CORRECTIONS TO APPARENT AZIMUTHS AND TRAVEL-TIME GRADIENTS FOR A DIPPING MOHOROVIČIĆ DISCONTINUITY

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ABSTRACT

When a layer is overlying a half-space with a tilted interface, the refraction of seismic waves emerging from the half-space generally results in their reorientation away from the vertical plane of incidence, with the following consequences:

1) The angle of emergence at the free surface and, thus, $dT/d\Delta$ will become azimuth dependent.

2) The apparent direction of approach of the wave front along the free surface will, in general, be different from the true azimuth. The azimuthal deviation also varies with azimuth.

A general formulation for the computation of the apparent azimuth and the angle of incidence at the free surface is obtained. The numerical corrections to the observed $dT/d\Delta$ and apparent azimuth, for a number of combinations of various dip angles and velocity contrasts, are tabulated.

The tables may be helpful when the first and second derivatives of the travel time data are to be analyzed. Their comparison with observation can also be useful for making inferences about the underlying crustal structure. The latter approach has been applied to the P arrivals across the Tonto Forest Seismological Observatory (TFSO) array, Arizona. On the basis of these observations, the Mohorovičić discontinuity under the observatory appears to be dipping locally as much as eight degrees in the $N70^\circ \pm 5^\circ E$ direction.

INTRODUCTION

In a recent study of the variation of the compressional velocity with depth in the upper mantle, Niazi and Anderson (1965) made use of the direct measurements $dT/d\Delta$ of P waves across the Tonto Forest Seismological Observatory (TFSO) array, Arizona, for epicentral distances of 12-30 degrees. Although their observed data showed a considerable amount of scatter, no azimuthal dependence was detected. It was, therefore, thought reasonable to assume a crustal model with perfectly horizontal interface.

When the results of the seismic refraction survey in the area (Warren *et al*, 1965) became known, the validity of such an assumption appeared questionable. According to refraction results, the M -discontinuity in the vicinity of TFSO is irregularly dipping to the northeast and it undergoes an abrupt drop of 5 km magnitude, about 20 km from the array in that direction. Therefore, an examination of the effect of a dipping Mohorovičić discontinuity on the angle of incidence and the apparent azimuth has been carried out and the results are discussed here.

It is noted that for epicentral distances of less than 30 degrees, the corrections are small and can be masked by the measurement errors. For larger epicentral distances, the corrections gradually become significant. With a few reasonable assump-

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arriving at O , from a new azimuth ϕ' , hereafter called the apparent azimuth. The apparent dip is δ' .

In order to determine i_0 and ϕ' , we make use of Snell's law in the configuration of Figure 1. Since the direction cosines of the incident rays and those of ON are $(\sin i \cos \phi, \sin i \sin \phi, \cos i)$ and $(0, \sin \delta, \cos \delta)$ respectively, we have

$$\cos i' = \sin i \sin \phi \sin \delta + \cos i \cos \delta \quad (1)$$

and

$$\sin r' = v_1 \sin i' / v_2 = v_1 [1 - (\sin i \sin \phi \sin \delta + \cos i \cos \delta)^2]^{1/2} / v_2. \quad (2)$$

Let the direction cosines of the line perpendicular to both, the incident ray and ON , i.e., to the apparent plane of incidence be α , β , and γ . We have

$$\begin{aligned} \alpha^2 + \beta^2 + \gamma^2 &= 1 \\ \alpha \sin i \cos \phi + \beta \sin i \sin \phi + \gamma \cos i &= 0 \\ \beta \sin \delta + \gamma \cos \delta &= 0. \end{aligned} \quad (3)$$

Solution of (3) results in

$$\begin{aligned} \alpha &= \frac{\tan \delta \cot i - \sin \phi}{R} \\ \beta &= \frac{\cos \phi}{R} \\ \gamma &= \frac{-\tan \delta \cos \phi}{R} \end{aligned} \quad (4)$$

where

$$R = [1 + \tan^2 \delta \cot^2 i + \tan^2 \delta \cos^2 \phi - 2 \sin \phi \tan \delta \cot i]^{1/2}.$$

The refracted ray with direction cosines l , m , and n should still remain in the plane perpendicular to the line (α, β, γ) , i.e.,

$$l\alpha + m\beta + n\gamma = 0. \quad (5)$$

We also have,

$$l^2 + m^2 + n^2 = 1$$

and

(6)

$$\cos r' = m \sin \delta + n \cos \delta;$$

$\cos r'$ is known from (2). Simultaneous solution of equations (5) and (6), gives l , m , and n the following form,

$$n = \cos r' \cos \delta \pm \alpha \sin \delta \sin r'$$

$$m = (\cos r' - n \cos \delta) / \sin \delta \quad (7)$$

$$l = -(m\beta + n\gamma) / \alpha.$$

In the expression obtained for n , only the minus sign leads to the correct numerical results. The apparent angles of incidence and azimuth can be found from

$$i_0 = \cos^{-1} n \quad (8)$$

and

$$\phi' = \tan^{-1}(m/l).$$

By an iteration process, it is possible to determine the corresponding angles for a more complex crustal model involving many interfaces with various strike directions and dip angles. For any new layer which is added on top, the i_0 and ϕ' obtained for previous case should be considered as new i and ϕ .

NUMERICAL RESULTS

Presently, there are several seismometer arrays operating in the United States and other countries. With the completion of the Large Aperture Seismic Array in Montana, consisting of 21 subarrays, and installation of new arrays and dense networks, it is likely that the first and second derivatives of the travel time data will be extensively used to supplement travel time and amplitude data. It is, therefore, desirable to have available tables of corrections to $dT/d\Delta$ and azimuth of approach in terms of i and ϕ , for various dip angles and velocity contrasts. Such corrections are computed for dip angles of 2, 5, and 8 degrees and velocity contrasts of .7, .8 and .9. The computation is carried out on an electronic computer and results are given in Tables 1A-9A and 1B-9B.

The first column of each table gives the true azimuth of the wave as measured from dip direction. Therefore, zero azimuth refers to waves traveling up-dip whereas 90 degrees azimuth refers to rays traveling along the strike, and 180 degrees azimuth corresponds to waves traveling down-dip. Since the problem is symmetrical with respect to the dip direction, the 0-180 degrees azimuths include all possibilities.

In the application of these corrections, however, caution should be exercised in assigning the proper sign to the azimuthal deviation. This problem will be further discussed in the following section. In Tables 1A-9A and 1B-9B the angle i ranges

TABLE 1A - SLOPE CORRECTION FOR $V_1/V_2 = 0.7$ AND DIP ANGLE = 2.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	0.	1.21	1.10	1.06	1.05	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
5.0	*	0.	1.21	1.10	1.06	1.05	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
10.0	*	0.	1.20	1.09	1.06	1.05	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
15.0	*	0.	1.20	1.09	1.06	1.05	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
20.0	*	0.	1.19	1.09	1.06	1.05	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
25.0	*	0.	1.18	1.09	1.06	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03
30.0	*	0.	1.17	1.08	1.05	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03
35.0	*	0.	1.16	1.08	1.05	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03
40.0	*	0.	1.14	1.07	1.05	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
45.0	*	0.	1.13	1.06	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
50.0	*	0.	1.11	1.06	1.04	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
55.0	*	0.	1.10	1.05	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.02	1.02	1.02	1.02
60.0	*	0.	1.08	1.04	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02
65.0	*	0.	1.06	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
70.0	*	0.	1.05	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
75.0	*	0.	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
80.0	*	0.	1.02	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
85.0	*	0.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
90.0	*	0.	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
95.0	*	0.	0.97	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100.0	*	0.	0.96	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	0.99	0.99	0.99
105.0	*	0.	0.95	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
110.0	*	0.	0.93	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
115.0	*	0.	0.92	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
120.0	*	0.	0.91	0.96	0.97	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98
125.0	*	0.	0.90	0.95	0.97	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98
130.0	*	0.	0.89	0.95	0.96	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
135.0	*	0.	0.89	0.94	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
140.0	*	0.	0.88	0.94	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
145.0	*	0.	0.87	0.93	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
150.0	*	0.	0.87	0.93	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97
155.0	*	0.	0.86	0.93	0.95	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97
160.0	*	0.	0.86	0.92	0.95	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97
165.0	*	0.	0.86	0.92	0.95	0.96	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97
170.0	*	0.	0.86	0.92	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97
175.0	*	0.	0.85	0.92	0.94	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.97	0.97	0.97
180.0	*	0.	0.85	0.92	0.94	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.97	0.97	0.97

TABLE 1B - AZIMUTH DEVIATION FOR $V_1/V_2 = 0.7$ AND DIP ANGLE = 2.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	*	175	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.0	*	170	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15.0	*	165	3	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
20.0	*	160	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25.0	*	155	5	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
30.0	*	150	6	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
35.0	*	145	7	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
40.0	*	140	7	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
45.0	*	135	8	4	3	2	2	1	1	1	1	1	1	1	1	1	1	1
50.0	*	130	8	4	3	2	2	1	1	1	1	1	1	1	1	1	1	1
55.0	*	125	9	4	3	2	2	2	1	1	1	1	1	1	1	1	1	1
60.0	*	120	9	5	3	2	2	2	2	1	1	1	1	1	1	1	1	2
65.0	*	115	10	5	3	2	2	2	2	1	1	1	1	1	1	1	2	2
70.0	*	110	10	5	3	3	2	2	2	2	1	1	1	1	1	2	2	2
75.0	*	105	10	5	3	3	2	2	2	2	1	1	1	1	1	2	2	2
80.0	*	100	10	5	3	3	2	2	2	2	2	1	1	1	1	2	2	2
85.0	*	95	10	5	3	3	2	2	2	2	2	1	1	1	2	2	2	2
90.0	*	90	10	5	3	3	2	2	2	2	2	1	1	1	2	2	2	2
95.0	*	85	10	5	3	3	2	2	2	2	2	1	1	1	2	2	2	2
100.0	*	80	9	5	3	3	2	2	2	2	2	1	1	1	1	2	2	2
105.0	*	75	9	5	3	3	2	2	2	2	2	1	1	1	1	1	2	2
110.0	*	70	9	5	3	2	2	2	2	2	1	1	1	1	1	1	2	2
115.0	*	65	8	4	3	2	2	2	2	2	1	1	1	1	1	1	1	2
120.0	*	60	8	4	3	2	2	2	2	1	1	1	1	1	1	1	1	1
125.0	*	55	7	4	3	2	2	2	2	1	1	1	1	1	1	1	1	1
130.0	*	50	7	4	2	2	2	1	1	1	1	1	1	1	1	1	1	1
135.0	*	45	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
140.0	*	40	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
145.0	*	35	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
150.0	*	30	4	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
155.0	*	25	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
160.0	*	20	3	2	1	1	1	1	1	1	0	0	0	0	0	0	1	1
165.0	*	15	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
170.0	*	10	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
175.0	*	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180.0	*	0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0

TABLE 2A - SLOPE CORRECTION FOR $V_1/V_2 = 0.7$ AND DIP ANGLE = 5.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	0.	1.76	1.28	1.18	1.13	1.11	1.09	1.08	1.08	1.07	1.07	1.07	1.07	1.08	1.08	1.08	1.09
5.0	*	0.	1.76	1.28	1.18	1.13	1.11	1.09	1.08	1.08	1.07	1.07	1.07	1.07	1.08	1.08	1.08	1.09
10.0	*	0.	1.73	1.28	1.17	1.13	1.11	1.09	1.08	1.08	1.07	1.07	1.07	1.07	1.08	1.08	1.08	1.09
15.0	*	0.	1.69	1.27	1.17	1.13	1.10	1.09	1.08	1.07	1.07	1.07	1.07	1.07	1.08	1.08	1.08	1.09
20.0	*	0.	1.64	1.26	1.16	1.12	1.10	1.09	1.08	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.08	1.08
25.0	*	0.	1.58	1.24	1.15	1.12	1.10	1.08	1.07	1.07	1.07	1.06	1.06	1.07	1.07	1.07	1.07	1.08
30.0	*	0.	1.51	1.22	1.15	1.11	1.09	1.08	1.07	1.07	1.06	1.06	1.06	1.06	1.06	1.07	1.07	1.08
35.0	*	0.	1.45	1.21	1.13	1.10	1.08	1.07	1.07	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.07	1.07
40.0	*	0.	1.38	1.19	1.12	1.09	1.08	1.07	1.06	1.06	1.05	1.05	1.05	1.05	1.05	1.06	1.06	1.06
45.0	*	0.	1.32	1.16	1.11	1.09	1.07	1.06	1.06	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.06
50.0	*	0.	1.26	1.14	1.10	1.08	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.05	1.05	1.05
55.0	*	0.	1.20	1.12	1.08	1.07	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.05
60.0	*	0.	1.15	1.10	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.04
65.0	*	0.	1.10	1.08	1.06	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
70.0	*	0.	1.06	1.06	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
75.0	*	0.	1.02	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01	1.02	1.02	1.02	1.02	1.02
80.0	*	0.	0.98	1.01	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
85.0	*	0.	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
90.0	*	0.	0.92	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
95.0	*	0.	0.89	0.96	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
100.0	*	0.	0.87	0.94	0.97	0.97	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98
105.0	*	0.	0.84	0.93	0.95	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
110.0	*	0.	0.82	0.91	0.94	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97
115.0	*	0.	0.80	0.90	0.93	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
120.0	*	0.	0.79	0.89	0.93	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.96
125.0	*	0.	0.77	0.88	0.92	0.94	0.95	0.95	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
130.0	*	0.	0.76	0.87	0.91	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95
135.0	*	0.	0.75	0.86	0.90	0.92	0.94	0.94	0.95	0.95	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95
140.0	*	0.	0.74	0.85	0.90	0.92	0.93	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
145.0	*	0.	0.73	0.84	0.89	0.91	0.93	0.94	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.94
150.0	*	0.	0.72	0.84	0.89	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.94
155.0	*	0.	0.71	0.83	0.88	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.94	0.94
160.0	*	0.	0.71	0.83	0.88	0.90	0.92	0.93	0.94	0.94	0.94	0.95	0.95	0.95	0.95	0.94	0.94	0.94
165.0	*	0.	0.71	0.83	0.88	0.90	0.92	0.93	0.93	0.94	0.94	0.94	0.95	0.94	0.94	0.94	0.94	0.94
170.0	*	0.	0.70	0.82	0.87	0.90	0.92	0.93	0.93	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
175.0	*	0.	0.70	0.82	0.87	0.90	0.92	0.93	0.93	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.93
180.0	*	0.	0.70	0.82	0.87	0.90	0.92	0.93	0.93	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.93

TABLE 2B - AZMUTH DEVIATION FOR $V_1/V_2 = 0.7$ AND DIP ANGLE = 5.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	*	175	4	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
10.0	*	170	7	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
15.0	*	165	11	4	3	2	2	1	1	1	1	1	1	1	1	1	1	1
20.0	*	160	14	5	3	2	2	2	2	2	1	1	1	1	1	2	2	2
25.0	*	155	17	7	4	3	3	2	2	2	2	2	2	2	2	2	2	2
30.0	*	150	19	8	5	4	3	3	2	2	2	2	2	2	2	2	2	3
35.0	*	145	21	9	6	4	3	3	3	3	2	2	2	2	2	3	3	3
40.0	*	140	23	10	6	5	4	3	3	3	3	3	3	3	3	3	3	3
45.0	*	135	24	10	7	5	4	3	3	3	3	3	3	3	3	3	3	3
50.0	*	130	25	11	7	5	5	4	4	3	3	3	3	3	3	3	3	4
55.0	*	125	25	12	8	6	5	4	4	3	3	3	3	3	3	3	3	4
60.0	*	120	26	12	8	6	5	4	4	4	3	3	3	3	3	3	4	4
65.0	*	115	26	12	8	6	5	4	4	4	4	4	3	4	4	4	4	4
70.0	*	110	25	13	8	6	5	5	4	4	4	4	4	4	4	4	4	4
75.0	*	105	25	13	9	7	5	5	4	4	4	4	4	4	4	4	4	4
80.0	*	100	25	13	9	7	5	5	4	4	4	4	4	4	4	4	4	4
85.0	*	95	24	12	9	7	5	5	4	4	4	4	4	4	4	4	4	4
90.0	*	90	23	12	8	7	5	5	4	4	4	4	4	4	4	4	4	4
95.0	*	85	22	12	8	6	5	5	4	4	4	4	4	4	4	4	4	4
100.0	*	80	22	12	8	6	5	5	4	4	4	4	4	4	4	4	4	4
105.0	*	75	21	11	8	6	5	4	4	4	4	3	3	3	3	3	3	4
110.0	*	70	19	11	8	6	5	4	4	4	3	3	3	3	3	3	3	4
115.0	*	65	18	10	7	6	5	4	4	3	3	3	3	3	3	3	3	4
120.0	*	60	17	10	7	5	4	4	3	3	3	3	3	3	3	3	3	3
125.0	*	55	16	9	6	5	4	4	3	3	3	3	3	3	3	3	3	3
130.0	*	50	14	8	6	5	4	3	3	3	3	3	3	3	3	3	3	3
135.0	*	45	13	8	5	4	4	3	3	3	2	2	2	2	2	2	2	3
140.0	*	40	12	7	5	4	3	3	3	2	2	2	2	2	2	2	2	2
145.0	*	35	10	6	4	3	3	2	2	2	2	2	2	2	2	2	2	2
150.0	*	30	9	5	4	3	2	2	2	2	2	2	2	2	2	2	2	2
155.0	*	25	7	4	3	2	2	2	2	2	1	1	1	1	1	1	2	2
160.0	*	20	6	4	3	2	2	1	1	1	1	1	1	1	1	1	1	1
165.0	*	15	4	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
170.0	*	10	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
175.0	*	5	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
180.0	*	0	0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0

TABLE 3A - SLOPE CORRECTION FOR $V_1/V_2 = 0.7$ AND DIP ANGLE = 8.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	0.	3.30	1.55	1.32	1.23	1.19	1.16	1.15	1.14	1.13	1.13	1.13	1.13	1.13	1.14	1.15	1.16
5.0	*	0.	3.21	1.55	1.32	1.23	1.19	1.16	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.14	1.15	1.16
10.0	*	0.	2.97	1.53	1.31	1.23	1.18	1.16	1.14	1.13	1.13	1.12	1.12	1.13	1.13	1.14	1.15	1.16
15.0	*	0.	2.68	1.51	1.30	1.22	1.18	1.15	1.14	1.13	1.12	1.12	1.12	1.12	1.13	1.13	1.14	1.15
20.0	*	0.	2.38	1.48	1.29	1.21	1.17	1.15	1.13	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.14	1.15
25.0	*	0.	2.12	1.44	1.27	1.20	1.16	1.14	1.13	1.12	1.11	1.11	1.11	1.11	1.12	1.12	1.13	1.14
30.0	*	0.	1.89	1.40	1.25	1.19	1.15	1.13	1.12	1.11	1.11	1.10	1.10	1.11	1.11	1.11	1.12	1.13
35.0	*	0.	1.70	1.35	1.23	1.17	1.14	1.12	1.11	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.12
40.0	*	0.	1.55	1.31	1.21	1.16	1.13	1.11	1.10	1.09	1.09	1.09	1.09	1.09	1.09	1.10	1.10	1.11
45.0	*	0.	1.41	1.27	1.18	1.14	1.12	1.10	1.09	1.09	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.10
50.0	*	0.	1.30	1.22	1.16	1.12	1.10	1.09	1.08	1.08	1.07	1.07	1.07	1.07	1.07	1.08	1.08	1.09
55.0	*	0.	1.21	1.18	1.13	1.10	1.09	1.08	1.07	1.07	1.06	1.06	1.06	1.06	1.06	1.07	1.07	1.07
60.0	*	0.	1.13	1.14	1.11	1.09	1.07	1.06	1.06	1.06	1.05	1.05	1.05	1.05	1.05	1.06	1.06	1.06
65.0	*	0.	1.06	1.10	1.08	1.07	1.06	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.05	1.05
70.0	*	0.	1.00	1.06	1.06	1.05	1.04	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.04	1.04
75.0	*	0.	0.94	1.03	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03
80.0	*	0.	0.90	1.00	1.01	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
85.0	*	0.	0.86	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
90.0	*	0.	0.82	0.94	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
95.0	*	0.	0.79	0.92	0.95	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98
100.0	*	0.	0.76	0.90	0.94	0.96	0.96	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97
105.0	*	0.	0.74	0.88	0.92	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.96
110.0	*	0.	0.72	0.86	0.91	0.93	0.94	0.95	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
115.0	*	0.	0.70	0.84	0.89	0.92	0.93	0.94	0.95	0.95	0.95	0.96	0.96	0.96	0.96	0.95	0.95	0.95
120.0	*	0.	0.68	0.83	0.88	0.91	0.92	0.93	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.94
125.0	*	0.	0.67	0.81	0.87	0.90	0.92	0.93	0.93	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
130.0	*	0.	0.65	0.80	0.86	0.89	0.91	0.92	0.93	0.93	0.94	0.94	0.94	0.94	0.94	0.94	0.93	0.93
135.0	*	0.	0.64	0.79	0.85	0.88	0.90	0.91	0.92	0.93	0.93	0.93	0.94	0.93	0.93	0.93	0.93	0.92
140.0	*	0.	0.63	0.78	0.84	0.88	0.90	0.91	0.92	0.92	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.92
145.0	*	0.	0.62	0.77	0.83	0.87	0.89	0.90	0.91	0.92	0.92	0.93	0.93	0.93	0.93	0.92	0.92	0.92
150.0	*	0.	0.61	0.76	0.83	0.86	0.89	0.90	0.91	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.91
155.0	*	0.	0.61	0.76	0.82	0.86	0.88	0.90	0.91	0.91	0.92	0.92	0.92	0.92	0.92	0.92	0.91	0.91
160.0	*	0.	0.60	0.75	0.82	0.86	0.88	0.89	0.90	0.91	0.92	0.92	0.92	0.92	0.92	0.92	0.91	0.91
165.0	*	0.	0.60	0.75	0.82	0.85	0.88	0.89	0.90	0.91	0.91	0.92	0.92	0.92	0.92	0.91	0.91	0.91
170.0	*	0.	0.60	0.75	0.81	0.85	0.87	0.89	0.90	0.91	0.91	0.91	0.92	0.92	0.92	0.91	0.91	0.90
175.0	*	0.	0.59	0.74	0.81	0.85	0.87	0.89	0.90	0.91	0.91	0.91	0.92	0.92	0.91	0.91	0.91	0.90
180.0	*	0.	0.59	0.74	0.81	0.85	0.87	0.89	0.90	0.91	0.91	0.91	0.92	0.92	0.91	0.91	0.91	0.90

TABLE 3B - AZMUTH DEVIATION FOR $V_1/V_2 = 0.7$ AND DIP ANGLE = 8.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	*	175	11	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
10.0	*	170	21	5	3	2	2	2	1	1	1	1	1	1	1	1	2	2
15.0	*	165	29	8	5	3	3	2	2	2	2	2	2	2	2	2	2	2
20.0	*	160	35	10	6	5	4	3	3	3	3	2	2	3	3	3	3	3
25.0	*	155	39	12	8	6	4	4	3	3	3	3	3	3	3	3	4	4
30.0	*	150	41	14	9	6	5	5	4	4	4	4	4	4	4	4	4	4
35.0	*	145	43	16	10	7	6	5	5	4	4	4	4	4	4	4	5	5
40.0	*	140	44	17	11	8	7	6	5	5	5	4	4	4	4	5	5	6
45.0	*	135	44	18	12	9	7	6	6	5	5	5	5	5	5	5	6	6
50.0	*	130	44	19	12	9	8	7	6	6	5	5	5	5	5	5	6	6
55.0	*	125	43	20	13	10	8	7	6	6	6	5	5	5	5	6	6	7
60.0	*	120	43	20	13	10	8	7	6	6	6	6	6	6	6	6	6	7
65.0	*	115	42	21	14	10	9	7	7	6	6	6	6	6	6	6	7	7
70.0	*	110	40	21	14	11	9	8	7	6	6	6	6	6	6	6	7	7
75.0	*	105	39	20	14	11	9	8	7	6	6	6	6	6	6	6	7	7
80.0	*	100	38	20	14	11	9	8	7	6	6	6	6	6	6	6	7	7
85.0	*	95	36	20	14	11	9	8	7	6	6	6	6	6	6	6	7	7
90.0	*	90	35	19	13	10	9	8	7	6	6	6	6	6	6	6	7	7
95.0	*	85	33	19	13	10	8	7	7	6	6	6	6	6	6	6	6	7
100.0	*	80	31	18	13	10	8	7	7	6	6	6	6	6	6	6	6	7
105.0	*	75	29	17	12	10	8	7	6	6	6	5	5	5	5	5	6	6
110.0	*	70	28	16	12	9	8	7	6	6	5	5	5	5	5	5	5	6
115.0	*	65	26	15	11	9	7	6	6	5	5	5	5	5	5	5	5	6
120.0	*	60	24	14	10	8	7	6	5	5	5	5	5	5	5	5	5	5
125.0	*	55	22	13	10	8	6	6	5	5	4	4	4	4	4	4	5	5
130.0	*	50	20	12	9	7	6	5	5	4	4	4	4	4	4	4	4	5
135.0	*	45	18	11	8	6	5	5	4	4	4	4	4	4	4	4	4	4
140.0	*	40	16	10	7	6	5	4	4	4	3	3	3	3	3	3	4	4
145.0	*	35	14	9	6	5	4	4	3	3	3	3	3	3	3	3	3	3
150.0	*	30	12	8	6	4	4	3	3	3	3	3	2	2	3	3	3	3
155.0	*	25	10	6	5	4	3	3	2	2	2	2	2	2	2	2	2	2
160.0	*	20	8	5	4	3	3	2	2	2	2	2	2	2	2	2	2	2
165.0	*	15	6	4	3	2	2	2	1	1	1	1	1	1	1	1	1	1
170.0	*	10	4	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
175.0	*	5	2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
180.0	*	0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0

TABLE 4A - SLOPE CORRECTION FOR V1/V2 = 0.8 AND DIP ANGLE = 2.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	0.	1.11	1.05	1.04	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
5.0	*	0.	1.11	1.05	1.04	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
10.0	*	0.	1.11	1.05	1.04	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
15.0	*	0.	1.11	1.05	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
20.0	*	0.	1.10	1.05	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
25.0	*	0.	1.10	1.05	1.03	1.03	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02
30.0	*	0.	1.09	1.05	1.03	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02
35.0	*	0.	1.09	1.04	1.03	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02
40.0	*	0.	1.08	1.04	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02
45.0	*	0.	1.07	1.04	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02
50.0	*	0.	1.07	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
55.0	*	0.	1.06	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
60.0	*	0.	1.05	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
65.0	*	0.	1.04	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
70.0	*	0.	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
75.0	*	0.	1.02	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01
80.0	*	0.	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
85.0	*	0.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
90.0	*	0.	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
95.0	*	0.	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100.0	*	0.	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
105.0	*	0.	0.97	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99
110.0	*	0.	0.96	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
115.0	*	0.	0.96	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
120.0	*	0.	0.95	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
125.0	*	0.	0.94	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
130.0	*	0.	0.94	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
135.0	*	0.	0.93	0.96	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
140.0	*	0.	0.93	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98
145.0	*	0.	0.92	0.96	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98
150.0	*	0.	0.92	0.96	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98
155.0	*	0.	0.92	0.96	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98
160.0	*	0.	0.91	0.95	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98
165.0	*	0.	0.91	0.95	0.97	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98
170.0	*	0.	0.91	0.95	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.98	0.98	0.98	0.98
175.0	*	0.	0.91	0.95	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
180.0	*	0.	0.91	0.95	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

TABLE 4B - AZMUTH DEVIATION FOR V1/V2 = 0.8 AND DIP ANGLE = 2.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	*	175	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.0	*	170	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.0	*	165	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
20.0	*	160	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
25.0	*	155	3	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1
30.0	*	150	3	2	1	1	1	1	1	1	0	0	0	0	1	1	1	1
35.0	*	145	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40.0	*	140	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
45.0	*	135	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50.0	*	130	5	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
55.0	*	125	5	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
60.0	*	120	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
65.0	*	115	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
70.0	*	110	6	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
75.0	*	105	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
80.0	*	100	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
85.0	*	95	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
90.0	*	90	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
95.0	*	85	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
100.0	*	80	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
105.0	*	75	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
110.0	*	70	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
115.0	*	65	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
120.0	*	60	5	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
125.0	*	55	4	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
130.0	*	50	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
135.0	*	45	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
140.0	*	40	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
145.0	*	35	3	2	1	1	1	1	1	1	0	0	0	1	1	1	1	1
150.0	*	30	3	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1
155.0	*	25	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
160.0	*	20	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
165.0	*	15	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
170.0	*	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
175.0	*	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180.0	*	0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0

TABLE 5A - SLOPE CORRECTION FOR $V_1/V_2 = 0.8$ AND DIP ANGLE = 5.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	0.	1.34	1.15	1.10	1.07	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.05	1.05	1.05	1.06	1.06
5.0	*	0.	1.34	1.15	1.10	1.07	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.05	1.05	1.05	1.06	1.06
10.0	*	0.	1.33	1.15	1.10	1.07	1.06	1.05	1.05	1.05	1.04	1.04	1.04	1.05	1.05	1.05	1.06	1.06
15.0	*	0.	1.32	1.14	1.09	1.07	1.06	1.05	1.05	1.04	1.04	1.04	1.04	1.05	1.05	1.05	1.06	1.06
20.0	*	0.	1.30	1.14	1.09	1.07	1.06	1.05	1.05	1.04	1.04	1.04	1.04	1.05	1.05	1.05	1.06	1.06
25.0	*	0.	1.29	1.13	1.09	1.07	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.04	1.05	1.05	1.05	1.06
30.0	*	0.	1.26	1.12	1.08	1.06	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.05	1.05
35.0	*	0.	1.24	1.11	1.08	1.06	1.05	1.04	1.04	1.04	1.04	1.03	1.04	1.04	1.04	1.04	1.04	1.05
40.0	*	0.	1.22	1.10	1.07	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.04	1.04	1.04	1.05
45.0	*	0.	1.19	1.09	1.06	1.05	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.04
50.0	*	0.	1.16	1.08	1.06	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.04
55.0	*	0.	1.14	1.07	1.05	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03
60.0	*	0.	1.11	1.06	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03
65.0	*	0.	1.08	1.05	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
70.0	*	0.	1.06	1.04	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02
75.0	*	0.	1.04	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
80.0	*	0.	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
85.0	*	0.	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
90.0	*	0.	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
95.0	*	0.	0.95	0.98	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99
100.0	*	0.	0.93	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
105.0	*	0.	0.92	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
110.0	*	0.	0.90	0.95	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98
115.0	*	0.	0.89	0.94	0.96	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
120.0	*	0.	0.87	0.94	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97
125.0	*	0.	0.86	0.93	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97
130.0	*	0.	0.85	0.92	0.95	0.96	0.97	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.97	0.97	0.97
135.0	*	0.	0.84	0.91	0.94	0.95	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
140.0	*	0.	0.83	0.91	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.96
145.0	*	0.	0.82	0.90	0.93	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.96	0.96
150.0	*	0.	0.82	0.90	0.93	0.95	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.96
155.0	*	0.	0.81	0.90	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.96	0.96
160.0	*	0.	0.81	0.89	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96
165.0	*	0.	0.80	0.89	0.92	0.94	0.95	0.96	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.96	0.96	0.96
170.0	*	0.	0.80	0.89	0.92	0.94	0.95	0.96	0.96	0.96	0.96	0.96	0.97	0.97	0.96	0.96	0.96	0.96
175.0	*	0.	0.80	0.89	0.92	0.94	0.95	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95
180.0	*	0.	0.80	0.89	0.92	0.94	0.95	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95

TABLE 5B - AZIMUTH DEVIATION FOR $V_1/V_2 = 0.8$ AND DIP ANGLE = 5.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	*	175	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
10.0	*	170	3	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1
15.0	*	165	5	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20.0	*	160	6	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
25.0	*	155	8	4	2	2	1	1	1	1	1	1	1	1	1	1	1	2
30.0	*	150	9	4	3	2	2	2	1	1	1	1	1	1	1	1	2	2
35.0	*	145	10	5	3	2	2	2	2	1	1	1	1	1	2	2	2	2
40.0	*	140	11	5	3	3	2	2	2	2	2	2	2	2	2	2	2	2
45.0	*	135	12	6	4	3	2	2	2	2	2	2	2	2	2	2	2	2
50.0	*	130	13	6	4	3	3	2	2	2	2	2	2	2	2	2	2	3
55.0	*	125	14	6	4	3	3	2	2	2	2	2	2	2	2	2	2	3
60.0	*	120	14	7	5	3	3	3	2	2	2	2	2	2	2	2	3	3
65.0	*	115	14	7	5	4	3	3	2	2	2	2	2	2	2	2	3	3
70.0	*	110	15	7	5	4	3	3	2	2	2	2	2	2	2	2	3	3
75.0	*	105	15	7	5	4	3	3	3	2	2	2	2	2	2	2	3	3
80.0	*	100	15	7	5	4	3	3	3	2	2	2	2	2	2	2	3	3
85.0	*	95	14	7	5	4	3	3	3	2	2	2	2	2	2	2	3	3
90.0	*	90	14	7	5	4	3	3	3	2	2	2	2	2	2	2	3	3
95.0	*	85	14	7	5	4	3	3	3	2	2	2	2	2	2	2	3	3
100.0	*	80	13	7	5	4	3	3	2	2	2	2	2	2	2	2	3	3
105.0	*	75	13	7	5	4	3	3	2	2	2	2	2	2	2	2	3	3
110.0	*	70	12	7	4	3	3	3	2	2	2	2	2	2	2	2	2	3
115.0	*	65	12	6	4	3	3	2	2	2	2	2	2	2	2	2	2	3
120.0	*	60	11	6	4	3	3	2	2	2	2	2	2	2	2	2	2	2
125.0	*	55	10	6	4	3	2	2	2	2	2	2	2	2	2	2	2	2
130.0	*	50	9	5	4	3	2	2	2	2	2	2	2	2	2	2	2	2
135.0	*	45	9	5	3	3	2	2	2	2	2	1	1	1	1	2	2	2
140.0	*	40	8	4	3	2	2	2	2	1	1	1	1	1	1	1	2	2
145.0	*	35	7	4	3	2	2	1	1	1	1	1	1	1	1	1	1	2
150.0	*	30	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
155.0	*	25	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
160.0	*	20	4	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
165.0	*	15	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
170.0	*	10	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
175.0	*	5	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180.0	*	0	0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0

TABLE 6A - SLOPE CORRECTION FOR $V_1/V_2 = 0.8$ AND DIP ANGLE = 8.0 DEGREES

[illegible]

TABLE 6B - AZMUTH DEVIATION FOR $V_1/V_2 = 0.8$ AND DIP ANGLE = 8.0 DEGREES

		I(°E)																	
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	
AZIMUTH FROM DIR. OF DIP																			
-0.	*	180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5.0	*	175	3	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	
10.0	*	170	7	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	
15.0	*	165	10	4	2	2	2	1	1	1	1	1	1	1	1	1	2	2	
20.0	*	160	13	5	3	2	2	2	2	2	1	1	2	2	2	2	2	2	
25.0	*	155	15	6	4	3	2	2	2	2	2	2	2	2	2	2	2	3	
30.0	*	150	17	7	5	4	3	3	2	2	2	2	2	2	2	2	3	3	
35.0	*	145	19	8	5	4	3	3	3	2	2	2	2	3	3	3	3	4	
40.0	*	140	21	9	6	4	4	3	3	3	3	3	3	3	3	3	3	4	
45.0	*	135	22	10	6	5	4	4	3	3	3	3	3	3	3	3	4	4	
50.0	*	130	23	10	7	5	4	4	3	3	3	3	3	3	3	3	4	4	
55.0	*	125	23	11	7	6	5	4	4	3	3	3	3	3	4	4	4	5	
60.0	*	120	24	11	8	6	5	4	4	4	3	3	3	4	4	4	4	5	
65.0	*	115	24	12	8	6	5	4	4	4	4	4	4	4	4	4	4	5	
70.0	*	110	24	12	8	6	5	4	4	4	4	4	4	4	4	4	5	5	
75.0	*	105	24	12	8	6	5	4	4	4	4	4	4	4	4	4	5	5	
80.0	*	100	23	12	8	6	5	5	4	4	4	4	4	4	4	4	5	5	
85.0	*	95	23	12	8	6	5	5	4	4	4	4	4	4	4	4	4	5	
90.0	*	90	22	12	8	6	5	4	4	4	4	4	4	4	4	4	4	5	
95.0	*	85	21	11	8	6	5	4	4	4	4	4	4	4	4	4	4	5	
100.0	*	80	20	11	8	6	5	4	4	4	4	3	3	3	4	4	4	5	
105.0	*	75	19	11	7	6	5	4	4	4	3	3	3	3	3	4	4	4	
110.0	*	70	18	10	7	5	5	4	4	3	3	3	3	3	3	3	4	4	
115.0	*	65	17	10	7	5	4	4	3	3	3	3	3	3	3	3	4	4	
120.0	*	60	16	9	6	5	4	4	3	3	3	3	3	3	3	3	3	4	
125.0	*	55	15	8	6	5	4	3	3	3	3	3	3	3	3	3	3	3	
130.0	*	50	14	8	5	4	4	3	3	3	3	2	2	2	3	3	3	3	
135.0	*	45	12	7	5	4	3	3	3	2	2	2	2	2	2	2	3	3	
140.0	*	40	11	6	5	4	3	3	2	2	2	2	2	2	2	2	2	3	
145.0	*	35	10	6	4	3	3	2	2	2	2	2	2	2	2	2	2	2	
150.0	*	30	8	5	3	3	2	2	2	2	2	2	2	2	2	2	2	2	
155.0	*	25	7	4	3	2	2	2	2	1	1	1	1	1	1	1	2	2	
160.0	*	20	6	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	
165.0	*	15	4	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	
170.0	*	10	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
175.0	*	5	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
180.0	*	0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	

TABLE 7A - SLOPE CORRECTION FOR V1/V2 = 0.9 AND DIP ANGLE = 2.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	0.	1.05	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
5.0	*	0.	1.05	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
10.0	*	0.	1.05	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
15.0	*	0.	1.05	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
20.0	*	0.	1.04	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
25.0	*	0.	1.04	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
30.0	*	0.	1.04	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
35.0	*	0.	1.04	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
40.0	*	0.	1.04	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
45.0	*	0.	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
50.0	*	0.	1.03	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01
55.0	*	0.	1.03	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01
60.0	*	0.	1.02	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01
65.0	*	0.	1.02	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01
70.0	*	0.	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
75.0	*	0.	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80.0	*	0.	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
85.0	*	0.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
90.0	*	0.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
95.0	*	0.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100.0	*	0.	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
105.0	*	0.	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
110.0	*	0.	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
115.0	*	0.	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
120.0	*	0.	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99
125.0	*	0.	0.97	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99
130.0	*	0.	0.97	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99
135.0	*	0.	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
140.0	*	0.	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
145.0	*	0.	0.96	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
150.0	*	0.	0.96	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
155.0	*	0.	0.96	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
160.0	*	0.	0.96	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
165.0	*	0.	0.96	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
170.0	*	0.	0.96	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
175.0	*	0.	0.96	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
180.0	*	0.	0.96	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

TABLE 7B - AZIMUTH DEVIATION FOR V1/V2 = 0.9 AND DIP ANGLE = 2.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	*	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.0	*	170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.0	*	165	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.0	*	160	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25.0	*	155	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30.0	*	150	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35.0	*	145	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
40.0	*	140	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
45.0	*	135	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1
50.0	*	130	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1
55.0	*	125	2	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1
60.0	*	120	2	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1
65.0	*	115	2	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1
70.0	*	110	2	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1
75.0	*	105	3	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1
80.0	*	100	3	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1
85.0	*	95	3	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1
90.0	*	90	3	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1
95.0	*	85	3	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1
100.0	*	80	2	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1
105.0	*	75	2	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1
110.0	*	70	2	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1
115.0	*	65	2	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1
120.0	*	60	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1
125.0	*	55	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1
130.0	*	50	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
135.0	*	45	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
140.0	*	40	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
145.0	*	35	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
150.0	*	30	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
155.0	*	25	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
160.0	*	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
165.0	*	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
170.0	*	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
175.0	*	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180.0	*	0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0

TABLE 8A - SLOPE CORRECTION FOR V1/V2 = 0.9 AND DIP ANGLE = 5.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	0.	1.13	1.06	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.04
5.0	*	0.	1.13	1.06	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.04
10.0	*	0.	1.12	1.06	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.04
15.0	*	0.	1.12	1.06	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.04
20.0	*	0.	1.12	1.06	1.04	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03
25.0	*	0.	1.11	1.05	1.04	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03
30.0	*	0.	1.11	1.05	1.04	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03
35.0	*	0.	1.10	1.05	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03
40.0	*	0.	1.09	1.05	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03
45.0	*	0.	1.08	1.04	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02	1.02
50.0	*	0.	1.07	1.04	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02
55.0	*	0.	1.06	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02
60.0	*	0.	1.05	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02
65.0	*	0.	1.04	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
70.0	*	0.	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
75.0	*	0.	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01
80.0	*	0.	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
85.0	*	0.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
90.0	*	0.	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
95.0	*	0.	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100.0	*	0.	0.98	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
105.0	*	0.	0.97	0.98	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99
110.0	*	0.	0.96	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
115.0	*	0.	0.95	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
120.0	*	0.	0.94	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
125.0	*	0.	0.94	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98
130.0	*	0.	0.93	0.96	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98
135.0	*	0.	0.92	0.96	0.97	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98
140.0	*	0.	0.92	0.96	0.97	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98
145.0	*	0.	0.91	0.96	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98
150.0	*	0.	0.91	0.95	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98
155.0	*	0.	0.91	0.95	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
160.0	*	0.	0.90	0.95	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
165.0	*	0.	0.90	0.95	0.96	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
170.0	*	0.	0.90	0.95	0.96	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
175.0	*	0.	0.90	0.95	0.96	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
180.0	*	0.	0.90	0.95	0.96	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97

TABLE 8B - AZIMUTH DEVIATION FOR V1/V2 = 0.9 AND DIP ANGLE = 5.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	*	175	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.0	*	170	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.0	*	165	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
20.0	*	160	2	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1
25.0	*	155	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30.0	*	150	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35.0	*	145	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40.0	*	140	5	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
45.0	*	135	5	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
50.0	*	130	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1	2
55.0	*	125	6	3	2	1	1	1	1	1	1	1	1	1	1	1	1	2
60.0	*	120	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	2
65.0	*	115	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	2
70.0	*	110	6	3	2	2	1	1	1	1	1	1	1	1	1	1	2	2
75.0	*	105	6	3	2	2	1	1	1	1	1	1	1	1	1	1	2	2
80.0	*	100	6	3	2	2	1	1	1	1	1	1	1	1	1	1	2	2
85.0	*	95	6	3	2	2	1	1	1	1	1	1	1	1	1	1	2	2
90.0	*	90	6	3	2	2	1	1	1	1	1	1	1	1	1	1	2	2
95.0	*	85	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	2
100.0	*	80	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	2
105.0	*	75	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	2
110.0	*	70	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	2
115.0	*	65	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
120.0	*	60	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
125.0	*	55	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
130.0	*	50	5	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
135.0	*	45	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
140.0	*	40	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
145.0	*	35	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
150.0	*	30	3	2	1	1	1	1	0	0	0	0	0	0	1	1	1	1
155.0	*	25	2	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1
160.0	*	20	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
165.0	*	15	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
170.0	*	10	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
175.0	*	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180.0	*	0	0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0

TABLE 9A - SLOPE CORRECTION FOR $V_1/V_2 = 0.9$ AND DIP ANGLE = 8.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	0.	1.22	1.10	1.07	1.05	1.04	1.04	1.04	1.04	1.03	1.04	1.04	1.04	1.04	1.05	1.06	1.07
5.0	*	0.	1.22	1.10	1.07	1.05	1.04	1.04	1.04	1.03	1.03	1.04	1.04	1.04	1.04	1.05	1.06	1.07
10.0	*	0.	1.22	1.10	1.07	1.05	1.04	1.04	1.04	1.03	1.03	1.03	1.04	1.04	1.04	1.05	1.06	1.07
15.0	*	0.	1.21	1.10	1.07	1.05	1.04	1.04	1.04	1.03	1.03	1.03	1.04	1.04	1.04	1.05	1.05	1.06
20.0	*	0.	1.20	1.10	1.06	1.05	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.04	1.04	1.05	1.05	1.06
25.0	*	0.	1.19	1.09	1.06	1.05	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.04	1.04	1.04	1.05	1.06
30.0	*	0.	1.18	1.09	1.06	1.05	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.04	1.05	1.06
35.0	*	0.	1.17	1.08	1.05	1.04	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.04	1.05
40.0	*	0.	1.15	1.07	1.05	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.04	1.05
45.0	*	0.	1.13	1.07	1.05	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.04
50.0	*	0.	1.12	1.06	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.04
55.0	*	0.	1.10	1.05	1.04	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03
60.0	*	0.	1.08	1.04	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03
65.0	*	0.	1.07	1.04	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02
70.0	*	0.	1.05	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.02
75.0	*	0.	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
80.0	*	0.	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01
85.0	*	0.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
90.0	*	0.	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
95.0	*	0.	0.97	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
100.0	*	0.	0.96	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
105.0	*	0.	0.94	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
110.0	*	0.	0.93	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98
115.0	*	0.	0.92	0.96	0.97	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98
120.0	*	0.	0.91	0.95	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98
125.0	*	0.	0.90	0.95	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
130.0	*	0.	0.89	0.94	0.96	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97
135.0	*	0.	0.88	0.94	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97
140.0	*	0.	0.88	0.93	0.95	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97
145.0	*	0.	0.87	0.93	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97
150.0	*	0.	0.86	0.93	0.95	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97
155.0	*	0.	0.86	0.92	0.95	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97
160.0	*	0.	0.86	0.92	0.95	0.96	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97
165.0	*	0.	0.85	0.92	0.94	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98	0.97	0.97	0.97	0.97	0.96
170.0	*	0.	0.85	0.92	0.94	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.96
175.0	*	0.	0.85	0.92	0.94	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.96
180.0	*	0.	0.85	0.92	0.94	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.96

TABLE 9B - AZIMUTH DEVIATION FOR $V_1/V_2 = 0.9$ AND DIP ANGLE = 8.0 DEGREES

		I (DEG)																
		0.	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
AZIMUTH FROM DIR. OF DIP																		
-0.	*	180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	*	175	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.0	*	170	2	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1
15.0	*	165	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20.0	*	160	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25.0	*	155	5	2	2	1	1	1	1	1	1	1	1	1	1	1	1	2
30.0	*	150	6	3	2	2	1	1	1	1	1	1	1	1	1	1	2	2
35.0	*	145	7	3	2	2	1	1	1	1	1	1	1	1	1	2	2	2
40.0	*	140	8	4	2	2	2	1	1	1	1	1	1	1	2	2	2	2
45.0	*	135	8	4	3	2	2	2	1	1	1	1	1	2	2	2	2	2
50.0	*	130	9	4	3	2	2	2	2	1	1	1	2	2	2	2	2	3
55.0	*	125	9	5	3	2	2	2	2	2	2	2	2	2	2	2	2	3
60.0	*	120	10	5	3	3	2	2	2	2	2	2	2	2	2	2	2	3
65.0	*	115	10	5	3	3	2	2	2	2	2	2	2	2	2	2	2	3
70.0	*	110	10	5	3	3	2	2	2	2	2	2	2	2	2	2	3	3
75.0	*	105	10	5	4	3	2	2	2	2	2	2	2	2	2	2	3	3
80.0	*	100	10	5	4	3	2	2	2	2	2	2	2	2	2	2	2	3
85.0	*	95	10	5	4	3	2	2	2	2	2	2	2	2	2	2	2	3
90.0	*	90	10	5	4	3	2	2	2	2	2	2	2	2	2	2	2	3
95.0	*	85	10	5	4	3	2	2	2	2	2	2	2	2	2	2	2	3
100.0	*	80	10	5	3	3	2	2	2	2	2	2	2	2	2	2	2	3
105.0	*	75	9	5	3	3	2	2	2	2	2	2	2	2	2	2	2	2
110.0	*	70	9	5	3	3	2	2	2	2	2	2	2	2	2	2	2	2
115.0	*	65	9	4	3	2	2	2	2	2	2	1	1	2	2	2	2	2
120.0	*	60	8	4	3	2	2	2	2	1	1	1	1	1	2	2	2	2
125.0	*	55	8	4	3	2	2	2	1	1	1	1	1	1	1	2	2	2
130.0	*	50	7	4	3	2	2	1	1	1	1	1	1	1	1	1	2	2
135.0	*	45	6	3	2	2	2	1	1	1	1	1	1	1	1	1	1	2
140.0	*	40	6	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1
145.0	*	35	5	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1
150.0	*	30	4	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
155.0	*	25	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
160.0	*	20	3	2	1	1	1	1	1	1	0	0	0	0	1	1	1	1
165.0	*	15	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1
170.0	*	10	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
175.0	*	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180.0	*	0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0

from 0–80, in steps of five degrees. This angle should not exceed $90-\delta$, otherwise for waves traveling up-dip, the ray beam would fall above the interface.

APPLICATION

When the dip and strike of the interface and the velocity contrast are known, the observed slopes ($dT/d\Delta$) should be increased by the correction factors listed in Tables 1A–9A. The corrected values are equivalent to the case of horizontal interface under otherwise identical conditions. Inversely, one can study the observed deviations of the azimuths or required corrections to the slopes in order to determine the attitudes of the interface and the velocity contrasts.

Here, we have used both types of data as observed across the TFSO array for the latter purpose. As is seen in Figure 2, deviations in azimuth are usually such

FIG. 2. For a dipping interface, the wave front appears to be approaching the recording station from a more up dip direction than the true azimuth to the source. Here azimuths are shown from the direction of dip. Solid lines are true azimuths and dashed lines are apparent azimuths. The sign of azimuthal deviation $\Delta\phi$ changes in and opposite to the direction of dip.

that the ray beam appears to be approaching the station from a slightly more up-dip direction than the true azimuth to the source. In this figure, solid lines show the true, and the dashed lines the apparent directions from which the wave front is arriving. For the rays situated in the plane perpendicular to the strike the azimuthal deviation is either 0 or 180 degrees. The 180 degrees deviation only occurs for the up-dip traveling rays for which

$$i < \sin^{-1}(v_2 \sin \delta / v_1) - \delta.$$

If, as is common, the azimuth is measured from the north, one will observe from Figure 2 that the sign of $\Delta\phi$ changes twice as ϕ varies from 0 to 360 degrees. The changes occur in and opposite to the direction of dip. Therefore, the observations of the sign of $\Delta\phi$ alone, should result in the determination of strike in an approximate but unique fashion. This procedure is demonstrated in Figure 3, where the observed azimuth deviations for various phases of *P* type are plotted against the

station-to-epicenter azimuth. Three relatively distinct regions can be noticed in Figure 3. The boundaries are not very sharp, but they lie within five degrees of 70 and 250 degrees.

The absolute value of $\Delta\phi$ at any azimuth should depend on the angle of incidence. For the angles of incidence at various epicentral distances those of the Jeffreys model computed by Ritsema (1958) are used. The true angle of incidence for the phases employed in the construction of Figure 3, i.e., P , P' , PcP , ScP , and $PKKP$, do not exceed 40 degrees. The largest value, 37.5 degrees, corresponds to the observation of the P wave at $\Delta = 32.5$ degrees.

In the absence of other data, and taking into account the pertinent i and ϕ , one may compare the amplitude of observed $\Delta\phi$ with those given in Tables 1B-9B and choose the pair of parameters δ and v_1/v_2 which best fit the observation. In doing so, the first column of the tables should be revised to account for the fact that the true

FIG. 3. Observed azimuthal deviations at TFSO as a function of azimuth. Sign of $\Delta\phi$ changes at about 70 and 250 degrees.

azimuth of direction of dip is not always zero. The revision may be easily done by sliding the first column up or down until the true azimuth of the dip lines up with the first line of the table.

There is, of course, no difficulty in the determination of strike, which is the midpoint between the zero crossings in Figure 3, i.e., $N20^\circ \pm 5^\circ W$. There are, however, two directions to choose from for the dip, i.e., $70^\circ \pm 5^\circ$ and $250^\circ \pm 5^\circ$. The rule for making such a selection turns out to be simple, and can be stated as follows: if the azimuths are read clockwise, the direction of dip is the point of transition of $\Delta\phi$ from negative to positive values; otherwise the alternative point. According to the data of Figure 3, therefore, the M -discontinuity in the vicinity of TFSO is dipping to the northeast ($N70^\circ \pm 5^\circ E$).

In practice, the determination of dip angle by this method involves unavoidable inaccuracies. In a large portion of each of the Tables 1B-9B, $\Delta\phi$ remains constant or varies only slightly. Moreover, often the inaccuracies in the determination of $\Delta\phi$ across a small array, such as TFSO, may be of the same order of magnitude as $\Delta\phi$ itself. Therefore, except in occasions of exceptional accuracy resulting, for

instance, from high speed recordings of higher frequency waves, or recording across a large area, use of absolute value of $\Delta\phi$ for the determination of dip angle is impractical, and even under those conditions should be regarded as a rough estimate. The advantage of a large array for attaining enough precision is, however, undermined by a higher probability of change of underlying conditions across the array.

Due to these difficulties, it was preferable to use the required corrections to $dT/d\Delta$ as a diagnostic feature of the dip angle. In particular, an attempt was made to compare the observed slopes for pairs of earthquakes, with epicenters at almost the same distance and opposite azimuths from the array. From Snell's law

$$\frac{\sin i_0}{v_0} = \frac{1}{V} = dT/d\Delta;$$

for each pair we have

$$\frac{\sin i_1}{\sin i_2} = \frac{V_2}{V_1} = \frac{dT_1}{dT_2} = k(i, \phi).$$

Here i_0 and v_0 are the incident angle and velocity below the free surface, and V is the apparent surface velocity. Subscripts 1 and 2 refer to rays arriving from opposite azimuths. Because the epicentral distances for each pair are the same, both rays emerge with identical i . Due to the symmetry of the problem, the theoretical tables of k in terms of i and ϕ can easily be constructed by dividing the elements of Tables 1A–9A by their symmetric elements with respect to $\phi = 90$ degrees. Then the ratios of observed slopes of the rays arriving from opposite directions but identical distances, are compared to these Tables.

With angle i at hand, one searches in the pertinent columns of the newly constructed tables to find the angle ϕ for which the k value is identical to the observed slope ratio. By doing so, one obtains three parameters for the underlying crustal structure which are compatible with observations. These parameters are, the dip angle δ , the angle ϕ related to the strike, and the velocity contrast v_1/v_2 . Since ϕ is the angle between the direction of dip and the epicenter-to-station azimuth, which is known, the direction of dip and, consequently, that of strike may be deduced.

This procedure gives, in general, more than one set of parameters. The selection is then made by applying the technique to several pairs of earthquakes and choosing that set of parameters which is common in all the results. We have used 32 earthquakes, in groups of two or more, to make twelve observations for this purpose. The relevant data regarding these observations are given in Table 10. Most of the epicenters lie in the circum-Pacific belt northwest or southeast of the TFSO array. In a few instances the observations on several earthquakes, occurring in the same vicinity are averaged. The maximum deviation from exact symmetry of the data of Table 10 is 2.7 degrees of distance and 9 degrees of azimuth. Figure 4 shows the reproduced seismograms of one such pair. The four traces are recorded at the NW, SE, NE, and SW ends of the array.

Except for the first group of earthquakes, each set of observations listed in Table 10 shows several possibilities for the underlying crustal structure. Numerical sub-

TABLE 10

COMPARISON OF THE OBSERVED $dT/d\Delta$ FOR EARTHQUAKES LOCATED AT ALMOST EQUAL DISTANCES BUT OPPOSITE AZIMUTHS FROM THE TFSO ARRAY FOR ESTIMATION OF THE DIRECTION AND MAGNITUDE OF THE DIP OF THE MOHROVIČIĆ DISCONTINUITY

Date	Δ ($^{\circ}$)	ϕ ($^{\circ}$)	h_s km	$dT/d\Delta$, sec/deg	Date	Δ ($^{\circ}$)	ϕ ($^{\circ}$)	h_s km	$dT/d\Delta$, sec/deg	k	i ($^{\circ}$)	Strike					
												1	2	3	5	6	9
1) 1964 Mar. 15	80.1	53	27	4.64	1963 July 25	81.9	239	205	6.05	.73	21.5			N13°W			
					1963 Nov. 16	82.7	237	33	6.16								
					1963 Nov. 16	82.7	237	33	6.21								
					1963 Nov. 20	82.8	237	33	6.59								
					1964 May 24	82.2	236	33	6.80								
2) 1963 Nov. 3	49.0	133	33	6.74	1964 July 26	48.9	312	100	8.64	.88	33.0		N11°E	N15°W		N8°E	
3) 1964 Jan. 2	69.0	137	110	5.94	1963 Nov. 6	68.6	312	33	6.53	.89	26.5		N3°W	N20°W	N45°E	N3°W	
					1964 Jan. 1	70.8	312	45	6.80								
					1964 July 24	68.9	313	33	6.59								
4) 1964 Jan. 26	62.8	137	116	6.10	1963 Nov. 21	62.6	314	80	6.48	.94	28.5	N1°E	N23°W	N28°W	N1°W	N20°W	N12°E
5) 1963 Nov. 11	40.2	132	33	7.33	1964 Jan. 12	42.8	314	33	8.37	.87	35.0		N22°E	N13°W		N32°E	
6) 1964 July 30	32.5	129	42	7.78	1963 Nov. 6*	68.6	312	33	8.65	.90	37.5		N3°W	N22°W		N1°W	
7) 1964 June 7	76.4	142	29	5.51	1964 June 23	75.5	313	77	6.32	.87	23.5		N5°E	N12°W		N9°E	
8) 1964 Feb. 13	73.5	126	33	5.73	1964 Feb. 20	72.4	312	50	6.48	.88	24.0		N14°W	N30°W		N10°W	
					1964 May 31	74.9	312	48	6.48								
					1964 May 31	74.7	312	33	6.59								
9) 1964 Mar. 20	46.7	134	71	7.24	1964 Feb. 1	45.6	311	34	8.32	.87	33.5		N19°E	N12°W	N45°E	N22°E	
10) 1963 Nov. 1	39.0	131	35	7.86	1964 May 17	39.0	315	33	8.65	.91	35.5		N9°E	N24°W	N45°E	N9°W	
11) 1963 Nov. 6	64.3	135	174	6.21	1964 Jan. 21	65.2	316	51	7.24	.86	28.0		N15°E	N13°W		N21°E	
12) 1964 Feb. 19	67.5	139	80	6.05	1964 Feb. 22	67.5	314	60	6.80	.89	27.0		N1°E	N16°W		N4°E	

* The *PP* phase of this earthquake was compared to the *P* phase of the July 30, 1964 event.

headings refer to the conditions of dip and velocity contrast of the tables with corresponding numbers. For instance, 6 refers to conditions of Table 6, i.e., $v_1/v_2 = 0.8$ and $\delta = 8$ degrees. Only under conditions of column 3, can all the observations be interpreted. According to these results the Mohorovičić discontinuity in the vicinity of TFSO, dips locally up to about 8 degrees in the northeast direction. The observed strikes vary from N12°W to N30°W, with a mean value of N18°W. This is in close agreement with the results obtained from the study of the azimuthal deviations. Our data were not adequate, to indicate any jump in the Mohorovičić discontinuity in the vicinity of the TFSO array.

The selected value of velocity contrast, 0.7, combined with a P_n velocity of 8.0 km/sec gives an average crustal P velocity of 5.6 km/sec. This velocity is lower than that found by Warren *et al.*, (1965) by 0.3–0.5 km/sec. Since in the construction of the tables, the velocity contrast has been varied in steps of 0.1, it can only be determined to within 0.05, i.e. $v_1/v_2 = 0.7 \pm .05$. This results in an inaccuracy of

FIG. 4. Two representative seismograms: (A) the earthquake of July 24, 1964, $\Delta = 68.9^\circ$, $\phi = 313^\circ$, $h = 33$ km, $M = 5.9$. (B) the earthquake of January 2, 1964, $\Delta = 69.0^\circ$, $\phi = 137^\circ$, $h = 110$ km, $M = 5.1$. The linear extent of the array is about 10 km and the NW-SE leg makes an angle of 53.1 degrees with north, the other leg being perpendicular to it.

about 0.4 km/sec on the selected average crustal velocity, which could account for the above difference.

The epicenters of the first group of observations of Table 10, which resulted in a unique crustal model, lie in azimuths different from the remaining data. The waves of this group of earthquakes approach the array in directions close to the normal to the strike. It appears, therefore, that in a study of this nature the azimuths close to the direction of dip leave one with fewer choices, and should be preferred for giving a unique structure.

The required corrections to $dT/d\Delta$, in general, increase with epicentral distance. For distances less than 30 degrees they are small, and in extreme cases do not exceed 10 per cent. The range of angles of incidence and azimuths covering over 95 per cent of the observations used by Niazi and Anderson (1965) is framed in Table 3A. In this range the required corrections to $dT/d\Delta$ remain within 6 per cent of the observed slopes. Although they may be partially responsible for scatter of data in that study, they are within the errors of measurements. Their application to those observations will not have any substantial effect on the conclusions drawn in that

paper. When a similar study is to be carried to larger epicentral distances, applications of these corrections become essential.

CONCLUSIONS

It has been observed that the slope of the travel time curve and the deviation of the direction of approach of the wave front from the station-to-source azimuth across the TFSO array vary with azimuth. These observations confirm the findings of Warren *et al.*, (1965) that the Mohorovičić discontinuity is dipping under TFSO.

The functional relationships between various parameters involved in the problem are formulated. The parameters include dip of the interface, velocity contrast between the materials of the crust and mantle, angle of incidence of the ray and the station-to-source azimuth. *The required corrections to $dT/d\Delta$ and apparent azimuth for different combinations of these parameters are computed and given in Tables 1-9.*

The variation of the sign of azimuthal deviations with true azimuth at TFSO indicates that the Mohorovičić discontinuity below the array is dipping in $N70^\circ \pm 5^\circ E$ direction. This is confirmed when the observed $dT/d\Delta$ of P waves arriving from sources located at equal distances, but opposite azimuths, are compared. This latter technique also reveals that the dip angle may locally be as large as eight degrees. The average crustal velocity obtained by this method agrees with that found by the seismic-refraction method.

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REFERENCES

- Niazi, M., and Don L. Anderson (1965). Upper mantle structure of western North America from apparent velocities of P waves, *J. Geophys. Res.* **70**, 18.
- Otsuka, M. (1965). Velocity anomalies of seismic waves measured on the central California network, Abstract, *Am. Geophys. Union. Trans.* **46**, 152.
- Ritsema, A. R. (1958). ($i-\Delta$) curves for bodily seismic waves of any focal depth, *Lembaga Meteorologi dan Geofisik, Djakarta, Verhand.* **54**.
- Warren, D. H., S. C. Roller and W. H. Jackson (1965). A seismic-refraction survey in the vicinity of the Tonto Forest Seismological Observatory, Arizona, Abstract, *Am. Geophys. Union Trans.* **46**, 155.

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