing Group. Its thickness beneath the city of Lawrence is about 43 m, approximately its maximum thickness. Lawrence lies over the middle of the Tonganoxie channel valley (Lins, 1950). Beneath Lawrence the Tonganoxie Sandstone is a fine-to-medium-grained crossbedded sandstone with rare thin shale and mudstone beds (Figure 1). Detailed analysis of the Tonganoxie section of the seismogram finds impressive channel and sand-body features on the seismogram. Instantaneous phase, in particular, enhances these low-amplitude events.

Local ground truth is provided by a cored drill hole about 150 m off the profile which penetrates to the Stanton Formation. A primative synthetic seismogram was derived from the core information by applying reasonable interval transit-time values for the rock units identified in core. A sonic log from a well 19 km WNW of the profile provided interval transit-time values for the rock units. A quadrature phase wavelet was applied to derive the synthetic seismogram. This resulted in a response of a peak for the thin Haskell Limestone and troughs for the coals. Fig. 1 shows the comparison of a portion of the seismic profile (a), the synthetic seismogram (b), the velocity log (c), and the well log (d). The coals are seen to be distinctive troughs on the section and they are continuous across the section in agreement with their known persistence geologically.

CONCLUSIONS

The reflection troughs associated with the coal are not the consequence of the shales associated with the coals as the velocity log shows that the coals are the most significant contributor to the seismic response and the shales are almost inconsequential. Removal of the coals from the synthetic seismogram model effectively also removes the seismic response (Figure 2).

Inspection of the velocity-time log (Figure 1c) shows that, although the depth thickness of the coals (0.3 m) is much less than that of the Haskell Limestone (2 m), the time thicknesses are almost equal (nearly 1 ms). Velocity of the limestone is almost exactly four times that of the coal. The acoustic contrast of the coal with surrounding shales and sandstones is actually greater than that of the limestone. The conclusion is thus obvious. It is much easier to detect thin coal beds than it is to detect thin limestones by a factor of about six. That is, if one can detect a two-meter limestone bed, it should be equally easy to detect a 30-cm coal bed.

REFERENCES

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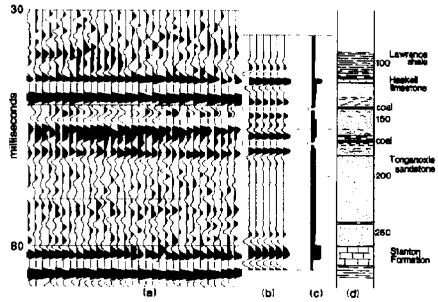

FIG. 1. (a) Portion of seismic profile showing coal response; trace spacing = 1 m. (b) Synthetic seismogram. (c) Velocity log. (d) Well log interpreted from core.

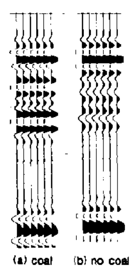

FIG. 2. Comparison of synthetic seismograms (a) with coal and (b) without coal.