Chapter 7

Crosshole transmission tomography

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1. Introduction

1.1 Crosshole seismics in general

The seismic crosshole technique offers a means to investigate the rock mass between two or more boreholes. Already in 1917 Reginald Fessenden proposed a method to locate ore bodies by crosshole measurements. Fig. 1 is redrawn from his original paper (Fessenden 1917). It is a plan view showing four vertical boreholes and two ore bodies in between. Using a source of seismic energy in one of the boreholes and a detector device in one of the others, the traveltime of waves that have been reflected at or transmitted through the ore bodies can be determined. Combining traveltimes from a number of source/receiver locations at different depths in different boreholes, it should be possible to roughly locate the ore bodies by hand interpretation using elementary geometry. This is the basic idea as outlined by Fessenden. Although the procedure requires a fairly simple medium (only one or two ore bodies, homogeneous surroundings), it points forward to the present use of crosshole tomography.

Among recent applications of crosshole seismics we may note Fehler and Pearson (1984). These authors made use of amplitude measurements to estimate the quality factor Q and locate fractures in crystalline rock at a hot dry rock geothermal reservoir. During heat extraction a decrease in average Q was noted due to extensive fracturing. A water-filled fracture will affect waveform character, frequency, and also amplitude. Shear wave amplitudes, in particular, will be greatly reduced. These effects constitute the basis of fracture location techniques.
Paulsson et al. (1985) reported successful monitoring of rock parameters in a small-scale crosshole experiment, the distance between the holes being a few m only. Electric heaters were used to simulate the thermal effect of nuclear waste. P-wave velocities were found to increase linearly with temperature. Changes in attenuation of the seismic waves were shown to be indicative of fracture closure and pore pressure changes during the heating process. Thermal damage to the rock mass resulted in permanently reduced P-wave velocities.

Ultrasonic crosshole measurements in a Swedish iron mine were performed by Nordqvist (1986). Rock mass classification was carried out by using the P-wave velocity, attenuation, and signal duration measures. Attenuation and signal duration proved to be more sensitive to joint frequency than P-wave velocity. Signal duration, a new parameter, was defined as the quotient between two root-mean-square (rms) values of the signal, taken over intervals some time after and immediately after the first-arrival, respectively. Joints and other discontinuities will give rise to a large signal duration because of later arrivals caused by scattering, reflections, and wave conversion. Nordqvist also showed that structural changes in the rock, caused by blasts or a changing stress field, could be effectively monitored by crosshole measurements. Applications to civil engineering were described by McCann et al. (1986). In one of their field examples, a railway tunnel between two boreholes was shown to have a significant effect on the velocity of propagation and amplitude of the transmitted seismic signals. Fig. 2 shows the tunnel and