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Appendix 1. Transforming Equations

In the wave equation approach to seismic data processing, as described in Chapter 3, it is necessary to transform the equations into several different coordinate systems. As an illustration of how these transformations are generally done, we will show in detail how equation (3-7) was obtained by transforming the scalar wave equation:

$$(\partial_{xx} + \partial_{zz} - \frac{1}{v^2} \partial_{tt}) P = 0 \qquad \text{(A1-1)}$$

according to the coordinate transformations

$$x' = x - z \tan\theta \qquad \text{(A1-2a)}$$

$$z' = z \qquad \text{(A1-2b)}$$

$$t' = - x(\sin\theta)/v - z(\cos\theta)/v + t \qquad \text{(A1-2c)}$$

The Jacobian of this transformation is:

$$x'_{x,z,t} = 1, -\tan\theta , 0 \qquad \text{(A1-3a)}$$

$$z'_{x,z,t} = 0, 1, 0 \qquad \text{(A1-3b)}$$

$$t'_{x,z,t} = -(\sin\theta)/v , -(\cos\theta)/v , 1 \qquad \text{(A1-3c)}$$

In terms of this Jacobian, equation (A1-1) can be rewritten as:

$$[(x'_x\partial_{x'} + z'_x\partial_{z'} + t'_x\partial_{t'})^2 + (x'_z\partial_{x'} + z'_z\partial_{z'} + t'_z\partial_{t'})^2 - \frac{1}{v^2}\partial_{t't'}] Q = 0 \qquad \text{(A1-4)}$$

Doing the implied multiplications in (A1-4), and substituting from (A1-3), we obtain the following coefficients:

$$Q_{x'x'} : \quad x'^2_x + x'^2_z = 1 + \tan^2\theta = \sec^2\theta \tag{A1-5a}$$

$$Q_{z'z'} : \quad z'^2_x + z'^2_z = 1 \tag{A1-5b}$$

$$Q_{t't'} : \quad t'^2_x + t'^2_z - \frac{1}{v^2} = \sin^2\theta/v^2 + \cos^2\theta/v^2 - \frac{1}{v^2} = 0 \tag{A1-5c}$$

$$Q_{x'z'} : \quad 2\,(x'_x\, z'_x + x'_z\, z'_z\,) = -\,2\,\tan\theta \tag{A1-5d}$$

$$Q_{x't'} : \quad 2\,(x'_x t'_x + x'_z t'_z\,) = 2\,(-\sin\theta/v + \tan\theta\cos\theta/v\,) = 0 \tag{A1-5e}$$

$$Q_{z't'} : \quad 2\,(z'_x\, t'_x + z'_z\, t'_z\,) = -\,2\,\cos\theta/\,v \tag{A1-5f}$$

which when inserted back into (A1-4) produce equation (3-7) :

$$v\,\sec^2\theta\; Q_{x'x'} + v\; Q_{z'z'} - 2\,v\tan\theta\; Q_{x'z'} - 2\,\cos\theta\; Q_{z't'} = 0 \tag{A1-6}$$

Appendix 2. Predicting Multiple Reflection Arrivals on Slant Stacks

In the case of slanted propagations and dipping sea bottoms, the multiples do not arrive at twice the primary travel time as is the case for vertical propagation. To get the proper results, a correction has to be made. The following is a ray approximation of such a correction.

The geometry corresponding to a plane wave propagating from left to right at an angle θ is depicted in Figure A2.1 where we have assumed that the two bounces of a first order multiple path occur close enough to consider a single dipping angle.

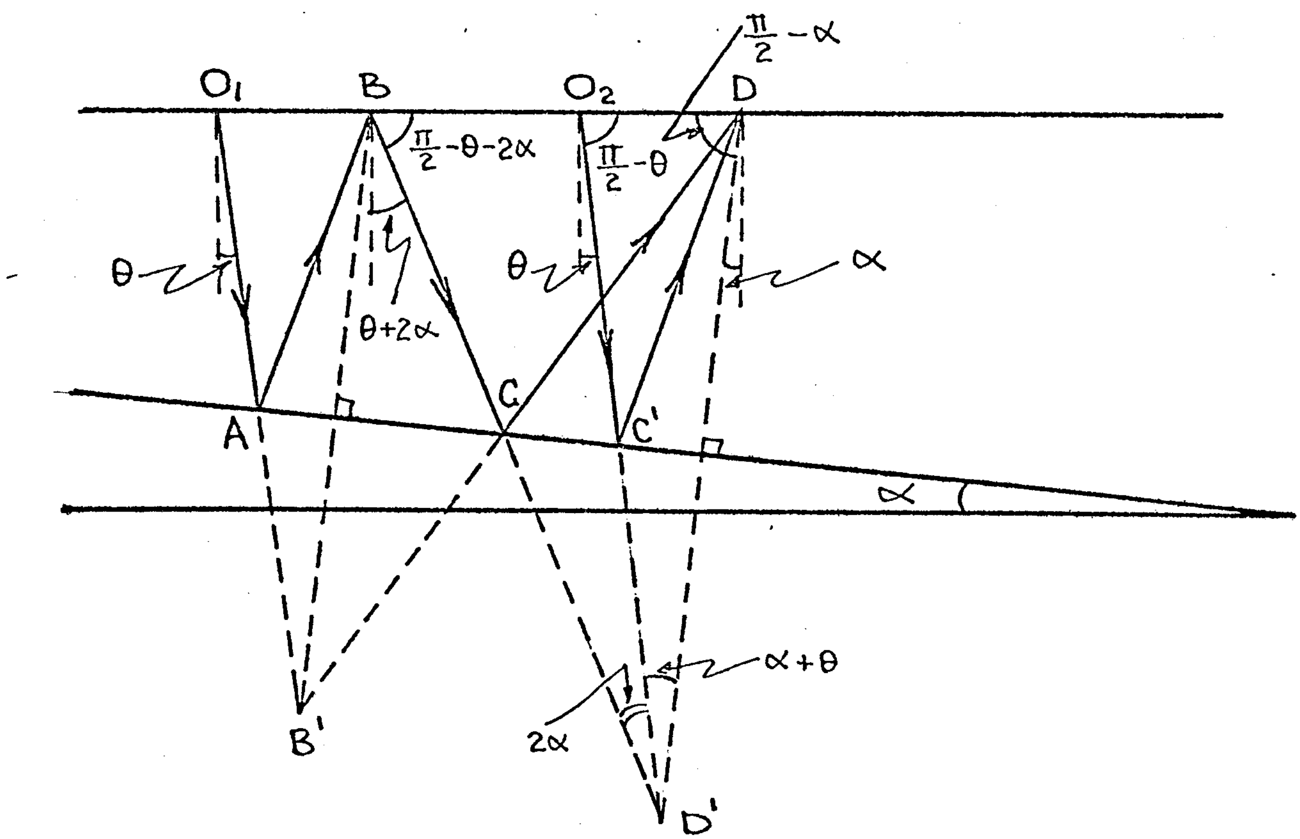

Figure A2.1

The idea then is to compute the travel time associated with the multiple's path 0_1ABCD (multiple at location D) as a function of the primaries' travel times associated with the paths 0_1AB and $0_2C'D$ (primaries at locations B and D , respectively). Of course, we will have to compute as well the horizontal distance between the two primaries' locations BO_2 .

From triangle BO_2D' we have:

$$BD' = [\cos\theta/\cos(\theta+2\alpha)]\, 0_2D' \, , \tag{A2.1}$$

and from triangle BDD' :

$$BD = [\sin(\theta+3\alpha)\,/\cos\alpha]\, BD' \tag{A2.2}$$

If now we call $t_{p_1} = 0_1B'/v$, the travel time up to the primary in location B(path 0_1AB) ;

$t_{p_2} = 0_2D'/v$, the travel time up to the primary in location D(path $0_2C'D$) ;

$t_{m_2} = (0_1B' + BD')/v$, the travel time up to the multiple in location D (path 0_1ABCD) ;

$Dx = BO_2$, the horizontal distance between the two primaries' location B and 0_2 ;

then from expressions (A2.1) and (A2.2) we obtain:

$$Dx = \frac{\cos\theta \ \sin(\theta+3\alpha)}{\cos\theta \ \cos(\theta+2\alpha)} \ vt_{p2} \ , \qquad \text{(A2.3)}$$

and

$$t_{m_2} = t_{p_1} + \frac{\cos\theta}{\cos(\theta+2\alpha)} \ t_{p_2} \qquad \text{(A2.4)}$$

Notice that when $\alpha = 0$, expression (A2.4) becomes $t_{m_2} = t_{p_1} + t_{p_2}$ as expected.

These results were computed in the so-called "interpretation frame," but in many instances we may like to work in the slanted frame. The implied coordinate transformation is summarized in Figure A2.2, where t is associated with the interpretation frame and t' with the slanted one.

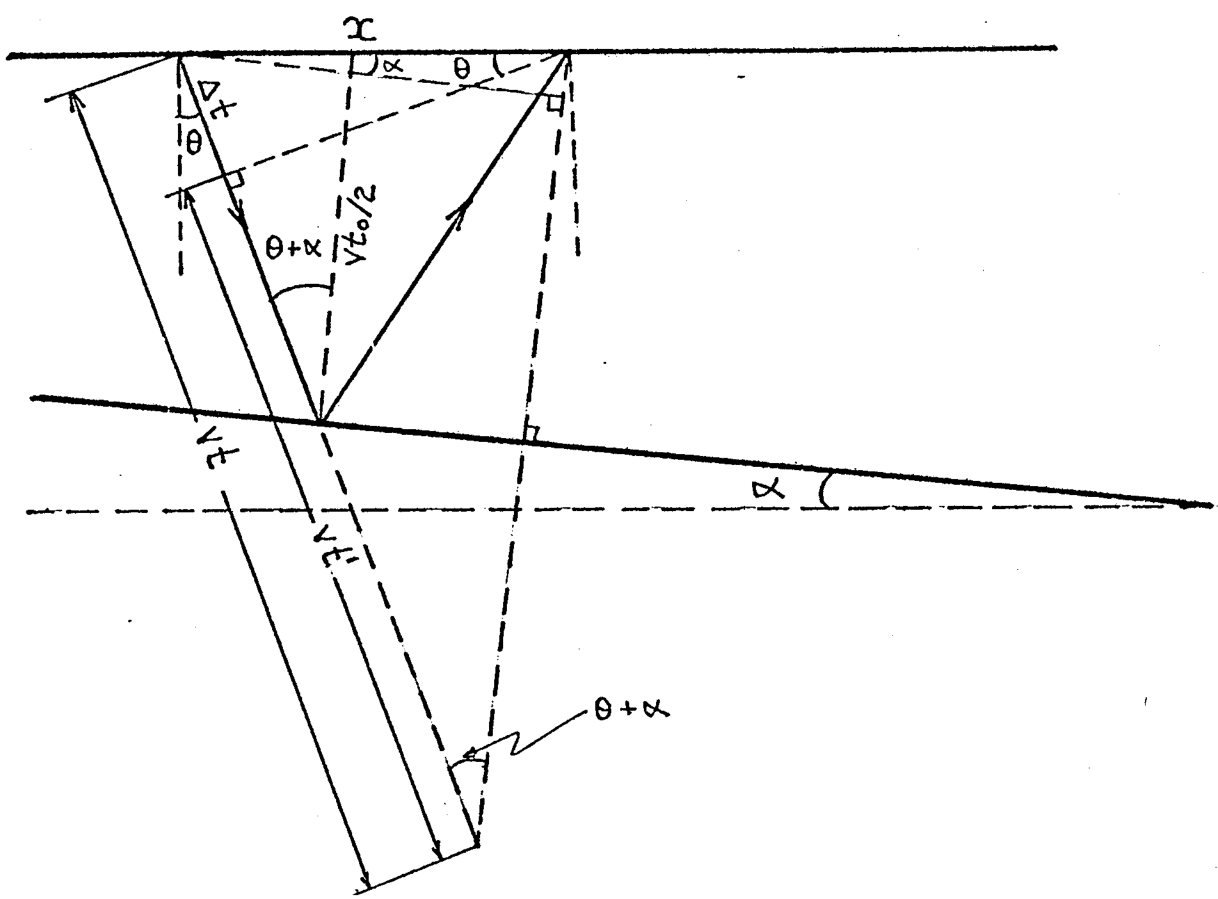

Figure A2.2

According to Figure A2.2, we have the following relations:

$$t = t' + \Delta t = [\,1 + \tan\theta\ \tan(\theta + \alpha)\,]\, t' . \tag{A2.5}$$

$$x = [\ \sin(\theta + \alpha) / \cos\alpha\ ]\ v\, t , \tag{A2.6}$$

$$x = \frac{\sin(\theta + \alpha)}{\cos\alpha} [\,1 + \tan\theta\ \tan(\theta + \alpha)\,]\, v\, t' , \tag{A2.7}$$

$$t_0 = \cos(\theta + \alpha)\ t . \tag{A2.8}$$

Substituting (A2.5) into (A2.3) and (A2.4) we finally set

$$Dx = \frac{\cos\theta\ \sin(\theta + 3\alpha)}{\cos\alpha\ \cos(\theta + 2\alpha)} [\,1 + \tan\theta\ \tan(\theta + \alpha)\,]\, v\, t'_{p_2} . \tag{A2.9}$$

$$t_{m'_2} = t_{p'_1} + \frac{\cos\theta}{\cos(\theta + 2\alpha)}\ \frac{1 + \tan\theta\ \tan(\theta + \alpha)}{1 + \tan(\theta + 2\alpha)\tan(\theta + 3\alpha)}\ t_{p'_2} \tag{A2.10}$$