Mapping the geology around mine zones is a key economic and safety concern at Saskatchewan potash mines. Experiments were carried out to investigate the feasibility of using a mining machine as a seismic source for in-seam reflection mapping. Using mining machines as a seismic source would provide a cost effective method to map ore-zone discontinuities. Twenty-four geophones were mounted on the roof of the mining rooms at the PCS Potash, Rocanville Division potash mine to record 1 second records. The records were then cross-correlated with a pilot trace that moved with the advancing machine. These experiments indicate that frequencies of at least 2000 Hertz are generated as both shear and compressional energy. The geophone records had spurious frequencies in the 900-1200Hz range, which were suppressed with predictive deconvolution. Strong linear events recorded at the shear wave velocity dominated the geophone records. The mining machine stacked section had coherent events that could be tied to synthetic seismograms and in-seam hammer seismic from the area. Based on these results the mining machine source is an effective method for in-seam recording.

Introduction

Predicting ore-zone discontinuity is a major economic and safety concern at all Saskatchewan potash mines. The major hazard is mining into a geological anomaly that causes brine inflow. To reduce this risk geophysical methods are used to image the formations surrounding the mine level. Surface 3D seismic is used to find large (>100m across) collapse structures and major faults, but at present there is no economic method for finding small-scale features. When anomalous zones are encountered ground penetrating radar (GPR) (Annan, Davis & Gendzwill, 1988) or seismic surveys can be conducted inseam, but both methods have drawbacks. With GPR, the mining machine must be moved back from the face of the room, while readings are taken. This causes obvious delays for the whole mine. The depth of investigation is limited to 30m when there is little shale near the ore-zone, and 5-10m when clay or other conductors are present. In-seam seismic with a hammer source has been used (Gendzwill & Brehm, 1993), but these surveys require mining to halt and take a long time to acquire and process.

If the mining machine could be harnessed as a seismic source it would offer a cost effective, continuous, real-time, method of monitoring formations above, below and possibly ahead of the advancing mining face. Mining machines generate a seismic signal that propagates through the rock; is it possible to utilize this signal to image impedance contrasts above the mine level? To test this possibility the properties of the seismic signal generated by the machine must be established. What is the frequency content? Is there useful signal strength? Is the source compressional or shear? Is a pilot trace required? All these questions must be answered for this technique to be successful.

Figure 1 illustrates the events that are expected in the potash environment. The first (Figure 1a) is the standard mining situation, with no geological variation. In this case the energy reflected from the boundary should form a strong coherent event. Figure 1b provides for a gently dipping erosional event that should give the same reflection strength but travel time will decrease as the mining face advances. An abrupt discontinuity (Figure 1c) is also possible; this would cause a reflection from the overlying boundary and a reflection from the anomaly. The anomalous reflection would be steeply dipping and cut across the normal reflectors.
The Mining Machine as a Seismic Source for In-seam Reflection Mapping

The potash ore zone at the PCS Rocanville mine is about 30m from the top of the Prairie Evaporite formation of the Elk Point Group. In this region the mining level is about 900m below surface. Below mine level is massive salt that is in total 120m thick. Carbonates of the overlying Dawson Bay formation can contain high-porosity water-bearing reservoirs. Imaging the tops of the Prairie Evaporite and 2nd Red Bed is the main objective, but mapping higher strata can also be of use.

Method

The mining machine source method is based on Seismic-While-Drilling (SWD) as laid out by Rector et al. 1988 & 1991. In the SWD method geophones mounted at the surface detect vibrations that travel through the earth from the drill bit to the surface. A pilot sensor on the top of the drillstring records input vibrations from the drill bit. The geophones record an output that includes a direct arrival, reflections and multiples. The geophone records can then be cross-correlated with the pilot trace. This provides a section that can then be processed in a traditional manner.

A similar method is used for the mining machine source. Geophones are mounted in the roof behind the mining machine to record reflections from the overlying layers. The geophone records are cross-correlated with a pilot trace that is mounted directly behind the mining machine. The pilot and geophones are mounted to measure vertical motion.

Example

To test the idea a pilot trace was mounted on the roof at a fixed offset from the mining face (Figure 2). By cross correlating the pilot trace with geophones at normal offsets a reflection section was created. The pilot was set up 16m from the mining face for each recording, moving along with the mining machine as it advanced. 40 records were recorded with geophones set up initially from 16 to 35 meters from the face, and then recordings were made for every 2 meters of mining machine advance. 20 geophones were spaced 1m apart with another geophone used as the pilot trace.

A Bison 9000 series recorder was used with a temporal sample rate of 0.2ms. Twenty 50Hz geophones were used to record the reflections while a single 50Hz phone was mounted directly behind the mining machine as a pilot trace. The 1 second records were used to create a section 0.1 seconds in length after cross correlation (Figure #3). Note that the seismic is imaging upwards in the geologic column and increases in time correspond with a decrease in depth.

The first processing step was predictive deconvolution to reduce spurious geophone resonance (Gendzwill & Brehm, 1993). Cross correlation was done after predictive deconvolution under the assumption that each geophone would have its own spurious frequency curve. The cross correlation collapsed the complicated input signal to emphasize impulsive events. After cross correlation the data was dominated by linear noise that had an apparent velocity of 2400m/s, the shear wave velocity of salt. FK filtering was used to attenuate the linear events. By applying gain recovery, FK filtering and NMO correction (Figure #4) reflectors can be observed on some of the shot gathers.

Conclusions

The initial test results are promising. The noise generated by a mining machine has been used to map reflections. The field gathers displayed weak or no compressional direct arrivals but a strong shear direct wave. Strong linear noise at 2400m/s appeared on the gathers and was removed with FK filtering. This method can provide a cost effective solution that provides minimum interference with mining operations.
The Mining Machine as a Seismic Source for In-seam Reflection Mapping

References


Gendzwill, D.J. and Brehm, R., 1993, High-resolution seismic reflections in a potash mine: Geophysics, 58, 741-748


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Figure 3 Source Gather after Correlation

Figure 4 Source Gathers with NMO and FK filter applied
The Mining Machine as a Seismic Source for In-seam Reflection Mapping

CDP (Spacing=0.5m)

Figure 5 Stacked section from mining machine source