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Analytic tomography of the mantle in a spherically Earth. The technique MZY

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Abstract. An explicit expression for P-wave velocity is proposed to develop a novel tomographic technique in a spherically symmetric model of the Earth (MZY). The distribution of the P velocity structure in the mantle is determined using only 34 P- and 2 PcP- observed traveltimes. By applying a non-linear inversion, the P-residuals in the range between 0º and 100º are minimised up to a maximum value of 0.015 s. Furthermore, from the high quality computation of PcP traveltimes, with residuals much better than 0.13 s., it is possible to infer the existence of a brief low velocity layer in the D” region. This is then followed by a gradual increasing in the velocity profile towards the core, which begins at a depth of 2893.9 km.

Key words: D” shell, Earth’s mantle, P-wave velocity, tomography, traveltimes.

Introduction

To date, numerous studies use the arrival times of seismic waves to explore the Earth structure. Seismic arrival times have provided a fundamental constraint on the radial and lateral velocity structure of our planet. Sengupta and Toksoz (1976), Clayton and Comer (1983), Dziewonski (1984) among others, studied the variation of the P-wave velocity in the lower mantle. These works have been extended rapidly to the whole mantle (Pulliam et al., 1993) from many different viewpoints and perspectives, but concluding in almost all cases in interesting correlations with the structure predicted by the plate tectonics. On the other hand, reference models constitute the common basis for all the different studies concerning the Earth. Some of them are fairly relevant and well known in the seismological literature, as PREM (Dziewonski and Anderson, 1981), IASP91 (Kennet and Engdahl, 1991) and SP6 (Morelli and Dziewonski, 1993). They constitute the starting point for a number of applications, including seismic tomography and synthetic seismogram calculations. The strategy of finding an agreement between physical meaningful and achieving observations is of crucial importance. A decreasing of the relative error between the reproduced and measured data becomes in an increasing knowledge of the main features concerning the Earth structure. In this sense, any effort made to improve the available reference models, will benefit on the current seismological knowledge, especially those concerning local deviations in boundary interfaces in the Earth's interior.

From this viewpoint, in this preliminary work we pretend to improve the fitting of reference traveltime tables (JB: Jeffreys and Bullen, 1958; BSSA: Herrin et al., 1968) to observed traveltimes and, as consequence of that, to infer the slight deviations of the whole structure with respect to the average models. We have focused our attention on the tomography of the mantle, using and developing a non-linear inversion technique based on the analytical solution of the elliptical integrals involved in the theory of wave propagation. In this sense the approach described in this paper cannot be viewed like an empirical model. We demonstrate that the range of the achievement is large enough and, therefore, the real interpretation is to be an improvement for the reference model derived from the Herrin et al. traveltime tables, used in this work. Eventually, this sort of agreement to respect the *observed* data (errors not larger than a particular threshold) has been imposed as a first objective of this study, but it is not unique. The use of an analytical function avoids the common strategy of deriving spherical averages from seismological observations via an inversion procedure (i.e., the least-square approach). An interesting comment of this performing can be found in Morelli and Dziewonski (1993). In our scheme, the inherent biased data distribution is largely overcome since only traveltime tables are taking into account. This absence of real data is a major lack in the model we present in this paper, and we agree. However, we keep the opinion that the results should be interpreted in a different way as those derived from a reference model, because they maintain internal consistency and do not pretend to be an alternative to PREM, ISAP91 or SP6 models.

The use of analytical functions to derive a model that globally reproduces the observed traveltimes by acting locally on a multilayer and spherical mantle does not prescribe the meaning, from a physical viewpoint, of the new model. Indeed, the analytical tomography results in an improved understanding of some particular areas, for example the D'' layer at the base of the mantle. These features are the most relevant conclusions of our work as they provide some slight differences to the current knowledge of the mantle.

Methodology

The trial P-wave velocity function used in this work to analyse the structure of the mantle can be summarised by the expression

$$v(r) = r \cdot (B - A \cdot ln(r)) \quad , \qquad (1)$$

where r is the radius, and (A,B) two independent parameters to be determined. This formula can be simplified by defining the function

$$w(r)=(B-A\cdot ln(r)) \quad , \qquad (2)$$

and then:

$$v(r)=r\cdot w(r) \quad . \qquad (3)$$

The P-wave velocity function expressed in Eq. (1) has been used (Lana-Renault and Cid, 1991; Lana-Renault, 1998) to obtain different Earth models by varying the different parameters. The smoothness of this function makes it adequate to tomographic studies of the Earth's mantle, once a proper parameterisation is applied, i.e. a division in many spherical layers, which is the one followed in this work. Another useful property of the function described in Eq. (1) is that converts the elliptical integrals arisen during the hamiltonian formulation of ray propagation, into analytical functions. For example, for a ray crossing the first layer (i = 1) of the mantle, who radius of the top surface is R_1 (Earth's radius), the epicentral distance Δ can be expressed as

$$\Delta = \frac{2\cdot w_1}{A_1}\cdot senh\left(\frac{A_1\cdot T}{2}\right) \quad , \qquad (4)$$

where:

$$w_1 = w_1\left(R_1\right)=B_1-A_1\cdot ln\left(R_1\right) \quad .$$

The general analytical expressions for Δ and T can be obtained using the classical integral expressions (Bullen and Bolt, 1985)

$$\Delta = p\cdot\int_{r_p}^{r_o} r^{-1}\cdot\sqrt{\eta^2-p^2}\,dr \quad ,$$

$$T=\int_{r_p}^{r_o} \eta^2\cdot r^{-1}\cdot\sqrt{\eta^2-p^2}\,dr \quad . \qquad (5)$$

Denoting the angle of incidence at the top surface of the i^{th} layer by I_i and its radius by R_i , and similarly for the variables at the bottom (I'_i and R'_i), see figure 1, it is always possible to write

$$w_i = w_i\left(R_i\right) = B_i - A_i \cdot ln\left(R_i\right) = \frac{sen\left(I_i\right)}{p} \quad , \qquad (6)$$

and

$$w\acute{}_i = w\acute{}_i\left(R\acute{}_i\right) = B_i - A_i \cdot ln\left(R\acute{}_i\right) = \frac{sen\left(I\acute{}_i\right)}{p} \quad . \qquad (7)$$

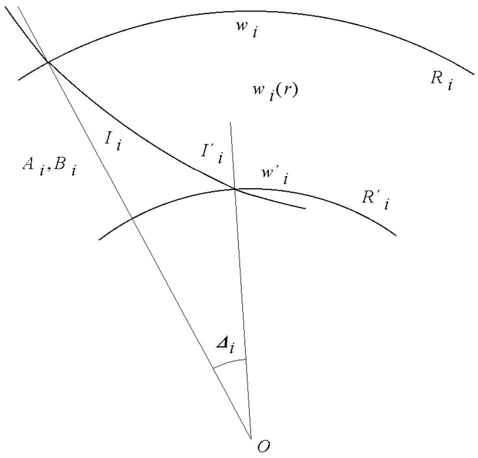

Fig. 1. P-trajectory traveling through a layer *i*

In general, for a point *P(r)* we have

$$w_i(r) = B_i - A_i \cdot ln(r) = \frac{sen(I)}{p} \quad . \qquad (8)$$

Hence, through its derivative,

$$\frac{dr}{r \cdot cos(I)} = -\frac{dI}{p \cdot A_i} \qquad (9)$$

we can calculate the expressions (5) for a P-trajectory which travels from R_i to $R\acute{}_i$

$$\Delta_i = \frac{cos\left(I_i\right) - cos\left(I\acute{}_i\right)}{p \cdot A_i} \quad , \qquad (10)$$

$$T_i = \frac{1}{A_i} \cdot ln\left[\frac{tg\left(\frac{I\acute{}_i}{2}\right)}{tg\left(\frac{I_i}{2}\right)}\right] \quad . \qquad (11)$$

Therefore, the observables at the Earth surface can be computed as a result of several additions of these computed values at each layer. That is, if one ray travels along *k* layers, the final epicentral distance and traveltime are calculated through of the following *2k+1* equations:

$$\Delta = \frac{2}{p}\cdot\left(\sum_i \frac{\cos\left(I_i\right) - \cos\left(I'_i\right)}{A_i} + \frac{\cos\left(I_k\right)}{A_k}\right) \quad , \qquad (12)$$

$$T = 2\cdot\left[\sum_i \frac{1}{A_i}\cdot \ln\left[\frac{tg\left(\frac{I'_i}{2}\right)}{tg\left(\frac{I_i}{2}\right)}\right] - \frac{1}{A_k}\cdot \ln\left(tg\left(\frac{I_k}{2}\right)\right)\right] \qquad (13)$$

and these *2k-1* auxiliary equations

$$p = \frac{sen\left(I_i\right)}{w_i\left(R_i\right)} = \frac{sen\left(I'_i\right)}{w_i\left(R'_i\right)} = \frac{sen\left(I_k\right)}{w_k\left(R_k\right)} \quad , \qquad (14)$$

where*: i = 1, 2, ..., k-1 .*

On the other hand, the observables for a PcP-trajectory are calculated by the following *2(k+1)* equations:

$$\Delta = \frac{2}{p}\cdot\left(\sum_i \frac{\cos\left(I_i\right) - \cos\left(I'_i\right)}{A_i}\right) \quad , \qquad (15)$$

$$T = 2\cdot\left[\sum_i \frac{1}{A_i}\cdot \ln\left[\frac{tg\left(\frac{I'_i}{2}\right)}{tg\left(\frac{I_i}{2}\right)}\right]\right] \qquad (16)$$

and these *2k* auxiliary equations

$$p = \frac{sen\left(I_i\right)}{w_i\left(R_i\right)} = \frac{sen\left(I'_i\right)}{w_i\left(R'_i\right)} \quad . \qquad (17)$$

where*: i = 1, 2, ..., k .*

Finally, by integrating Eq. (9) between *P(R$_i$)* and *P(r)*, it is easy to calculate the radius of any single point *P(r)* along the trajectory:

$$r = R_i\cdot \exp\left(\frac{sen\left(I_i\right) - sen(I)}{p\cdot A_i}\right) = R_i\cdot \exp\left(\frac{w_i - w_i(r)}{A_i}\right) \quad . \qquad (18)$$

Results

With a single collection of observed traveltimes, it is possible to reproduce the observations on the Earth's surface for any event. For the sake of simplicity, as an example of the versatility and functionality of the proposed methodology, we have selected the datasets reproduced in *Herrin et al.* (1968). The sequence of calculations consists of determining the specific constants A_i , w_i and w'_i ($i = 1,...,N$), for each layer, N being the number of layers.

(Note that w'_i is a measure of the thickness of the i^{th} layer and that we don't use B_i . The parameter B_i is calculated after using the Eq. (6))

Let suppose these quantities are already known for the first k-1 layers, except w'_{k-1}, the starting point for the k^{th} layer. The inverse problem can be posed as a system of non-linear equations (12-14) that will provide the parameters A_k *and* w_k of the layer k. We must use three P-observed trajectories reproducing three fixed points (Δ_l , T_{ol} ; l = 1,2,3) as boundary conditions for the system of $3(2k+1)$ non linear equations with $3(2k+1)$ unknowns (p_l , I_{il} , I'_{il} , I_{kl} , w'_{k-1} , w_k , A_k). The solution is then iterated till assure a convergence criterion, in our case, a threshold for the computed residuals less than a certain value (10^{-15}).

Known the values w'_{k-1} , w_k , y A_k , we prove that the residual times T_o-T_c (observed minus computed time) of the all the others P-trajectories which also return to the surface-focus from the k^{th} layer are smaller than a determined ε . If it is not so, we begin again taking others three observables (Δ_l , T_{ol}) nearer among them.

It is to be noted that the algebra applied in our methodology permits a discontinuity of the 1st kind ($w'_{k-1} \neq w_k$) in the velocity function.

This last property can be analysed through the study of the derivative ($dT/d\Delta$) (*Herrin et al.*, 1968), in order to detect jumps in the selected velocity pattern. If we have the security that only a discontinuity of the 2nd kind ($w'_{k-1} = w_k$) is present, then it is possible to work with only 2 observables (Δ , T_o) or fixed boundary conditions, thus eliminating $2k+1$ redundant equations from the global system.

In this case, the experience tells us that is much better to work with one observable (Δ , T_o) and, thus, fixing the final of the k-1^{th} layer by a value for w'_{k-1}. and insuring that the residual times of all the P-trajectories which return from the k-1^{th} layer to the surface-focus are less than our ε . Thereby, we resolve a non linear system with only $2k+1$ equations.

We have performed a complete description of the Mantle using a maximum residual time ε = 0.015 s. and only 34 P-observed traveltimes. The total number of layers used in this description is 28. The last one finishes at a depth of 2810.1 km., maximum for the last P-observed trajectory at $\Delta = 100^o$ according to *Herrin et al.* (1968), with $T_o = 826.7303$ *s.* Once known the problematic of the lack of information for $\Delta > 100^o$ and the special case of the D" shell, we have worked with data available from $\Delta > 88^o$ and maximum residuals of 0.002 *s.* See Table 1 and Residuals of P-travel times (Figure 2) for a graphic representation and further details.

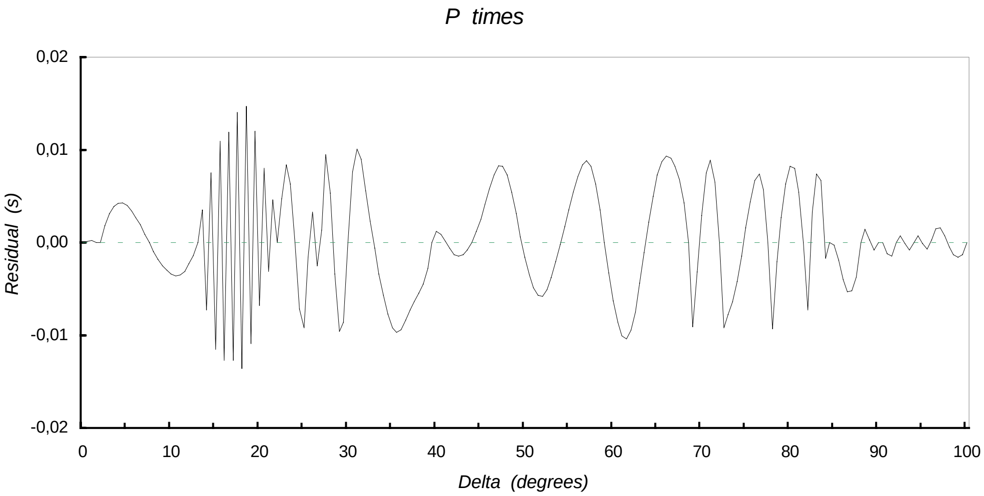

Fig. 2. P-residual times T_o-T_c . Δ: $0 – 100^o$ every 0.5^o. Maximum residual 0.015 *sec.* at $\Delta = 18.5^o$.

The 29th layer. Since the derivative associated with the surface-focus travel time ($dT/d\Delta$) is effectively constant (*Herrin et al.*, 1968) beyond 99.0º, and that our residuals are practically zero for those points, we consider the boundary condition $w'_{28} = 1/p(100^o) = w_{29}$ produces the best results. Thus, our problem is reduced to calculate the parameters w'_{29} (final layer) and A_{29}. For this purpose, we pose a non linear system with two PcP observables. One of these fixed points should always be the axial trajectory ($\Delta = 0^o$; $T_o = 511.3$ *sec.*) that allows us to use only one equation:

$$T = 2\cdot\sum_i \frac{1}{A_i}\cdot \ln\left(\frac{w'_i}{w_i}\right) \qquad (19)$$

We have considered that the other observable should be very separated from the first, and thus, selected $\Delta = 93^o$; $T_o = 795.2$ *s* as second observable. Once obtained the values w'_{29} and A_{29}, all the PcP residuals were balanced with an error less than 0.13 s. (Figure 3, Table 2 of PcP-travel times). By applying Eq. (18) we found the outer core at 2893.9 km. Further details can be seen in Figures 4, 5, 6 and Table 3 of P-wave velocity.

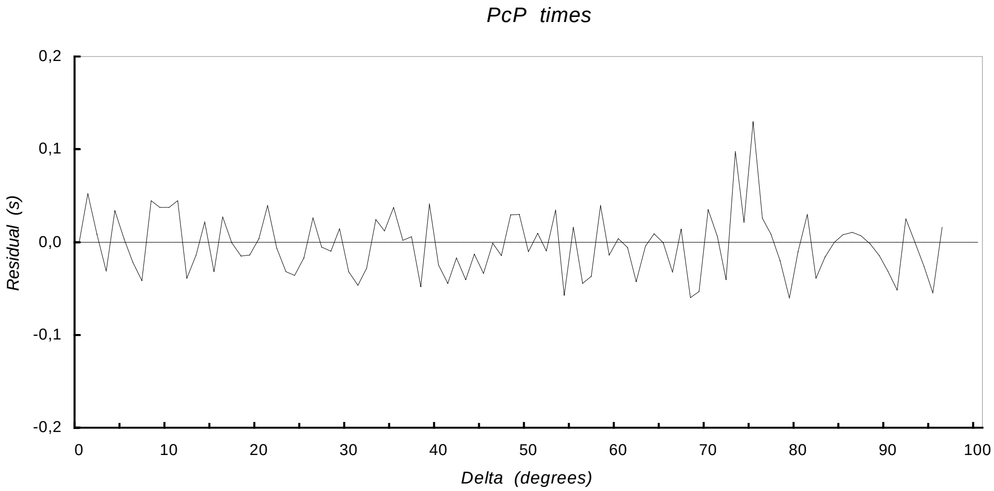

Fig. 3. PcP-residual times T_o-T_c . Δ: *0 – 96°* every *1°.* Maximum residual *0.13 sec.* at Δ = *75°.* Depth Outer Core: *2893.9 km.*

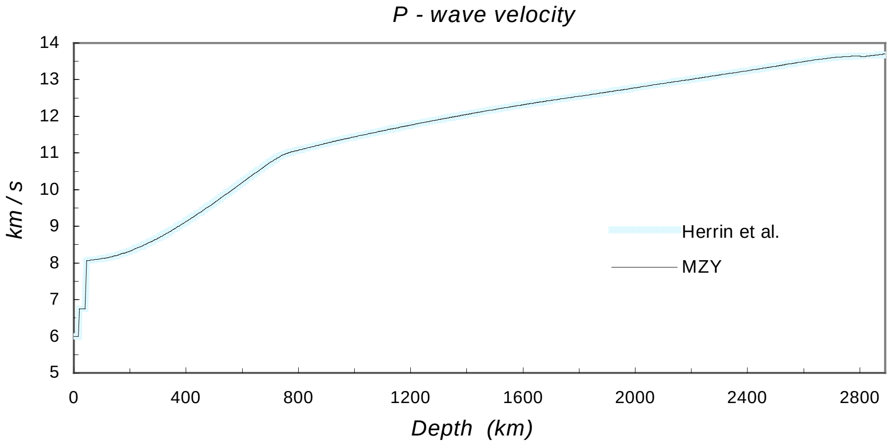

Fig. 4. P-wave velocity in the mantle. *Herrin et al.* versus *MZY*.

Fig. 4 shows a comparison between our velocity distribution and the one provided by *Herrin et al*. (1968). The most conspicuous difference is observed at *2749.8 km*., final of the *25th* layer, where the last trajectory returns to the surface at Δ = *92°* and the corresponding residual is null. Figure 5 exhibits residuals of computed velocity *Herrin et al.* minus *MZY*. Let us note how the maximum residual is *0.0044 km/s* at a depth of *755 km.*

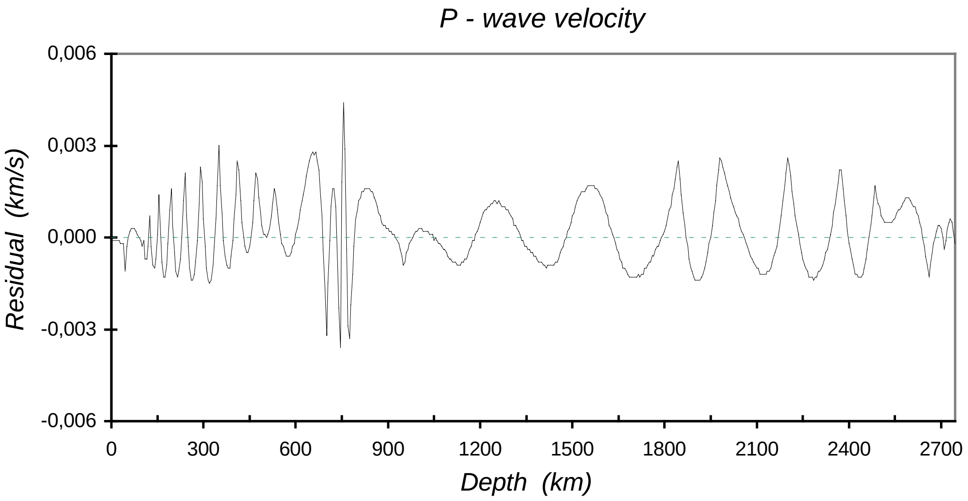

Fig. 5. Residual velocity *Herrin et al.* minus *MZY* in the mantle until a depth of *2745 km.* Maximum residual: *0.0044 km/sec* at a depth of *755 km.*

From 2749.8 km. until the core-mantle boundary (*region D"*), our velocity distribution begins to be completely different to *Herrin et al*. (1968), as can be seen in Fig. 6. This is due that *Herrin et al.* adopted a special smooth velocity distribution to the region D" to explain the last results from *Taggart and Engdahl,* (1968)*,* which indicated a slow increase of velocity towards the core. Morelli and Dziewonski (1993), in their SP6 model, obtained a continuous decrease from 2741 km. In our MZY model, we propose that D" region begins at 2780.7 km. with a brief (29.4 km.) negative gradient (layers number 27 and 28) followed by a slow increase until the core. With this profile we insure the residuals of all the observables P and PcP from *Herrin et al*. (1968) are minima, and reproduce accurately the observed times.

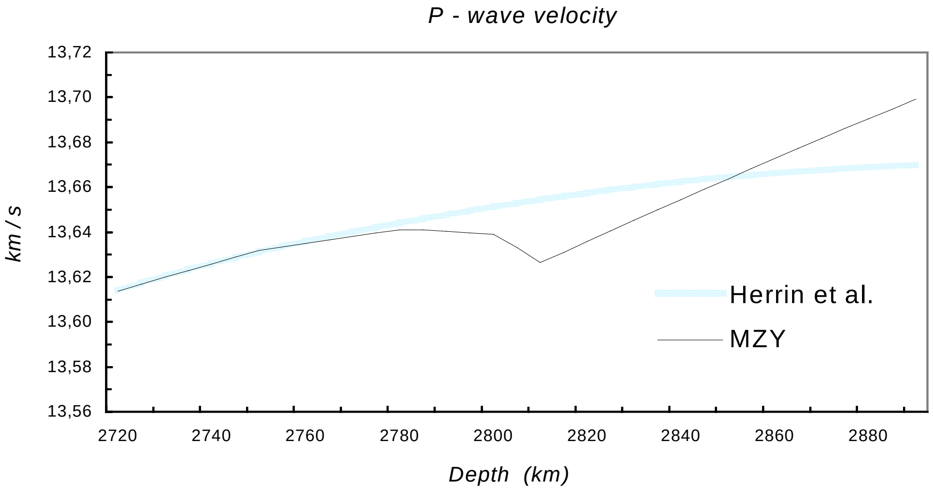

Fig. 6. P-wave velocity in D" region. *Herrin et al.* versus *MZY*

Concluding remarks

We have presented a new technique to tomography the interior of the Earth for which one is able to obtain residual times less than a determined value ε for all observed trajectories P. The more minor is the value of ε, more genuine and real is the tomography.

Also, we have seen that the technique MZY developed is very easy to apply. Its potentiality is based in the function velocity found that it provides us analytical solutions for Δ and T.

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Table 1 **P travel times** *(sec.)* p. 1/2

La-yers	Δ initial Δ final	Δ	Observed (Herrin & al.)	Computed MZY	Residual T_o - T_c
1	0	0.00	0.0000	0.0000	0.0000
		0.50	9.2663	9.2662	0.0001
	7.85	1.00	18.5323	18.5321	0.0002
2	0.52	1.50	26.9525	26.9525	0.0000
	10.66				
3	0.989	2.00	34.8630	34.8630	0.0000
		2.50	41.7231	41.7213	0.0018
		3.00	48.5813	48.5782	0.0031
		3.50	55.4373	55.4334	0.0039
		4.00	62.2906	62.2864	0.0042
		4.50	69.1410	69.1367	0.0043
		5.00	75.9880	75.9840	0.0040
		5.50	82.8312	82.8278	0.0034
		6.00	89.6703	89.6676	0.0027
		6.50	96.5049	96.5030	0.0019
		7.00	103.3346	103.3337	0.0009
		7.50	110.1591	110.1591	0.0000
		8.00	116.9779	116.9789	-0.0010
		8.50	123.7908	123.7926	-0.0018
		9.00	130.5973	130.5998	-0.0025
		9.50	137.3970	137.4000	-0.0030
		10.00	144.1896	144.1930	-0.0034
		10.50	150.9747	150.9783	-0.0036
		11.00	157.7519	157.7554	-0.0035
		11.50	164.5209	164.5240	-0.0031
		12.00	171.2813	171.2836	-0.0023
		12.50	178.0326	178.0340	-0.0014
	13.15	13.00	184.7746	184.7746	0.0000
4	13.15	13.50	191.4964	191.4929	0.0035
	14.14	14.14	200.0582 *	200.0655	-0.0073
5	14.14	14.50	204.8555	204.8480	0.0075
	15.13	15.13	213.1831 *	213.1946	-0.0115
6	15.13	15.50	218.0429	218.0320	0.0109
	16.11	16.11	225.9644 *	225.9771	-0.0127
7	16.11	16.50	230.9845	230.9726	0.0119
	17.09	17.09	238.4697 *	238.4824	-0.0127
8	17.09	17.50	243.6096	243.5956	0.0140
	18.08	18.08	250.7491 *	250.7627	-0.0136
9	18.08	18.50	255.8408	255.8261	0.0147
	19.06	19.06	262.4864 *	262.4973	-0.0109
10	19.06	19.50	267.6136	267.6016	0.0120
	20.04	20.04	273.7653 *	273.7721	-0.0068
11	20.04	20.50	278.9036	278.8956	0.0080
	21.02	21.02	284.5832 *	284.5863	-0.0031
12	21.02	21.50	289.7160	289.7114	0.0046
	22	22.00	294.9501	294.9501	0.0000
13	22	22.50	300.0806	300.0759	0.0047
		23.00	305.1134	305.1050	0.0084
		23.50	310.0533	310.0470	0.0063
		24.00	314.9070	314.9070	0.0000
		24.50	319.6818	319.6890	-0.0072
	25.46	25.00	324.3869	324.3961	-0.0092
14	25.46	25.46	328.6614 *	328.6630	-0.0016
		26.00	333.6295	333.6262	0.0033
		26.50	338.1848	338.1873	-0.0025
	27.14	27.14	343.9656 *	343.9643	0.0013

La-yers	Δ initial Δ final	Δ	Observed (Herrin & al.)	Computed MZY	Residual T_o - T_c
15	27.14	27.50	347.2025	347.1930	0.0095
		28.00	351.6796	351.6743	0.0053
		28.50	356.1456	356.1490	-0.0034
		29.00	360.6048	360.6144	-0.0096
		29.50	365.0596	365.0682	-0.0086
	30	30.00	369.5086	369.5086	0.0000
16	30	30.50	373.9477	373.9401	0.0076
		31.00	378.3751	378.3650	0.0101
		31.50	382.7900	382.7810	0.0090
		32.00	387.1923	387.1867	0.0056
		32.50	391.5831	391.5808	0.0023
		33.00	395.9621	395.9627	-0.0006
		33.50	400.3281	400.3315	-0.0034
		34.00	404.6807	404.6864	-0.0057
		34.50	409.0193	409.0270	-0.0077
		35.00	413.3435	413.3527	-0.0092
		35.50	417.6532	417.6629	-0.0097
		36.00	421.9479	421.9573	-0.0094
		36.50	426.2269	426.2353	-0.0084
		37.00	430.4894	430.4967	-0.0073
		37.50	434.7347	434.7411	-0.0064
		38.00	438.9626	438.9681	-0.0055
		38.50	443.1730	443.1775	-0.0045
		39.00	447.3662	447.3690	-0.0028
	39.5	39.50	451.5425	451.5425	0.0000
17	39.5	40.00	455.7020	455.7008	0.0012
		40.50	459.8449	459.8440	0.0009
		41.00	463.9710	463.9709	0.0001
		41.50	468.0802	468.0808	-0.0006
		42.00	472.1723	472.1736	-0.0013
		42.50	476.2473	476.2488	-0.0015
		43.00	480.3051	480.3064	-0.0013
		43.50	484.3454	484.3462	-0.0008
		44.00	488.3680	488.3680	0.0000
		44.50	492.3728	492.3716	0.0012
		45.00	496.3596	496.3571	0.0025
		45.50	500.3285	500.3244	0.0041
		46.00	504.2791	504.2733	0.0058
		46.50	508.2111	508.2038	0.0073
		47.00	512.1242	512.1159	0.0083
		47.50	516.0178	516.0096	0.0082
		48.00	519.8920	519.8847	0.0073
		48.50	523.7469	523.7415	0.0054
		49.00	527.5828	527.5797	0.0031
		49.50	531.4001	531.3995	0.0006
		50.00	535.1992	535.2008	-0.0016
		50.50	538.9802	538.9837	-0.0035
		51.00	542.7433	542.7482	-0.0049
		51.50	546.4887	546.4944	-0.0057
		52.00	550.2164	550.2222	-0.0058
		52.50	553.9266	553.9317	-0.0051
		53.00	557.6192	557.6230	-0.0038
		53.50	561.2941	561.2962	-0.0021
		54.00	564.9510	564.9512	-0.0002
		54.50	568.5899	568.5882	0.0017
		55.00	572.2107	572.2072	0.0035

Table 1 **P travel times** *(sec.)* p. 2/2

La-yers	Δ initial Δ final	Δ	Observed (Herrin & al.)	Computed MZY	Residual $T_o - T_c$
17		55.50	575.8137	575.8082	0.0055
		56.00	579.3986	579.3915	0.0071
		56.50	582.9653	582.9569	0.0084
		57.00	586.5135	586.5047	0.0088
		57.50	590.0430	590.0348	0.0082
		58.00	593.5538	593.5475	0.0063
		58.50	597.0462	597.0427	0.0035
	59	59.00	600.5205	600.5205	0.0000
18	59	59.50	603.9770	603.9803	-0.0033
		60.00	607.4162	607.4225	-0.0063
		60.50	610.8385	610.8471	-0.0086
		61.00	614.2444	614.2545	-0.0101
		61.50	617.6343	617.6447	-0.0104
		62.00	621.0084	621.0179	-0.0095
		62.50	624.3668	624.3743	-0.0075
		63.00	627.7094	627.7138	-0.0044
		63.50	631.0356	631.0367	-0.0011
		64.00	634.3452	634.3430	0.0022
		64.50	637.6379	637.6329	0.0050
		65.00	640.9137	640.9064	0.0073
		65.50	644.1724	644.1637	0.0087
		66.00	647.4142	647.4049	0.0093
		66.50	650.6392	650.6301	0.0091
		67.00	653.8477	653.8395	0.0082
		67.50	657.0398	657.0330	0.0068
		68.00	660.2151	660.2108	0.0043
		68.50	663.3731	663.3731	0.0000
	69.08	69.08	667.0129 *	667.0220	-0.0091
19	69.08	69.50	669.6355	669.6387	-0.0032
		70.00	672.7383	672.7354	0.0029
		70.50	675.8202	675.8127	0.0075
		71.00	678.8805	678.8716	0.0089
		71.50	681.9193	681.9128	0.0065
	72.35	72.00	684.9366	684.9366	0.0000
20	72.35	72.35	687.0340 *	687.0432	-0.0092
		73.00	690.9092	690.9170	-0.0078
		73.50	693.8665	693.8729	-0.0064
		74.00	696.8054	696.8096	-0.0042
		74.50	699.7264	699.7279	-0.0015
		75.00	702.6299	702.6283	0.0016
		75.50	705.5159	705.5115	0.0044
		76.00	708.3843	708.3776	0.0067
		76.50	711.2346	711.2272	0.0074
		77.00	714.0661	714.0604	0.0057
	77.9	77.50	716.8776	716.8776	0.0000
21	77.9	77.90	719.1107 *	719.1200	-0.0093
		78.50	722.4405	722.4426	-0.0021
		79.00	725.1920	725.1893	0.0027
		79.50	727.9234	727.9171	0.0063
		80.00	730.6349	730.6267	0.0082
		80.50	733.3270	733.3190	0.0080
		81.00	735.9998	735.9944	0.0054
	81.8	81.50	738.6533	738.6533	0.0000
22	81.8	81.80	740.2336 *	740.2409	-0.0073
		82.50	743.9007	743.8974	0.0033
		83.00	746.4926	746.4852	0.0074
		83.50	749.0611	749.0544	0.0067
	84.04	84.04	751.8075 *	751.8092	-0.0017
23	84.04	84.50	754.1271	754.1271	0.0000
		85.00	756.6260	756.6263	-0.0003
		85.50	759.1042	759.1061	-0.0019
		86.00	761.5636	761.5676	-0.0040
		86.50	764.0064	764.0117	-0.0053
		87.00	766.4338	766.4390	-0.0052
		87.50	768.8465	768.8502	-0.0037
	88	88.00	771.2455	771.2455	0.0000
24	88	88.50	773.6315	773.6301	0.0014
		89.00	776.0056	776.0053	0.0003
		89.50	778.3687	778.3695	-0.0008
	90	90.00	780.7222	780.7222	0.0000
25	90	90.50	783.0673	783.0673	0.0000
		91.00	785.4049	785.4061	-0.0012
		91.50	787.7356	787.7371	-0.0015
	92	92.00	790.0597	790.0597	0.0000
26	92	92.50	792.3774	792.3767	0.0007
		93.00	794.6891	794.6892	-0.0001
		93.50	796.9953	796.9961	-0.0008
	94.03	94.03	799.4344 *	799.4344	0.0000
27	94.03	94.50	801.5937	801.5930	0.0007
		95.00	803.8872	803.8873	-0.0001
		95.50	806.1777	806.1784	-0.0007
	96.123	96.123	809.0282 *	809.0279	0.0003
28	96.123	96.50	810.7518	810.7503	0.0015
		97.00	813.0361	813.0345	0.0016
		97.50	815.3192	815.3185	0.0007
		98.00	817.6016	817.6021	-0.0005
		98.50	819.8838	819.8851	-0.0013
		99.00	822.1660	822.1676	-0.0016
		99.50	824.4481	824.4494	-0.0013
	100	100.00	826.7303	826.7303	0.0000
29	100	99.5	824.4481	824.4498	-0.0017
		99.0	822.1660	822.1694	-0.0034
		98.5	819.8838	819.8892	-0.0054
		98.0	817.6016	817.6094	-0.0078
		97.5	815.3192	815.3302	-0.0110
		97.0	813.0361	813.0520	-0.0159
		96.5	810.7518	810.7757	-0.0239
		96.0	808.4658	808.5028	-0.0370
		95.618	806.7177 *	806.7715	-0.0538
		96.0	808.4658	808.4805	-0.0147
	96.289	96.289	809.7871 *	809.7642	0.0229

interpolated *

Table 2 **PcP travel times** *(sec.)*

Δ	Observed	Computed	Residual	Δ	Observed	Computed	Residual
	(Herrin & al.)	MZY	$T_o - T_c$		(Herrin & al.)	MZY	$T_o - T_c$
0	511.3	511.300	0.00	49	611.9	611.870	0.03
1	511.4	511.348	0.05	50	615.5	615.511	-0.01
2	511.5	511.492	0.01	51	619.2	619.191	0.01
3	511.7	511.731	-0.03	52	622.9	622.910	-0.01
4	512.1	512.066	0.03	53	626.7	626.666	0.03
5	512.5	512.497	0.00	54	630.4	630.458	-0.06
6	513.0	513.022	-0.02	55	634.3	634.284	0.02
7	513.6	513.641	-0.04	56	638.1	638.144	-0.04
8	514.4	514.355	0.04	57	642.0	642.037	-0.04
9	515.2	515.163	0.04	58	646.0	645.961	0.04
10	516.1	516.063	0.04	59	649.9	649.914	-0.01
11	517.1	517.055	0.04	60	653.9	653.896	0.00
12	518.1	518.139	-0.04	61	657.9	657.906	-0.01
13	519.3	519.314	-0.01	62	661.9	661.943	-0.04
14	520.6	520.578	0.02	63	666.0	666.005	0.00
15	521.9	521.932	-0.03	64	670.1	670.091	0.01
16	523.4	523.373	0.03	65	674.2	674.201	0.00
17	524.9	524.901	0.00	66	678.3	678.333	-0.03
18	526.5	526.515	-0.01	67	682.5	682.486	0.01
19	528.2	528.214	-0.01	68	686.6	686.660	-0.06
20	530.0	529.996	0.00	69	690.8	690.853	-0.05
21	531.9	531.861	0.04	70	695.1	695.065	0.04
22	533.8	533.806	-0.01	71	699.3	699.294	0.01
23	535.8	535.832	-0.03	72	703.5	703.540	-0.04
24	537.9	537.936	-0.04	73	707.9	707.802	0.10
25	540.1	540.117	-0.02	74	712.1	712.079	0.02
26	542.4	542.374	0.03	75	716.5	716.370	0.13
27	544.7	544.705	-0.01	76	720.7	720.675	0.03
28	547.1	547.110	-0.01	77	725.0	724.992	0.01
29	549.6	549.586	0.01	78	729.3	729.320	-0.02
30	552.1	552.132	-0.03	79	733.6	733.660	-0.06
31	554.7	554.747	-0.05	80	738.0	738.010	-0.01
32	557.4	557.428	-0.03	81	742.4	742.370	0.03
33	560.2	560.176	0.02	82	746.7	746.739	-0.04
34	563.0	562.988	0.01	83	751.1	751.116	-0.02
35	565.9	565.863	0.04	84	755.5	755.500	0.00
36	568.8	568.798	0.00	85	759.9	759.892	0.01
37	571.8	571.794	0.01	86	764.3	764.290	0.01
38	574.8	574.848	-0.05	87	768.7	768.693	0.01
39	578.0	577.959	0.04	88	773.1	773.102	0.00
40	581.1	581.125	-0.02	89	777.5	777.515	-0.01
41	584.3	584.345	-0.04	90	781.9	781.932	-0.03
42	587.6	587.617	-0.02	91	786.3	786.352	-0.05
43	590.9	590.940	-0.04	92	790.8	790.775	0.03
44	594.3	594.313	-0.01	93	795.2	795.200	0.00
45	597.7	597.734	-0.03	94	799.6	799.627	-0.03
46	601.2	601.202	0.00	95	804.0	804.055	-0.05
47	604.7	604.714	-0.01	96	808.5	808.484	0.02
48	608.3	608.271	0.03	96.289		809.764	

Table 3

p. 1/4

Data MZY			P-wave velocity (km/s)		
			Radius of surface-focus = 6371.028		
Radius (km) **Layers** Depth (km)	v_i (km/s) B_i ($x\ 10^{-2}$) A_i ($x\ 10^{-3}$) v'_i (km/s)	Depth (km)	Herrin & al.	MZY	Residual H. & al. - MZY
6371.028	6.0000	0	6.0000	6.0001	-0.0001
1	0.92341045	5	6.0000	6.0001	-0.0001
	0.94666548	10	6.0000	6.0001	-0.0001
15.001533	6.0001	15	6.0000	6.0001	-0.0001
6356.026467	6.7500	20	6.7500	6.7501	-0.0001
2	1.04491768	25	6.7500	6.7501	-0.0001
	1.07194400	30	6.7500	6.7502	-0.0002
		35	6.7500	6.7502	-0.0002
40.053935	6.7502	40	6.7500	6.7502	-0.0002
6330.974065	8.0540	45	8.0582	8.0593	-0.0011
		50	8.0642	8.0645	-0.0003
		55	8.0698	8.0698	0.0000
		60	8.0753	8.0751	0.0002
		65	8.0806	8.0803	0.0003
3	2.16670136	70	8.0859	8.0856	0.0003
	2.32998530	75	8.0911	8.0908	0.0003
		80	8.0962	8.0960	0.0002
		85	8.1013	8.1012	0.0001
		90	8.1064	8.1064	0.0000
		95	8.1115	8.1116	-0.0001
104.957687	8.1219	100	8.1165	8.1168	-0.0003
6266.070313	8.1219	105	8.1219	8.1220	-0.0001
4	2.51841026	110	8.1285	8.1292	-0.0007
	2.73226453	115	8.1356	8.1363	-0.0007
		120	8.1432	8.1435	-0.0003
125.320	8.1511	125	8.1513	8.1506	0.0007
6245.707939	8.1511	130	8.1599	8.1602	-0.0003
		135	8.1690	8.1699	-0.0009
5	2.97405843	140	8.1786	8.1796	-0.0010
	3.25362200	145	8.1886	8.1893	-0.0007
		150	8.1991	8.1990	0.0001
155.027311	8.2087	155	8.2101	8.2087	0.0014
6216.000689	8.2087	160	8.2214	8.2213	0.0001
		165	8.2332	8.2340	-0.0008
6	3.50244082	170	8.2454	8.2467	-0.0013
	3.85853274	175	8.2580	8.2593	-0.0013
		180	8.2710	8.2719	-0.0009
		185	8.2843	8.2845	-0.0002
193.795314	8.3067	190	8.2980	8.2971	0.0009
6177.232686	8.3067	195	8.3120	8.3104	0.0016
		200	8.3264	8.3260	0.0004
		205	8.3410	8.3415	-0.0005
7	4.03019188	210	8.3560	8.3571	-0.0011
	4.46315376	215	8.3713	8.3726	-0.0013
		220	8.3870	8.3881	-0.0011
		225	8.4029	8.4036	-0.0007
		230	8.4191	8.4191	0.0000
239.227039	8.4476	235	8.4357	8.4345	0.0012
6131.800961	8.4476	240	8.4525	8.4504	0.0021
		245	8.4696	8.4689	0.0007
		250	8.4870	8.4873	-0.0003
		255	8.5047	8.5057	-0.0010
8	4.55770255	260	8.5227	8.5241	-0.0014
	5.06801092	265	8.5410	8.5424	-0.0014
		270	8.5595	8.5607	-0.0012
		275	8.5783	8.5791	-0.0008
		280	8.5973	8.5974	-0.0001
		285	8.6167	8.6156	0.0011
291.392218	8.6390	290	8.6362	8.6339	0.0023
6079.635782	8.6390	295	8.6561	8.6543	0.0018
		300	8.6762	8.6756	0.0006
		305	8.6966	8.6969	-0.0003
		310	8.7172	8.7182	-0.0010
9	5.09632938	315	8.7380	8.7394	-0.0014
	5.68621977	320	8.7591	8.7606	-0.0015
		325	8.7804	8.7818	-0.0014
		330	8.8020	8.8029	-0.0009
		335	8.8238	8.8241	-0.0003
		340	8.8458	8.8452	0.0006
349.737938	8.8862	345	8.8680	8.8663	0.0017
6021.290062	8.8862	350	8.8905	8.8875	0.0030
		355	8.9131	8.9114	0.0017
		360	8.9360	8.9352	0.0008
		365	8.9590	8.9591	-0.0001
		370	8.9823	8.9829	-0.0006
10	5.59329351	375	9.0058	9.0067	-0.0009
	6.25724227	380	9.0294	9.0304	-0.0010
		385	9.0532	9.0542	-0.0010
		390	9.0773	9.0779	-0.0006
		395	9.1015	9.1016	-0.0001
		400	9.1258	9.1252	0.0006
		405	9.1503	9.1489	0.0014
411.322422	9.1787	410	9.1750	9.1725	0.0025
5959.705578	9.1787	415	9.1999	9.1977	0.0022
		420	9.2248	9.2236	0.0012
		425	9.2499	9.2494	0.0005
		430	9.2752	9.2752	0.0000
		435	9.3007	9.3010	-0.0003
11	5.99325871	440	9.3262	9.3267	-0.0005
	6.71735442	445	9.3519	9.3524	-0.0005
		450	9.3778	9.3781	-0.0003
		455	9.4038	9.4038	0.0000
		460	9.4299	9.4294	0.0005
		465	9.4562	9.4550	0.0012
472.071820	9.4911	470	9.4826	9.4805	0.0021
5898.956180	9.4911	475	9.5091	9.5072	0.0019
		480	9.5358	9.5345	0.0013
		485	9.5626	9.5618	0.0008
		490	9.5895	9.5891	0.0004
		495	9.6165	9.6164	0.0001
12	6.31396167	500	9.6437	9.6436	0.0001
	7.08672019	505	9.6709	9.6709	0.0000
		510	9.6981	9.6980	0.0001
		515	9.7255	9.7252	0.0003
		520	9.7530	9.7523	0.0007
		525	9.7805	9.7794	0.0011
531.559687	9.8149	530	9.8080	9.8064	0.0016
5839.468313	9.8149	535	9.8356	9.8342	0.0014
		540	9.8632	9.8623	0.0009
		545	9.8908	9.8903	0.0005
		550	9.9185	9.9184	0.0001
		555	9.9462	9.9464	-0.0002
		560	9.9740	9.9743	-0.0003
		565	10.0018	10.0023	-0.0005
		570	10.0296	10.0302	-0.0006
		575	10.0574	10.0580	-0.0006
		580	10.0853	10.0859	-0.0006
		585	10.1132	10.1137	-0.0005
		590	10.1411	10.1414	-0.0003
		595	10.1690	10.1692	-0.0002
		600	10.1970	10.1969	0.0001
		605	10.2249	10.2246	0.0003
13	6.50401417	610	10.2528	10.2522	0.0006
	7.30586668	615	10.2807	10.2798	0.0009
		620	10.3086	10.3074	0.0012
		625	10.3364	10.3350	0.0014
		630	10.3642	10.3625	0.0017
		635	10.3920	10.3900	0.0020
		640	10.4197	10.4174	0.0023
		645	10.4474	10.4449	0.0025
		650	10.4750	10.4723	0.0027
		655	10.5024	10.4996	0.0028
		660	10.5297	10.5270	0.0027
		665	10.5570	10.5542	0.0028
		670	10.5840	10.5815	0.0025
		675	10.6109	10.6087	0.0022
		680	10.6375	10.6359	0.0016
		685	10.6638	10.6631	0.0007
		690	10.6899	10.6903	-0.0004
		695	10.7157	10.7174	-0.0017
700.177664	10.7454	700	10.7412	10.7444	-0.0032

Table 3

Data MZY		Depth (km)	P-wave velocity (km/s)		
Radius (km) **Layers** Depth (km)	v_i (km/s) B_i (x 10^{-2}) A_i (x 10^{-3}) v'_i (km/s)		Radius of surface-focus = 6371.028		
			Herrin & al.	MZY	Residual H. & al. - MZY
5670.850336	10.7454	705	10.7664	10.7679	-0.0015
		710	10.7911	10.7912	-0.0001
		715	10.8154	10.8144	0.0010
14	5.85891401	720	10.8392	10.8376	0.0016
	6.55949029	725	10.8624	10.8608	0.0016
		730	10.8850	10.8840	0.0010
		735	10.9068	10.9071	-0.0003
744.109784	10.9492	740	10.9279	10.9302	-0.0023
5626.918216	10.9492	745	10.9479	10.9515	-0.0036
		750	10.9663	10.9645	0.0018
15	4.12047826	755	10.9819	10.9775	0.0044
	4.54632080	760	10.9933	10.9904	0.0029
		765	11.0029	11.0033	-0.0004
772.052042	11.0215	770	11.0134	11.0163	-0.0029
5598.975958	11.0215	775	11.0240	11.0273	-0.0033
		780	11.0348	11.0370	-0.0022
		785	11.0455	11.0467	-0.0012
		790	11.0561	11.0564	-0.0003
		795	11.0666	11.0660	0.0006
		800	11.0766	11.0757	0.0009
		805	11.0865	11.0853	0.0012
		810	11.0962	11.0949	0.0013
		815	11.1060	11.1045	0.0015
		820	11.1156	11.1141	0.0015
		825	11.1252	11.1236	0.0016
		830	11.1348	11.1332	0.0016
		835	11.1443	11.1427	0.0016
		840	11.1538	11.1522	0.0016
		845	11.1632	11.1617	0.0015
		850	11.1726	11.1711	0.0015
16	3.57557893	855	11.1819	11.1806	0.0013
	3.91494425	860	11.1912	11.1900	0.0012
		865	11.2004	11.1994	0.0010
		870	11.2096	11.2088	0.0008
		875	11.2189	11.2182	0.0007
		880	11.2281	11.2276	0.0005
		885	11.2373	11.2369	0.0004
		890	11.2466	11.2462	0.0004
		895	11.2558	11.2555	0.0003
		900	11.2651	11.2648	0.0003
		905	11.2743	11.2741	0.0002
		910	11.2835	11.2833	0.0002
		915	11.2927	11.2926	0.0001
		920	11.3019	11.3018	0.0001
		925	11.3110	11.3110	0.0000
		930	11.3201	11.3202	-0.0001
		935	11.3291	11.3293	-0.0002
		940	11.3381	11.3385	-0.0004
		945	11.3470	11.3476	-0.0006
950.864911	11.3583	950	11.3558	11.3567	-0.0009
5420.163089	11.3583	955	11.3646	11.3654	-0.0008
		960	11.3734	11.3739	-0.0005
		965	11.3820	11.3824	-0.0004
		970	11.3907	11.3909	-0.0002
		975	11.3993	11.3994	-0.0001
		980	11.4079	11.4079	0.0000
		985	11.4164	11.4163	0.0001
		990	11.4249	11.4247	0.0002
		995	11.4333	11.4331	0.0002
		1000	11.4418	11.4415	0.0003
		1005	11.4502	11.4499	0.0003
		1010	11.4585	11.4582	0.0003
		1015	11.4668	11.4666	0.0002
		1020	11.4751	11.4749	0.0002
		1025	11.4834	11.4832	0.0002
		1030	11.4917	11.4915	0.0002
		1035	11.4999	11.4998	0.0001
17	3.48245516	1040	11.5081	11.5080	0.0001
	3.80663410	1045	11.5163	11.5162	0.0001
		1050	11.5244	11.5245	-0.0001
		1055	11.5326	11.5326	0.0000
		1060	11.5407	11.5408	-0.0001
		1065	11.5488	11.5490	-0.0002
		1070	11.5569	11.5571	-0.0002
		1075	11.5649	11.5652	-0.0003
		1080	11.5730	11.5734	-0.0004
		1085	11.5810	11.5814	-0.0004
		1090	11.5890	11.5895	-0.0005
		1095	11.5970	11.5976	-0.0006
		1100	11.6049	11.6056	-0.0007
		1105	11.6129	11.6136	-0.0007
		1110	11.6208	11.6216	-0.0008

Data MZY		p. 2/4	P-wave velocity (km/s)		
Radius (km) **Layers** Depth (km)	v_i (km/s) B_i (x 10^{-2}) A_i (x 10^{-3}) v'_i (km/s)	Depth (km)	Herrin & al.	MZY	Residual H. & al. - MZY
		1115	11.6288	11.6296	-0.0008
		1120	11.6367	11.6375	-0.0008
		1125	11.6446	11.6455	-0.0009
		1130	11.6525	11.6534	-0.0009
		1135	11.6604	11.6613	-0.0009
		1140	11.6684	11.6692	-0.0008
		1145	11.6763	11.6771	-0.0008
		1150	11.6842	11.6849	-0.0007
		1155	11.6921	11.6928	-0.0007
		1160	11.7000	11.7006	-0.0006
		1165	11.7080	11.7084	-0.0004
		1170	11.7159	11.7162	-0.0003
		1175	11.7238	11.7239	-0.0001
		1180	11.7316	11.7317	-0.0001
		1185	11.7395	11.7394	0.0001
		1190	11.7473	11.7471	0.0002
		1195	11.7551	11.7548	0.0003
		1200	11.7629	11.7624	0.0005
		1205	11.7707	11.7701	0.0006
		1210	11.7785	11.7777	0.0008
		1215	11.7862	11.7853	0.0009
		1220	11.7938	11.7929	0.0009
		1225	11.8015	11.8005	0.0010
		1230	11.8091	11.8081	0.0010
		1235	11.8167	11.8156	0.0011
		1240	11.8242	11.8231	0.0011
		1245	11.8318	11.8306	0.0012
		1250	11.8393	11.8381	0.0012
		1255	11.8467	11.8456	0.0011
		1260	11.8542	11.8530	0.0012
		1265	11.8616	11.8605	0.0011
		1270	11.8689	11.8679	0.0010
		1275	11.8763	11.8753	0.0010
		1280	11.8836	11.8826	0.0010
		1285	11.8909	11.8900	0.0009
		1290	11.8982	11.8973	0.0009
		1295	11.9054	11.9046	0.0008
17	3.48245516	1300	11.9126	11.9119	0.0007
	3.80663410	1305	11.9198	11.9192	0.0006
		1310	11.9269	11.9265	0.0004
		1315	11.9341	11.9337	0.0004
		1320	11.9412	11.9409	0.0003
		1325	11.9483	11.9481	0.0002
		1330	11.9554	11.9553	0.0001
		1335	11.9624	11.9625	-0.0001
		1340	11.9695	11.9696	-0.0001
		1345	11.9765	11.9768	-0.0003
		1350	11.9836	11.9839	-0.0003
		1355	11.9906	11.9910	-0.0004
		1360	11.9976	11.9980	-0.0004
		1365	12.0046	12.0051	-0.0005
		1370	12.0116	12.0121	-0.0005
		1375	12.0185	12.0191	-0.0006
		1380	12.0255	12.0261	-0.0006
		1385	12.0324	12.0331	-0.0007
		1390	12.0393	12.0401	-0.0008
		1395	12.0462	12.0470	-0.0008
		1400	12.0531	12.0539	-0.0008
		1405	12.0599	12.0608	-0.0009
		1410	12.0668	12.0677	-0.0009
		1415	12.0736	12.0746	-0.0010
		1420	12.0805	12.0814	-0.0009
		1425	12.0873	12.0882	-0.0009
		1430	12.0941	12.0950	-0.0009
		1435	12.1009	12.1018	-0.0009
		1440	12.1077	12.1086	-0.0009
		1445	12.1145	12.1153	-0.0008
		1450	12.1213	12.1221	-0.0008
		1455	12.1281	12.1288	-0.0007
		1460	12.1349	12.1354	-0.0005
		1465	12.1417	12.1421	-0.0004
		1470	12.1485	12.1488	-0.0003
		1475	12.1553	12.1554	-0.0001
		1480	12.1620	12.1620	0.0000
		1485	12.1688	12.1686	0.0002
		1490	12.1755	12.1752	0.0003
		1495	12.1822	12.1817	0.0005
		1500	12.1889	12.1882	0.0007
		1505	12.1956	12.1948	0.0008
		1510	12.2023	12.2013	0.0010
1516.957451	12.2103	1515	12.2089	12.2077	0.0012

Table 3

Data MZY		p. 3/4	P-wave velocity (km/s)		
Radius (km) **Layers** Depth (km)	v_i (km/s) B_i ($x\,10^{-2}$) A_i ($x\,10^{-3}$) v'_i (km/s)	Depth (km)	Radius of surface-focus = 6371.028		
			Herrin & al.	MZY	Residual H. & al. - MZY
4854.070549	12.2103	1520	12.2155	12.2142	0.0013
		1525	12.2221	12.2207	0.0014
		1530	12.2287	12.2272	0.0015
		1535	12.2352	12.2337	0.0015
		1540	12.2417	12.2402	0.0015
		1545	12.2482	12.2466	0.0016
		1550	12.2547	12.2530	0.0017
		1555	12.2611	12.2594	0.0017
		1560	12.2675	12.2658	0.0017
		1565	12.2738	12.2721	0.0017
		1570	12.2801	12.2784	0.0017
		1575	12.2864	12.2848	0.0016
		1580	12.2926	12.2910	0.0016
		1585	12.2988	12.2973	0.0015
		1590	12.3050	12.3036	0.0014
		1595	12.3111	12.3098	0.0013
		1600	12.3172	12.3160	0.0012
		1605	12.3232	12.3222	0.0010
		1610	12.3292	12.3284	0.0008
		1615	12.3352	12.3345	0.0007
		1620	12.3411	12.3407	0.0004
		1625	12.3471	12.3468	0.0003
		1630	12.3530	12.3529	0.0001
		1635	12.3589	12.3589	0.0000
		1640	12.3648	12.3650	-0.0002
		1645	12.3706	12.3710	-0.0004
		1650	12.3765	12.3770	-0.0005
		1655	12.3823	12.3830	-0.0007
		1660	12.3882	12.3890	-0.0008
		1665	12.3940	12.3950	-0.0010
18	3.49547729	1670	12.3999	12.4009	-0.0010
	3.82197670	1675	12.4057	12.4068	-0.0011
		1680	12.4115	12.4127	-0.0012
		1685	12.4173	12.4186	-0.0013
		1690	12.4231	12.4244	-0.0013
		1695	12.4289	12.4302	-0.0013
		1700	12.4347	12.4360	-0.0013
		1705	12.4405	12.4418	-0.0013
		1710	12.4463	12.4476	-0.0013
		1715	12.4521	12.4533	-0.0012
		1720	12.4578	12.4591	-0.0013
		1725	12.4636	12.4648	-0.0012
		1730	12.4693	12.4705	-0.0012
		1735	12.4751	12.4761	-0.0010
		1740	12.4808	12.4818	-0.0010
		1745	12.4865	12.4874	-0.0009
		1750	12.4922	12.4930	-0.0008
		1755	12.4978	12.4986	-0.0008
		1760	12.5035	12.5041	-0.0006
		1765	12.5091	12.5097	-0.0006
		1770	12.5148	12.5152	-0.0004
		1775	12.5204	12.5207	-0.0003
		1780	12.5259	12.5262	-0.0003
		1785	12.5315	12.5316	-0.0001
		1790	12.5371	12.5371	0.0000
		1795	12.5426	12.5425	0.0001
		1800	12.5481	12.5479	0.0002
		1805	12.5537	12.5533	0.0004
		1810	12.5592	12.5586	0.0006
		1815	12.5648	12.5639	0.0009
		1820	12.5703	12.5693	0.0010
		1825	12.5759	12.5745	0.0014
		1830	12.5814	12.5798	0.0016
		1835	12.5870	12.5851	0.0019
1844.100891	12.5946	1840	12.5926	12.5903	0.0023
4526.927109	12.5946	1845	12.5982	12.5957	0.0025
		1850	12.6037	12.6018	0.0019
		1855	12.6093	12.6079	0.0014
		1860	12.6149	12.6141	0.0008
		1865	12.6205	12.6201	0.0004
		1870	12.6262	12.6262	0.0000
		1875	12.6319	12.6322	-0.0003
		1880	12.6376	12.6383	-0.0007
		1885	12.6433	12.6443	-0.0010
		1890	12.6491	12.6502	-0.0011
		1895	12.6549	12.6562	-0.0013
		1900	12.6607	12.6621	-0.0014
19	3.65834366	1905	12.6666	12.6680	-0.0014
	4.01545527	1910	12.6725	12.6739	-0.0014
		1915	12.6784	12.6798	-0.0014
		1920	12.6843	12.6856	-0.0013
		1925	12.6902	12.6914	-0.0012
		1930	12.6962	12.6972	-0.0010
		1935	12.7022	12.7030	-0.0008
		1940	12.7082	12.7087	-0.0005
		1945	12.7142	12.7144	-0.0002
		1950	12.7202	12.7202	0.0000
		1955	12.7262	12.7258	0.0004
		1960	12.7323	12.7315	0.0008
		1965	12.7383	12.7371	0.0012
		1970	12.7444	12.7427	0.0017
		1975	12.7505	12.7483	0.0022
1981.009473	12.7550	1980	12.7565	12.7539	0.0026
4390.018527	12.7550	1985	12.7626	12.7601	0.0025
		1990	12.7687	12.7664	0.0023
		1995	12.7747	12.7726	0.0021
		2000	12.7808	12.7789	0.0019
		2005	12.7868	12.7851	0.0017
		2010	12.7928	12.7913	0.0015
		2015	12.7988	12.7975	0.0013
		2020	12.8048	12.8037	0.0011
		2025	12.8108	12.8098	0.0010
		2030	12.8167	12.8159	0.0008
		2035	12.8227	12.8220	0.0007
		2040	12.8286	12.8280	0.0006
		2045	12.8345	12.8341	0.0004
		2050	12.8403	12.8401	0.0002
		2055	12.8462	12.8461	0.0001
		2060	12.8520	12.8520	0.0000
		2065	12.8578	12.8580	-0.0002
		2070	12.8636	12.8639	-0.0003
		2075	12.8693	12.8698	-0.0005
20	3.78936074	2080	12.8751	12.8757	-0.0006
	4.17166810	2085	12.8808	12.8815	-0.0007
		2090	12.8865	12.8873	-0.0008
		2095	12.8922	12.8931	-0.0009
		2100	12.8979	12.8989	-0.0010
		2105	12.9036	12.9046	-0.0010
		2110	12.9092	12.9104	-0.0012
		2115	12.9149	12.9161	-0.0012
		2120	12.9205	12.9217	-0.0012
		2125	12.9262	12.9274	-0.0012
		2130	12.9318	12.9330	-0.0012
		2135	12.9375	12.9386	-0.0011
		2140	12.9431	12.9442	-0.0011
		2145	12.9487	12.9497	-0.0010
		2150	12.9544	12.9552	-0.0008
		2155	12.9601	12.9607	-0.0006
		2160	12.9657	12.9662	-0.0005
		2165	12.9714	12.9717	-0.0003
		2170	12.9771	12.9771	0.0000
		2175	12.9829	12.9825	0.0004
		2180	12.9886	12.9879	0.0007
		2185	12.9944	12.9932	0.0012
		2190	13.0002	12.9985	0.0017
		2195	13.0059	13.0038	0.0021
2201.417284	13.0106	2200	13.0117	13.0091	0.0026

Table 3

Data MZY			**P-wave velocity** (km/s)		
			Radius of surface-focus = 6371.028		
Radius (km) **Layers** Depth (km)	v_i (km/s) B_i ($x\,10^{-2}$) A_i ($x\,10^{-3}$) v'_i (km/s)	Depth (km)	Herrin & al.	MZY	Residual H. & al. - MZY
4169.610716	13.0106	2205	13.0175	13.0151	0.0024
		2210	13.0234	13.0214	0.0020
		2215	13.0292	13.0277	0.0015
		2220	13.0350	13.0339	0.0011
		2225	13.0408	13.0401	0.0007
		2230	13.0466	13.0462	0.0004
		2235	13.0525	13.0524	0.0001
		2240	13.0583	13.0585	-0.0002
		2245	13.0641	13.0646	-0.0005
		2250	13.0700	13.0707	-0.0007
		2255	13.0758	13.0767	-0.0009
		2260	13.0817	13.0827	-0.0010
		2265	13.0876	13.0887	-0.0011
		2270	13.0934	13.0947	-0.0013
		2275	13.0993	13.1006	-0.0013
21	3.96471462	2280	13.1052	13.1065	-0.0013
	4.38203609	2285	13.1110	13.1124	-0.0014
		2290	13.1169	13.1182	-0.0013
		2295	13.1228	13.1241	-0.0013
		2300	13.1287	13.1298	-0.0011
		2305	13.1345	13.1356	-0.0011
		2310	13.1404	13.1414	-0.0010
		2315	13.1462	13.1471	-0.0009
		2320	13.1521	13.1528	-0.0007
		2325	13.1579	13.1584	-0.0005
		2330	13.1637	13.1641	-0.0004
		2335	13.1696	13.1697	-0.0001
		2340	13.1754	13.1753	0.0001
		2345	13.1812	13.1808	0.0004
		2350	13.1871	13.1863	0.0008
		2355	13.1929	13.1918	0.0011
		2360	13.1987	13.1973	0.0014
		2365	13.2046	13.2028	0.0018
2372.501241	13.2109	2370	13.2104	13.2082	0.0022
3998.526759	13.2109	2375	13.2163	13.2141	0.0022
		2380	13.2221	13.2205	0.0016
		2385	13.2280	13.2268	0.0012
		2390	13.2339	13.2332	0.0007
		2395	13.2397	13.2395	0.0002
		2400	13.2456	13.2458	-0.0002
		2405	13.2516	13.2520	-0.0004
		2410	13.2575	13.2582	-0.0007
		2415	13.2635	13.2644	-0.0009
22	4.13594750	2420	13.2694	13.2706	-0.0012
	4.58849794	2425	13.2755	13.2767	-0.0012
		2430	13.2815	13.2828	-0.0013
		2435	13.2876	13.2889	-0.0013
		2440	13.2937	13.2950	-0.0013
		2445	13.2998	13.3010	-0.0012
		2450	13.3060	13.3070	-0.0010
		2455	13.3122	13.3129	-0.0007
		2460	13.3184	13.3188	-0.0004
		2465	13.3247	13.3247	0.0000
		2470	13.3310	13.3306	0.0004
		2475	13.3372	13.3365	0.0007
2484.009390	13.3469	2480	13.3436	13.3423	0.0013

Data MZY		p. 4/4	**P-wave velocity** (km/s)		
Radius (km) **Layers** Depth (km)	v_i (km/s) B_i ($x\,10^{-2}$) A_i ($x\,10^{-3}$) v'_i (km/s)	Depth (km)	Herrin & al.	MZY	Residual H. & al. - MZY
3887.018610	13.3469	2485	13.3499	13.3482	0.0017
		2490	13.3562	13.3549	0.0013
		2495	13.3626	13.3615	0.0011
		2500	13.3690	13.3680	0.0010
		2505	13.3753	13.3746	0.0007
		2510	13.3817	13.3811	0.0006
		2515	13.3881	13.3876	0.0005
		2520	13.3945	13.3940	0.0005
		2525	13.4009	13.4004	0.0005
		2530	13.4073	13.4068	0.0005
		2535	13.4137	13.4132	0.0005
		2540	13.4200	13.4195	0.0005
		2545	13.4264	13.4258	0.0006
		2550	13.4327	13.4321	0.0006
		2555	13.4391	13.4383	0.0008
		2560	13.4454	13.4445	0.0009
23	4.28150596	2565	13.4516	13.4507	0.0009
	4.76460375	2570	13.4578	13.4568	0.0010
		2575	13.4640	13.4629	0.0011
		2580	13.4702	13.4690	0.0012
		2585	13.4763	13.4750	0.0013
		2590	13.4823	13.4810	0.0013
		2595	13.4883	13.4870	0.0013
		2600	13.4942	13.4930	0.0012
		2605	13.5000	13.4989	0.0011
		2610	13.5058	13.5048	0.0010
		2615	13.5116	13.5106	0.0010
		2620	13.5172	13.5164	0.0008
		2625	13.5229	13.5222	0.0007
		2630	13.5285	13.5280	0.0005
		2635	13.5340	13.5337	0.0003
		2640	13.5394	13.5394	0.0000
		2645	13.5448	13.5451	-0.0003
		2650	13.5501	13.5507	-0.0006
		2655	13.5554	13.5563	-0.0009
2660.414706	13.5623	2660	13.5606	13.5619	-0.0013
3710.613294	13.5623	2665	13.5657	13.5666	-0.0009
		2670	13.5707	13.5712	-0.0005
		2675	13.5756	13.5758	-0.0002
		2680	13.5804	13.5804	0.0000
24	4.13634936	2685	13.5851	13.5849	0.0002
	4.58799171	2690	13.5898	13.5894	0.0004
		2695	13.5942	13.5938	0.0004
		2700	13.5986	13.5983	0.0003
		2705	13.6027	13.6027	0.0000
2711.399520	13.6083	2710	13.6067	13.6071	-0.0004
3659.628480	13.6083	2715	13.6105	13.6106	-0.0001
		2720	13.6140	13.6137	0.0003
25	3.94351119	2725	13.6173	13.6168	0.0005
	4.35296986	2730	13.6205	13.6199	0.0006
		2735	13.6234	13.6229	0.0005
		2740	13.6261	13.6259	0.0002
2749.829382	13.6318	2745	13.6287	13.6289	-0.0002
3621.198618	13.6318	2750	13.6312	13.6318	-0.0006
		2755	13.6336	13.6335	0.0001
26	3.72963470	2760	13.6359	13.6350	0.0009
	4.09197173	2765	13.6381	13.6366	0.0015
		2770	13.6402	13.6382	0.0020
		2775	13.6422	13.6397	0.0025
2780.705225	13.6413	2780	13.6441	13.6411	0.0030
3590.322775	13.6413	2785	13.6460	13.6409	0.0051
27	3.40172802	2790	13.6478	13.6403	0.0075
	3.69140151	2795	13.6495	13.6397	0.0098
2800.782857	13.6390	2800	13.6512	13.6391	0.0121
3570.245143	13.6390	2805	13.6528	13.6332	0.0196
28	2.39586620				
	2.46180014				
2810.096720	13.6263	2810	13.6544	13.6264	0.0280
3560.931280	13.6263	2815	13.6559	13.6310	0.0249
		2820	13.6574	13.6358	0.0216
		2825	13.6588	13.6405	0.0183
		2830	13.6601	13.6452	0.0149
		2835	13.6613	13.6499	0.0114
		2840	13.6625	13.6545	0.0080
		2845	13.6636	13.6592	0.0044
		2850	13.6646	13.6637	0.0009
29	4.30127189	2855	13.6655	13.6683	-0.0028
	4.79178003	2860	13.6663	13.6728	-0.0065
		2865	13.6670	13.6772	-0.0102
		2870	13.6677	13.6817	-0.0140
		2875	13.6683	13.6861	-0.0178
		2880	13.6689	13.6904	-0.0215
		2885	13.6694	13.6948	-0.0254
		2890	13.6698	13.6991	-0.0293
2893.913546	13.7024	2894	13.6700		

Radius outer core = 3477,114454

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