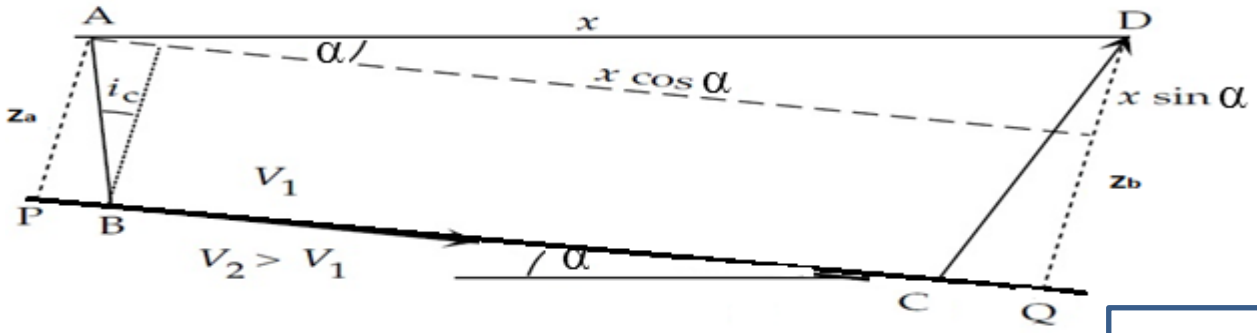

$$T_{ABCD} = \frac{AB + CD}{V_1} + \frac{BC}{V_2}$$

$$T_{ABCD} = \frac{(z_a + z_b)}{V_1 \cos i_c} + \frac{x\cos\alpha - (z_a + z_b)\tan i_c}{V_2}$$

$$= \frac{x\cos\alpha}{V_2} + \frac{(z_a + z_b)}{V_1}\cos i_c$$

$$AB = \frac{z_a}{\cos i_c} \qquad CD = \frac{z_b}{\cos i_c}$$

$$PB = z_a \tan i_c \qquad CQ = z_b \tan i_c$$

$$BC = x\cos\alpha - (PB + CQ)$$

Using:

$$\tan i_c = \frac{\sin i_c}{\cos i_c} \quad , \quad V_2 = \frac{V_1}{\sin i_c}$$

and $\sin^2 i_c + \cos^2 i_c = 1$

The above equation can be simplified by noting that:

$$z_b = z_a + x\sin\alpha \ , \ \frac{1}{V_2} = \frac{\sin i_c}{V_1} \text{ and } \sin(i_c + \alpha) = \sin i_c \cos\alpha + \cos i_c \sin\alpha$$

After substitution and gathering terms the down-dip travel-time is given by

$$T_{ABCD} = \frac{x\sin i_c \cos\alpha}{V_1} + \frac{x\cos i_c \sin\alpha}{V_1} + \frac{2\mathbf{Za}\cos i_c}{V_1}$$

$$= \frac{x}{V_1}\sin(i_c + \alpha) + t_{id}$$

where t_{id} is the intercept time for the down-dip shot:

$$t_{id} = \frac{2\,\mathbf{Za}}{V_1}\cos i_c$$

The analysis for shooting in the up-dip direction is analogous and gives

$$t_u = \frac{x}{V_1}\sin(i_c - \alpha) + t_{iu}$$

where t_{iu} is the intercept time for the up-dip shot:

$$t_{iu} = \frac{2\,\mathbf{Zb}}{V_1}\cos i_c$$