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D. TRAVEL TIME ANOMALIES AND CRUSTAL STRUCTURE BENEATH NORSAR

Depth varying interfaces in the crust or mantle beneath the array have most commonly been used as the explanation of the kind of P-wave travel time anomalies observed at NORSAR (Berteussen 1974). Therefore an experiment has been made in order to find out how much of the observed anomalies that possibly can be explained by such interfaces.

The first step was to recompute the slowness calibrations and time delay corrections so they gave deviations relative to the wavefront predicted from the azimuth and distance to the NOAA epicenter solution. The part of these deviations which were from P-waves were then averaged in intervals of 10 degrees in azimuth. The first interface tested was a dipping plane. The equation for this may be written

$$Z = A + B \cdot X + C \cdot Y \qquad (1)$$

The coordinate system is centered in the array's center with X-axis towards east, Y-axis towards north and Z-axis upwards. The reference depth of all the interfaces tested was set to 33 km, that is, the interfaces may be thought of as the crust-mantle boundary. The velocity contrast was set to 6.6/8.2 (Kanestrøm 1971). The parameters B and C were then varied systematically until the sum of the squared differences between observed and predicted (because of the dipping plane) time deviations had its minimum. The values found for the parameters in eq. (1) and the percent reduction in mean square deviations are listed in row 1 Table D1. As seen, the plane is

TABLE D1

Table of coefficients for best plane, second degree interface and third degree interface. Per cent reduction in mean squared deviations is also listed for the three models.

Model	A	$B\cdot10^3$	$C\cdot10^3$	$D\cdot10^3$	$E\cdot10^3$	$F\cdot10^3$	$G\cdot10^6$	$H\cdot10^6$	$I\cdot10^6$	$J\cdot10^6$	% Gain
Plane	-33.0	90.4	22								17.9
2nd degree	-33.4	99.3	-7.9	0.47	-2.0	0.3					21.4
3rd degree	-33.3	222.9	13.1	0.003	-1.55	0.17	33.	-13.5	-51.0	-3.9	24.3

able to explain 17.9 per cent of the squared deviations. This plane has a dip of 6 degrees and updip direction 94 degrees clockwise from north. With another velocity contrast the dip of the interface would change while the updip direction would still be the same. The per cent reduction in mean square deviations would also be unchanged. This implies that nothing can be gained by moving the interface to another depth.

Since a dipping plane cannot satisfactorily explain the deviations, we will go further and try a second degree interface. The equation for this is:

$$Z = A + BX + CY + DX^2 + EXY + FY^2 \qquad (2)$$

When a curved interface can be described in this way, ray-tracing is especially simple and not very time-consuming on a computer. The procedure has been as before, namely, to vary all the coefficients in eq. (2) systematically. For each set of coefficients conventional ray-tracing has been applied in order to find the deviations this particular interface would give for our data points. The best interface is then the interface where the sum of the squared differences between predicted and observed deviations has been reduced to a minimum. The coefficients for this surface are listed in row 2, Table D1. As also can be seen from Table D1, this interface is able to explain only 21.4% of the squared deviations. The depth contours for this interface are plotted in Fig. D1.

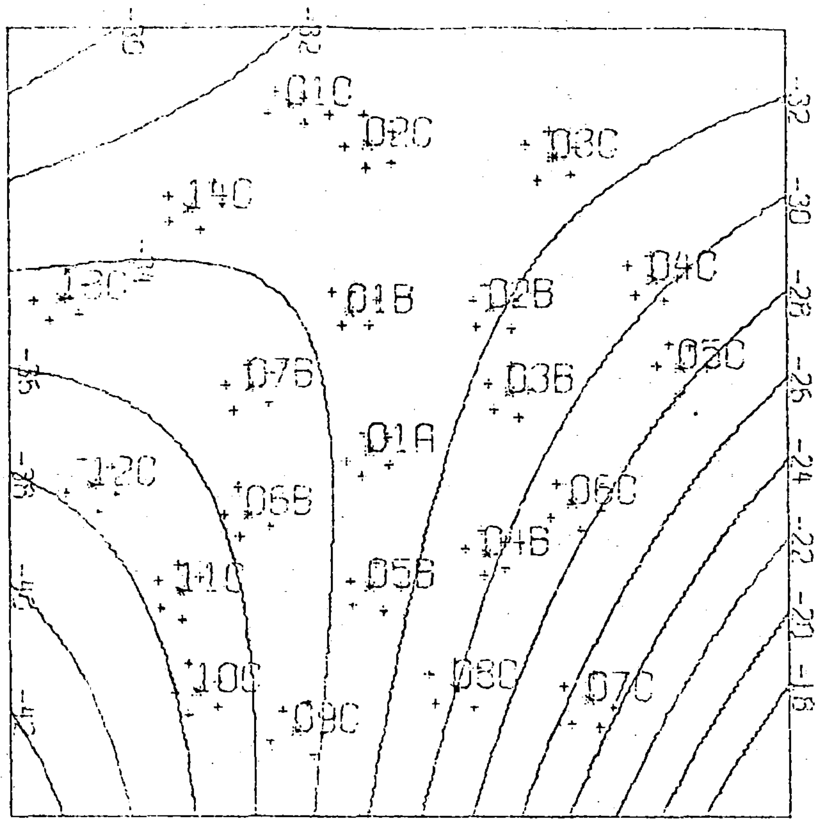

Fig. D1 Depth contours for best 2nd degree interface. V_C=6.6 km/sec, V_M=8.2 km/sec. The NORSAR array configuration is also included.

The next step was to use the same procedure over again, except that this time a polynomial of third order was used. The equation for this is:

$$Z = A + BX + CY + DX^2 + EXY + FY^2 + GX^3 + HX^2Y + IXY^2 + JY^3 \quad (3)$$

The coefficients for this interface are listed in row 3, Table D1. This interface is able to explain 24.3% of the observed squared deviations. The contours for this are drawn in Fig. D2.

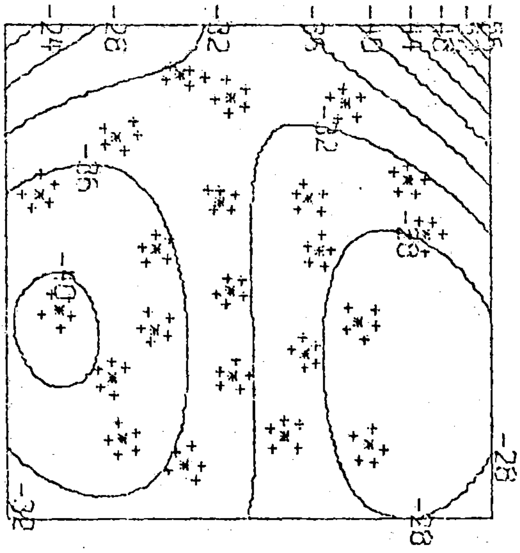

Fig. D2 Depth contours for best 3rd degree interface V_C=6.6 km/sec, V_M=8.2 km/sec.

As seen from Figs. D1 and D2, the interfaces found do exhibit such large elevation differences that their physical reality is questionable. To increase the order of the polynomial to higher degrees than 3 cannot be done because we then will end up with such a detailed map that simple ray theory may not be used. If the velocity in the crust above the interface is set to 6.2 km/sec, a second degree polynomial found in the same way as described in the above section will be able to explain 24.9% of the squared deviations. The conclusion is that it is not possible to construct a physically realistic interface which is able to explain more than say 25% of the sum of the squared deviations observed at NORSAR. It thus seems that in order to explain the bulk of the deviations observed, other models have to be introduced; that is, models where wave scattering and possibly multipathing take a more important part.

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